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Fruit Drying Process Investigation in Infrared Film Dryer

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Abstract. The work analyzes three different product (apple slices, banana slices and grape halves) drying process in the infrared film dryer. Such drying takes place at low temperatures (to 40 °C), allowing to keep the maximum value of fresh products. The drying process is analyzed in detail in the first 8 hours. The quantity of water runoff, drying product temperature changes and flowing air humidity changes during drying were analyzed. It demonstrates the impact of the product placement on the drying progress. Using the experimental data, average diffusion coefficients are obtained for each product group. The results showed that diffusion coefficients were changing during the drying process. Using mathematical modelling and experimental data, the concentration-dependent diffusion coefficient for apple slices was obtained. The study finds that apple and banana drying using the infrared film is comparatively successful, but the drying process of the half of grape berry is slower. This can be explained by the impact of grape peel on the water diffusion.

Key words: infrared film, fruits, drying coefficient, model, moisture.

INTRODUCTION

The drying process is the most common process of processing agricultural products, in which heat is transferred from the heated air to the product by convection, and later the evaporated water is also transported to the air by convection. In convective drying, resistances to the heat and mass transfer are in the boundary layer and their magnitude is dependent on the air velocity. On the other hand, resistances to heat and mass transfer in the material during drying are high and strongly affect the kinetics of water evaporation. Convective drying usually requires a great amount of time and causes many undesirable changes in the material (Nowak & Lewicki, 2004).

Infrared drying (IR) is based on the fact that the infrared radiation of certain wavelengths is actively absorbed by water contained in the product, but is not absorbed by tissue of a dried product. That is, unlike all other types of drying, energy is applied directly to the water of the product, and this is achieved by high efficiency and economy. When infrared waves are radiated to the material to be dried, the internal temperature of the particle is increased. The moisture concentration (content) gradient is the driving force for the moisture to transfer towards the sample surface, where it is removed by the surrounding air (Sharma et al., 2005; Abbasi & Mowla, 2008). The depth of penetration depends on the property of the material and wavelength of radiation. When a material is exposed to radiation, it is intensely heated and the temperature gradient in the material reduces within a short period of time. Under this principle, it is not necessary to raise the temperature significantly for product drying, and the evaporation process can be rapidly conducted at a temperature of 40–60 °C, which gives almost complete preserve of vitamins, biologically active substances, natural color, flavor and aroma of the dried products.

When using other methods it is necessary to warm the product up to 100–105 °C, otherwise the drying process will last for 20–30 hours.

Infrared radiation is harmless to the environment and humans, because the main source of infrared rays is the sun, which our ancestors used for drying products for many centuries. Drying of products based on this technology can save the contents of vitamins and other biologically active substances in the dry product at a level of 80–90% from the baseline. The results of infrared drying compared to conventional drying allowed to conclude that this process provides a more uniformly heated product, resulting in better quality characteristics (Hebbar & Rastagi, 2001).

The product quality is also better, particularly in drying of heat sensitive materials (Ginzburg, 1969). IR drying has been the subject of investigations by recent researchers. Paakkonen et al. (1999) have shown that IR drying improves the quality of herbs, Pan et al. (2005), Sharma et al. (2005) studied the quality characteristics and advantages of onion infrared drying with different drying temperatures and inlet air velocities, Prabhanjan et al. (1995) investigated thin layer carrot microwave assisted convective drying, Funebo & Ohlsson (1998) investigated microwave assisted mushroom dehydration and showed a possibility to reduce the drying time. Zbicinski et al. (1992), investigating convective air drying and IR drying, have suggested that the use of an intermittent irradiation drying mode coupled with convective air drying is the best for heat sensitive materials.

The advantages of infrared radiation cover high heat transfer coefficients, short time of drying and easy control of material temperature (Nowak & Lewinski, 2004). In view of these advantages it is likely that IR drying in combination with convection or vacuum will become increasingly popular (Mujumdar, 1995). Jaturonglumlert & Kiatsiriroat (2010) showed that higher mass transfer is obtained with combined convective and far-infrared drying.

Nowadays, many food properties exist, which can help evaluate the quality of dried products, such as the color, texture, flavor, and nutritional content, ability to absorb water, mechanical properties, microstructure and others.

Such material properties as the color, ability to uptake water, and mechanical resistance to breakage are not dependent on the way how the heat is supplied to the material undergoing drying (Kocabiyik & Tezer, 2009). There are two most important parameters: the drying rate and material drying temperature. High drying rate damages tissue and the material becomes fragile (Kocabiyik & Tezer, 2009). During IR drying, the drying rate decreases with the moisture content decreasing and with the infrared power decreasing (Ong & Law, 2011). Drying temperature causes some browning because of chemical changes (Kocabiyik & Tezer, 2009).

For short soaking (15–20 minutes) after infrared drying, the product restores all its natural physical, chemical properties and can be used fresh or subjected to any type of cooking. Infrared ray dried products at low ambient humidity can be stored without special packaging. Even in such conditions of storage the products will lose 10–15% of vitamins.

Recently numerous researches in the infrared drying use for individual products have been carried out. Nowak & Lewicki (2004), Slegun & Popa (2009) studied apple slice drying, Renata C. dos Reis et al. (2012) investigated the temperature effects on basil leaves in the IR drying process. Chua and Chou (2005) investigated potato and carrot IR drying.

The present paper has two specific objectives. Firstly, to examine the IR film drying possibilities with small heating up to 40 °C. Most of the researchers use IR drying temperature from 60 to 90 °C. Secondly, to investigate and compare three different products: apple slices, banana slices and grape halves.

MATERIALS AND METHODS

The experiment was carried out at the Grain Drying and Storage Scientific Laboratory at the Latvia University of Agriculture.

Equipment and materials

The infrared (IR) dryer (Fig. 1) consisted of a drying chamber (80 x 50 x 30 cm) with a heat source IR film (South Korea EXCEL) with total area 0.8 m^2 mounted on the top and bottom of the chamber. The maximum heating of this film is not more than 40–45 °C. The IR film power is 140 W m^{-2}.

Figure 1. IR dryer in practice.

Figure 2. Samples at the beginning of the drying experiment.

The experiments were performed with the fan with a total maximum capacity of 100 m^3 h^{-1} and power 15 W, which is placed on the top of the side wall of the equipment, the air intake peephole is located on the bottom of the opposite side wall, Fig. 3.

The apples and bananas were cut into 1 cm thick slices and the grapes were cut in halves, Fig. 2. The samples were placed on a round drying tray (diameter 20 cm) which consisted of a fine mesh aluminum screen with a plastic frame. These sample plates were put on the drying chamber trays. The trays were placed 10 cm from the IR film on the top and bottom, the distance between the trays was 10 cm, Fig. 3.

The moisture content in the material was identified by gravimetric measurement in time intervals. The samples were weighed on the digital laboratory balance

KERN-440-35N with maximum load weight 400 g and with resolution 0.01 g. The total drying time was adapted to the need for determination of the final moisture content.

The average inlet air temperature during the experiment was 18.8 °C with standard division 0.6 °C. The dry matter is determined by laboratory equipment Memmert, drying the product at 102 °C to constant weight of the product.

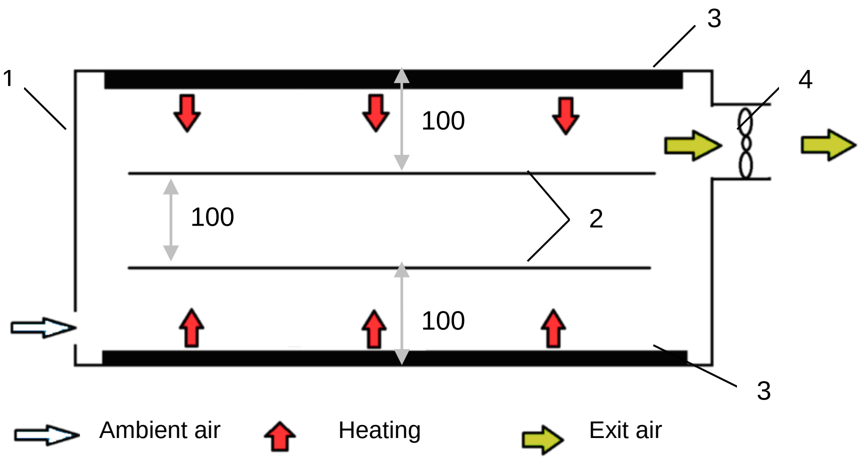

Figure 3. Schematic view of IR dryer: 1 – Body of dryer; 2 – Trays; 3 – IR drying film; 4 – Fan.

Mathematical model

In order to determine the effective moisture diffusion, we use the mass maintenance law usually presented in the following form:

$$\frac{\partial \tilde{c}}{\partial t} = div\left(D\, grad\, \tilde{c}\right) \qquad (1)$$

D – coefficient of diffusion; $\tilde{c}(x, y, z, t)$ – concentration of moisture in sample; x,y,z – space coordinates; t – time.

Since the surface of apple and banana slices on the top and bottomis greater than on the sides, the overal diffusion of vapours on the top and the bottom is greater than on the side, and we can choose 1-dimentional model with D_x (diffusion in a plane sheet $\tilde{c}(x, y, z, t) \approx c(x, t)$).

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial x}\left[D_x \frac{\partial c}{\partial x}\right] \qquad (2)$$

We have a case, where diffusion occurs through all surfaces of the samples, and we assume that the diffusion coefficient D_x is constant. At the moment $t = 0$, concentration of moisture in the samples is constant, c_s. The water vapour concentration on the surfaces is constant, $c(x, t)$ =0. The diffusion process in our case can be considered as a symmetrical situation, and we get a mathematical problem:

$$\frac{\partial c}{\partial t} = D_x \frac{\partial^2 c}{\partial x^2} \qquad -l < x < l \ , \quad t > 0 \tag{3}$$

$$c\big|_{t=0} = c_s \tag{4}$$

$$c\big|_{x=-l} = c\big|_{x=l} = 0 \ , \tag{5}$$

where $2l$ – sample thickness in x direction.

The problem (3) – (5) with $D_x = const$ solution is (Crank, 1956):

$$c(x,t) = \frac{4c_s}{\pi} \sum_{n=0}^{\infty} \frac{(-1)^n}{2n+1} \cdot e^{-\frac{D_x (2n+1)^2 \pi^2 \cdot t}{4l^2}} \cdot \cos\frac{(2n+1)\pi \cdot x}{2l} \tag{6}$$

If M_t denotes the amount of diffusing moisture which has come out from the material at time t, and M_∞ the corresponding quantity after infinite time, then (Crank, 1956):

$$\frac{M_t}{M_\infty} = 1 - \sum_{n=0}^{\infty} \frac{8}{(2n+1)^2 \pi^2} \cdot e^{-\frac{D_x (2n+1)^2 \pi^2 \cdot t}{4l^2}} \tag{7}$$

At first we must estimate D_x. Looking at the series (7), we see that itconvergesvery fastand that is whywe chooseonly the firstmember of theseries and expression (7) becomes

$$\frac{8}{\pi^2} \cdot e^{-\frac{D_x \cdot \pi^2 \cdot t}{4l^2}} = 1 - \frac{M_t}{M_\infty} \tag{8}$$

The right-hand side of the equation (8) is known (experimental data at time $t = t_i$), and the coefficient of diffusion can be expressed:

$$D_x = -\frac{4l^2 \ln\left(\frac{\pi^2 (M_\infty - M_t)}{8 \cdot M_\infty}\right)}{\pi^2 \cdot t} \tag{9}$$

We can calculate D_x^i for each experimental measurement at time t_i from (9) and find $D_x = const$ as

$$D_x = \tfrac{1}{k} \sum_{i=1}^{k} D_x^i \ ,$$

where k – number of measurements.

If D_x depends on the drying time $D_x = D_x(t)$, we can use the methodology, see (Aboltins, 2013) and find the expression of $D_x(t)$. For solving (2),(4),(5) $D_x(t)$, we can use difference schemes (Samarskii, 1988).

RESULTS AND DISCUSSION

The moisture removal dynamics shows that the grape half drying rate is less than the drying rate of the apple and banana slices, Fig. 4.

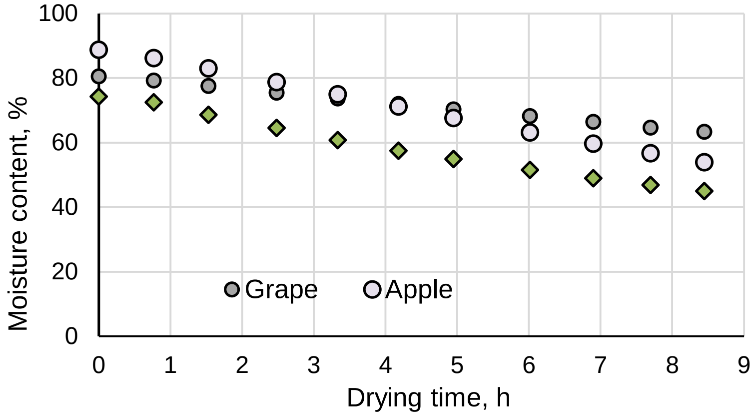

Figure 4. Moisture changes of fruit samples by forced convection in IR film dryer.

This can be explained by the fact that the grape peel has significant impact on decreasing the drying speed. Grape mostly dries from the cut part.

Temperature and humidity fluctuations are observed at the beginning of the drying process.

For banana samples, fluctuations are shown in Fig. 5.

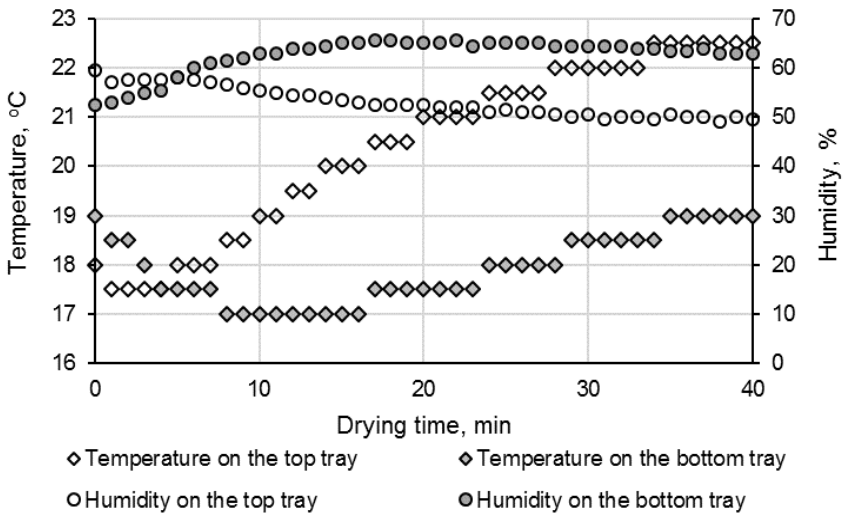

Figure 5. Banana sample temperature and humidity changes on top and bottom trays at the first 40 min of drying.

These fluctuations can be explained by moisture removal from the sample surface. It is happening faster on the upper tray because there IR rays directly affect the samples. IR rays interfere with the tray base on which the samples are placed on the bottom. Air humidity on the top tray is lower due to the faster output by the help of the fan, and the sample temperature is higher. These differences decrease during drying.

Similar situation is observed in all samples. After the first 15 minutes the wet is removed from the boundary layer and the temperature begins to rise steadily. This indicates that there is moisture diffusion of the sample inside.

Using the experimental data and (9) average diffusion coefficients for the viewed fruit samples were calculated (Table 1).

Table 1. Average diffusion coefficients of samples

Fruit samples	Average diffusion coefficient, m^2 s^{-1}	Standard deviation, m^2 s^{-1}
Apple slices	2.04E-10	1.17E-10
Banana slices	2.10E-10	9.11E-11
Grape halves	1.56E-10	1.05E-10

The results show that the diffusion coefficients of the apple and banana slices are practically the same, but for the grape halves they are remarkably lower (Table 1).This can be explained by the consistency of the samples and grape peel effect on the drying process. The processed results of the high standard deviation value indicate that the diffusion coefficient is variable depending on the drying time or the moisture content of the sample. Using the proposed methodology (Aboltins, 2013), we can calculate the changing drying coefficient $K(t)$ depending on the drying time t at constant drying conditions.

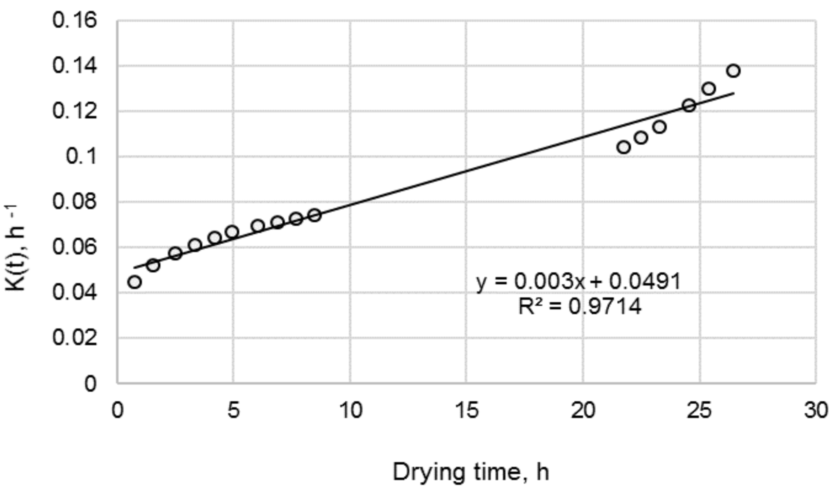

Figure 6. Drying coefficient determination of apple slice drying in IR film dryer.

The drying coefficient of apple slices was $K(t) = 0.003 \cdot t + 0.0491$ with the determination coefficient R^2=0.97 (Fig. 6), where t – drying time, h.

We can calculate D_x^i for each experimental measurement at time t_i from (9) and find $D_x^i = D_x(t_i)$. Eatch time moment t_i corresponds to the product concentration c_i, and we can get $D_x^i = D_x(c_i)$. Using data processing, it is possible to obtain the changing diffusion coefficient D(c) (Fig. 7).

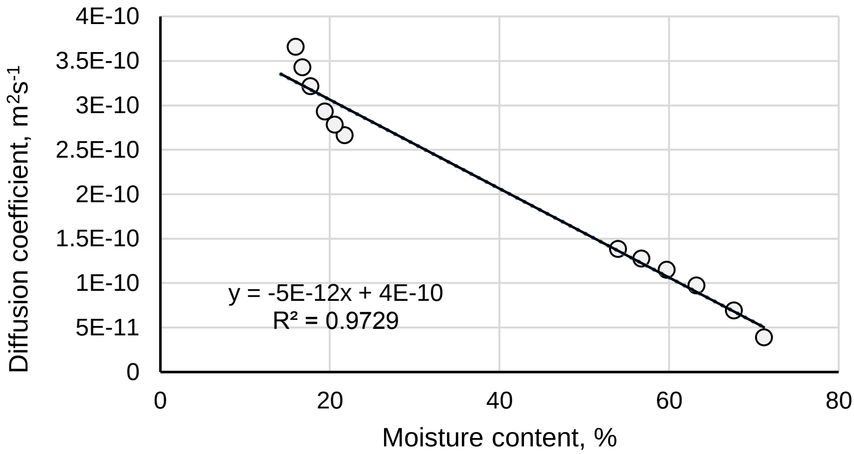

Figure 7. Diffusion coefficient determination of apple slice drying in IR film dryer.

Using the experimental results of apple slice drying in the IR film dryer, we determined the expression of the diffusion coefficient depending on the moisture concentration c:

$$D(c) = -5 \cdot 10^{-12} \cdot c + 4 \cdot 10^{-10}$$

It is possible to use difference schemes (Samarskii, 1988) for solving the problem (2), (4), (5) with the changing diffusion coefficient $D(c)$.

CONCLUSIONS

The study finds that apple and banana slice drying using the IR film is comparatively successful, but the drying process of the half of grape berry is slower. The average diffusion coefficient of the grape halves is 25% lower than for the apple and banana slices. This can be explained by the impact of grape peel on the water diffusion.

The experimental data processing showed that the diffusion coefficients are changing during the drying process. The proposed methodology allows calculating the diffusion coefficient depending on the concentration.

In order to ensure suitable moisture for drying products with economic benefits, optimization of the drying time is necessary and should be respected.

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Use of thermal images for optimizing burner height, operating pressure, and burner angle of a weed flamer

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Abstract. A two-meter wide prototype weed flamer was developed as a tool for thermal weed control. The weed flamer consists of an LPG tank, pressure regulator, back pressure valve, flow valves, and burners. The burner adjustments are flexible with height setting from 0 to 450 mm and flame angle setting from and 0 to 90°.The thermal camera images were studied at different heights (150, 200, 250, and 300 mm), burner angles (30 and 45°), and pressures (0.1, 0.15, 0.2, 0.25 MPa) to determine the best settings under stationary operating conditions. Based on thermal camera image results, it was found that the burner should be set at 200–250 mm with 0.2–0.25 MPa to obtain the highest temperatures and longest flames. The initial tests of the gas burning system were completed as a broadcast flaming machine and gas doses from 15 to 90 kg ha^{-1} were applied from 0.25 m above the ground at 30° flaming angle at 0.2 MPa. The dose-response curves of a weed (*Convolvulus arvensis* L.*)* were generated to determine the effectiveness of the weed flamer. *C. arvensis* could be controlled with gas doses from 40 to 82 kg ha^{-1} depending on the growth stage at 14 day after treatment (DAT). The theoretical field capacity of the 2 m wide flamer varies from 0.32 to 1.62 ha h^{-1} depending on the gas dose to be applied.

Key words: weed control, flaming, thermal image, dose-response, LPG.

INTRODUCTION

Controlling the weeds in arable lands is challenging due to complex nature of the weeds and their ability to sustain in different ways. In today’s agricultural practices, the most efficient way to cope with weeds is to use herbicides, a common type of pesticides. However, the drawbacks of using pesticides are well known to humans, animals, and environment. The governments and the related organizations tend to put strong emphasis on reducing pesticides, urging researchers to develop alternative methods to reduce agricultural chemicals. One of the methods that can be technically applicable is flaming, a thermal method of weed control. The cost-effectiveness of the thermal methods was discussed in the literature and some researchers reported results in favor of weed flaming, particularly in organic farming (Parish, 1990; Ascard, 1995; Bond & Grundy, 2001; Rifai et al., 2003). The weed flaming was studied for both field crops (Pelletier et al., 1995; Seifert & Snipes, 1998; Ulloa et al, 2010), vegetable growing (Netland Set al., 1994; Wszelaki et al., 2007; Sivesind, 2010), and for disease control (Laguë et al., 1997; Mirzakhani & Ehsani, 2014). Flamers are also used in urban areas where pesticides are avoided (Rask et al., 2012; Raffaelli et al., 2013). Selective flaming can be an option particularly in areas where the labor is expensive for weeding (Sivesind, 2010).

Several researchers studied the technical and engineering aspects of a weed flamer. Knezevic et al. (2011) recommended that a research type weed flamer consists of a tank, flow safety valve, strainer, master solenoid valve, shut off valve, flow regulator, pressure gage, pilot solenoid valve, and burners. The performance of different flamers was studied (Lague et al., 1997) and a research flamer was developed by other researchers (Ascard, 1995; Kang, 2001; Knezevic et al., 2007).

The calibration of a flaming machine depends upon the working width and ground speed during the application (Kang, 2001). The speed affects the gas (propane or LPG) dose (kg ha^{-1}) applied in the field. The calibration may be done by measuring the gas flow rate at different pressures and choosing an applicable pressure to obtain sufficient gas flow rate that will provide gas doses from 15 to 90 kg ha^{-1} (Knezevic & Ulloa, 2007; Sivesind et al., 2009) or higher doses than 90 kg ha^{-1} (Kristoffersen et al., 2008).

The low propane doses require high ground speeds at a given pressure or gas flow rate. The ground speeds were reported from 1.0 to 7.5 km h^{-1}, however, an acceptable constant ground speed may be chosen in which case the pressure setting needs to be adjusted to provide the desired propane doses (Mutch et al., 2008; Ullua et al., 2010).

Different types of thermocouples were used by researchers for measuring the flame temperatures to develop the burners, optimize the adjustments, or determine the effect of flaming on weed control (Ascard, 1995; Laguë et al, 1997; Ascard, 2008; Mojžiš & Varga, 2013). However, flame images were not extensively utilized to study the heat variation behind the burner. The general objective of this study was to develop a weed flamer that can be used for surface and row flaming. The specific objective of the study was to use thermal camera images of the flames to determine the best operating conditions for the burner angle, burner height, and gas pressure and to use the flamer to obtain the dose-response curve of a given weed.

MATERIALS AND METHODS

Materials

An LPG burning system was developed in this study, which is the sub-system of the cultivator-flamer machine developed under a different project not reported in this paper. The gas burning system consists of an LPG tank, pressure reducing valve, a valve group to distribute the gas to the burners, and burners with a 1.5 mm gas nozzle. The LPG tank was designed with 1.7 MPa operating pressure and a burst pressure of 3.0 MPa. However, the gas pressure inside the tank was not greater than 1.0 MPa after being filled with LPG up to 80% of the theoretical tank capacity.

Chromium shafts were used as the carrier of the burners. The burners were also manufactured using chromium metal sheets.

A cultivator was used to integrate the gas burning system with mechanical unit. The tank was mounted on the cultivator frame and burners were mounted on a shaft that was attached to the rear bar of the cultivator. This part of the study was not included in this paper.

A thermal camera (Testo T885) was used to capture the flame images behind the tractor from the side view. For field tests, a weed species (*C. arvensis*) was selected to determine the applicability of the weed flamer for effective weed control.

Methods

First, the gas burning system was designed, which comprised a gas tank with 12 kg capacity to develop the burner with a 1.5 mm gas nozzle. The nozzle and the burner were tested at different pressures (0.05, 0.1, 0.15, 0.20, 0.25 MPa) to determine the flow rate of the nozzle as a function of pressure (Güleç et al., 2015). The flow rate of the nozzle was determined using gravimetric method by measuring the weight difference of the tank for a given time interval (60 s) using an electronic scale. These tests were replicated four times providing the pressure-flow rate characteristic of the nozzle, the width and the length of the flame obtained from the burner. LPG was used to burn in the system and the calibration of the burner was done by using the flame width of a single burner and the gas doses (15, 30, 45, 60, 75, and 90 kg ha^{-1}) to obtain the necessary ground speed of the flamer.

Then a 580 L capacity gas tank was built and mounted on a cultivator frame for the field operations. The gas burning system was modified to work with 8 burners with 0.25 m flame width for each burner, resulting in a 2 m wide working width for broadcast flaming. A hood was built and mounted over the burners to improve the efficiency of the flaming. The flamer can be used with or without the hood depending on field conditions during a specific application.

The angle of the flame (30° and 45°), the height of the burner (150, 200, 250, and 300 mm), and the pressure were varied to determine the best settings for flaming during the tests conducted under stationary conditions. The flame temperature values, the heat distribution behind the burner, and the flame lengthweremonitored using the thermal camera so that the height, the angle, and the operating pressure of the burner could be optimized.

Field tests were conducted to confirm that the weed flamer could be used to find the dose-response curves of a given weed species. For this purpose, *C. arvensis,* a common weed throughout the country, was chosen. The field trials were done in the walnut and mixed fruit orchards of İnönü University to obtain the dose-response curves of *C. arvensis* during hooded flaming. Based on the adjusted heights and pressure values found from thermal camera images, 0.25 m height, 30° flame angle, and 0.2 MPa gas pressure were set for field application.

The weed control rate was determined based on visual observations in the 1, 7, and 14 DAT with four replications at 2–4, 6–8, and 10–12 leaf stages. Log-logistic model was used to obtain the weed control rates (Streibig et al., 1993; Seefeldt et al., 1995) and the results were graphed using the dose-response curve statistic (Knezevic et al., 2007) added to the R program (R Development Core Team, 2006). The biological efficiency of flaming was determined by using control rates of 50%, 80%, and 90%.

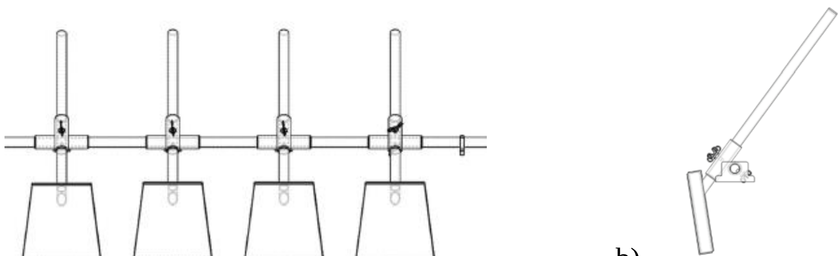
RESULTS AND DISCUSSION

The weed flamer

The picture of the weed flaming machine developed in this study is given in Fig. 1. The system comprises a pressure release valve, pressure regulator, gas level indicator, and a charging inlet for LPG.

Figure 1. The weed flamer developed in this study.

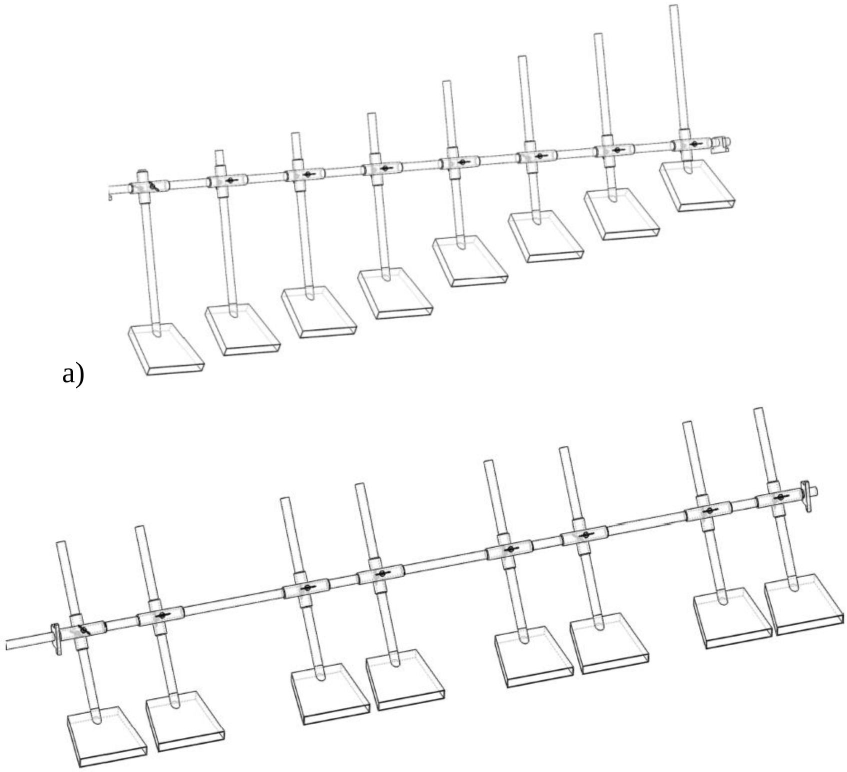
The burners of the flamer were set equally spaced on the carrier shaft for surface flaming (Fig. 2a). The angle of each flamer with respect to the ground can be adjusted by rotating the burner shaft around the carrier shaft (Fig. 2b).



a) b)

Figure 2. a) The carrier shaft and the burners, b) Angle of the burner set towards the ground.

The height of each burner can be adjusted separately by sliding the burner shaft up and down inside the vertical pipe of the apparatus that allows lateral and vertical movement of the burners (Fig. 3a). The burners could be grouped up with multiple numbers for band flaming or for row flaming (Fig. 3b).



a)

b)

Figure 3. a) Flexible height adjustment of burners, b) Spacing adjustment of burners.

The burners could be rotated on the vertical axis so that a burner faces to the sides to control intra-row weeds on the crop rows (Fig. 4). In such configuration, either two burners will face against each other or can be staggered with a small modification so that the flame could be directed towards the rows.

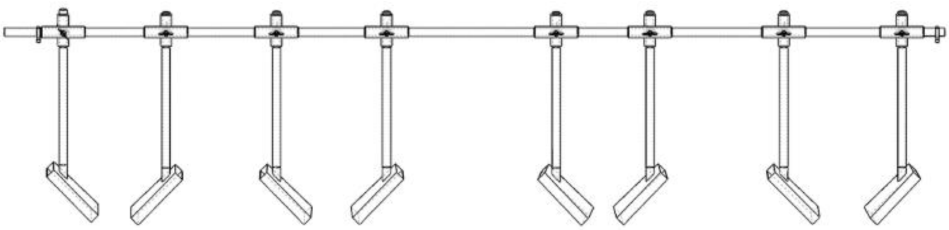
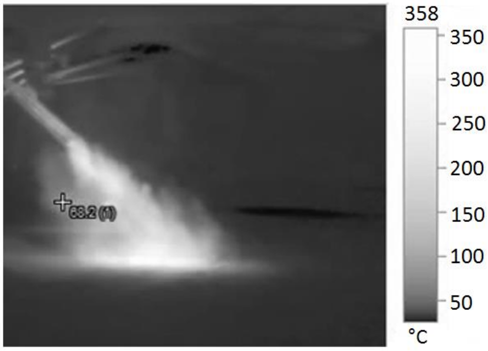


Figure 4. Rotating the burners towards row plants for intra-row flaming.

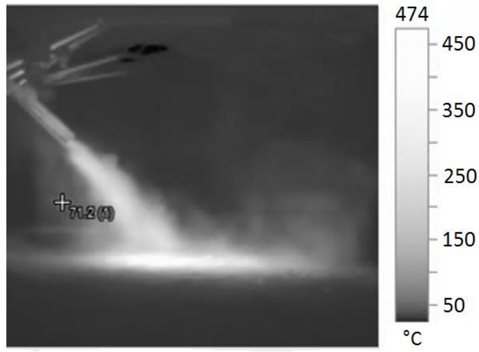
Thermal camera images

The thermal camera images at different gas pressures, burner heights, and burner angles were studied based on visual observations. The effect of burner angle and the gas pressure at a given burner height is given in Fig. 5. At a burner height of 300 mm and burner angle of 45° (Fig. 5a), the flame temperatures above the ground at 0.1 MPa were much lower (320 °C) compared to the temperature values (about 400 °C) at 0.25 MPa.

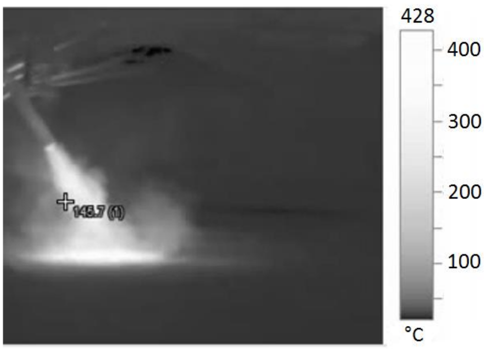
When the burner angle was set to 30° (Fig. 5b), the flame was better directed towards the ground and increased the temperatures approximately by 50 °C at both 0.1 and 0.25 MPa, compared to the burner angle of 45°. It was inferred that operating the gas burning system at low pressures and big burner height settings with 45° burner angle would not be efficient to obtain high temperature over the ground.



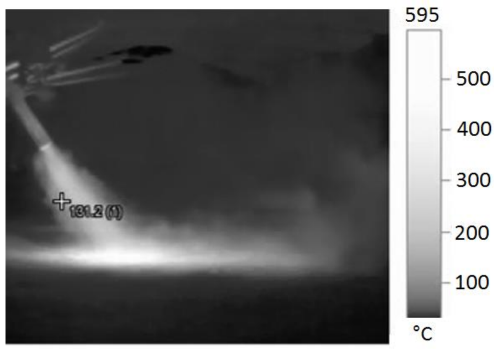
a) 45°, 0.1 MPa, 300 mm



45°, 0.25 MPa, 300 mm

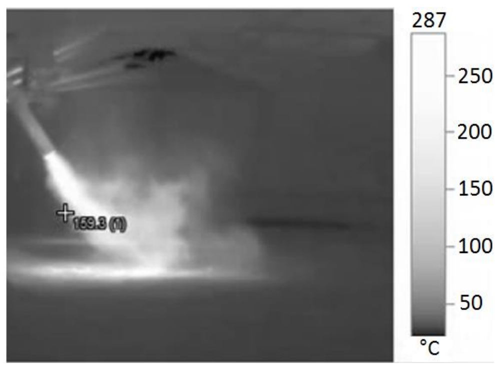


b) 30°, 0.1 MPa, 300 mm



30°, 0.25 MPa, 300 mm

c) Wind effect. 45°, 0.1 MPa, 300 mm

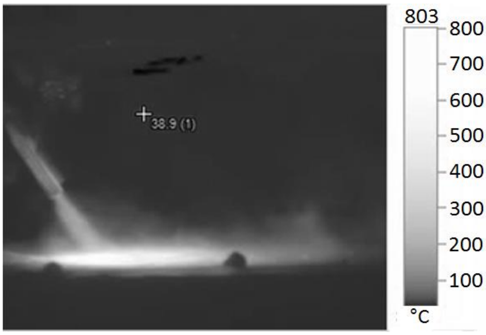


30°, 0.1 MPa, 300 mm

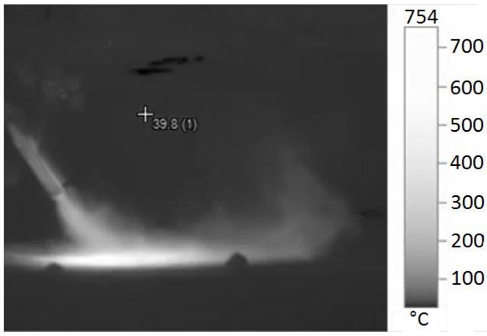
Figure 5. Effect of pressure on heat trace behind the burner at 300 mm height and 0.1 MPa pressure setting: a) at 45°, b) at 30° c) wind effect at 45° and 30°.

An image was also obtained when there was wind in the opposite direction of the flame angle at 0.1 MPa (Fig. 5c). The flame was significantly affected by the wind and was found to be weak to reach the ground at 45°. The same observation was made at the burner angle of 30° at 0.1 MPa (Fig. 5c) under the effect of wind speed of 0.5 to 1.5 m s^{-1}. It was concluded that the low gas pressure and increased burner height settings could not efficiently spread the heat over the ground under the field conditions, especially in the presence of wind in opposite direction. Based on the observations made above, the lowest gas pressure (0.1 MPa) and the greatest burner height setting (300 mm) were considered inefficient for weed flaming with the system developed in this study.

Lower temperature values were obtained over the ground when the burner height was set to 150 mm at both 45 and 30° flaming angles, compared to the burner height settings at 200 and 250 mm. Therefore, the images taken at burner height of 150 mm were not presented in the results. The more applicable burner heights to achieve high flame temperature and longer flame length were 200 and 250 mm at gas pressures of 0.2 and 0.25 MPa (Fig. 6).

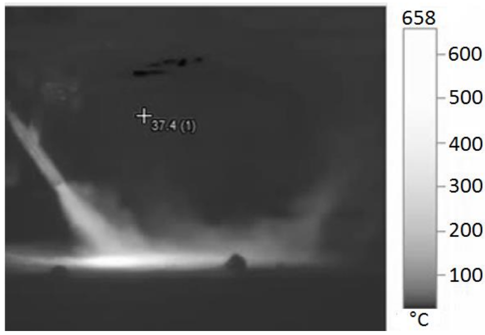


a) 30°, 0.25 MPa, 200 mm



30°, 0.20 MPa, 200 mm

b) 30°, 0.25 MPa, 250 mm



30°, 0.20 MPa, 250 mm

Figure 6. The flame patterns at 30° flame angle at different 0.25 and 0.2 MPa with 200 mm (a) and 250 mm (b) burner heights.

The flame length increased and was about 600 mm under 0.2 and 0.25 MPa. Also, the temperatures in Fig. 6 were greater, compared to Fig. 5, as shown on the temperature bars next to the images. The highest measured flame temperatures in Fig. 5 ranged from 280 to 590 °C depending on the burner and gas pressure settings whereas the greatest temperatures in Fig. 6 ranged from 650 to 800 °C. It was concluded that the gas pressures of 0.20 and 0.25 MPa with 200 and 250 mm heights could be used in field applications whereas the pressures of 0.1 and 0.15 MPa with 150 and 300 mm would not be effective.

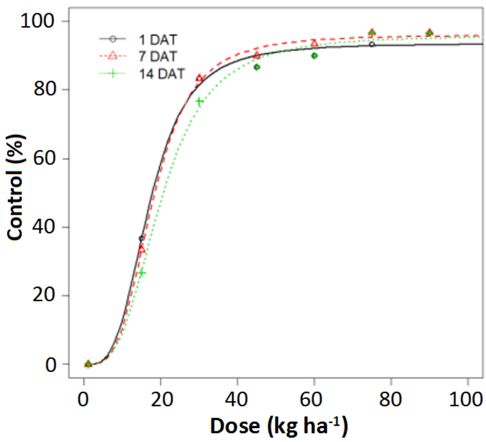
It should be noted that the greatest temperatures on the temperature bars in Figs 5–6 relate to the spot temperature where the flame hits the ground, resulting from directing the flame on the same spot during the test. Therefore the flame temperatures over the ground were less than the hot spot temperature on the ground. In this study, the thermal camera images were helpful to see under which conditions the flame reached the ground and spread well over the ground by studying the side view of flame. The measured hot spot temperatures will probably not be exposed to the weeds under field conditions. These tests were conducted under stationary conditions to obtain the images, thus increasing the surface temperature during the experiments. Despite this poor representation of field working conditions, the images were helpful to determine the differences in flame shape behind the burner, providing useful data on the best combinations for the gas pressure, burner height, and burner angle settings.
Storeheier (1994) used burner angles of 22.5°, 45°, and 67.5° at heights of 20, 40, and 60 mm with pressures between 0.12 and 0.25 MPa. The burner was suggested to be close to ground with angles between 22.5 and 45°. Also, it was found that the burner angle was not important as the height of the burner increased, according to Storeheier (1994). The current study agrees that the burner height defines whether the flame can reach the ground independent of the burner angle. At the burner height of 300 mm, the greatest height used in this study, the tested burner angles could not generate high temperatures on the ground. Ascard (2008) directed the burner towards the ground at 33°, 45°, and 90° (straight down) at a height of 10 cm from the ground and found that 33° provided the best weed reduction. In terms of burner angle setting, the findings of our study were similar to those of Ascard (2008), suggesting that the burner angle should be close to 30° rather than 45°.

Dose-response curves

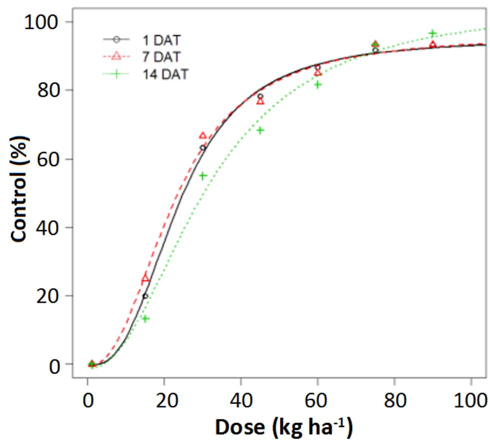
Among the four combinations of burner angle, gas pressure, and burner height given in Fig. 6, 0.2 MPa operating gas pressure and 250 mm burner height were chosen and six different gas doses (15, 30, 45, 60, 75, and 90 kg ha^{-1}) were applied in the field conditions to determine the control rate of the selected weed (*C. arvensis*). Fig. 7 shows the dose-response curves at three different growth stages at 1, 7, and 14 DAT.

The control rate of the weed in Fig. 7 improved with increased applied dose. The control rate increased rapidly with increasing gas dose at low doses from 20 to 40 kg ha^{-1}. Less than 80% control could be achieved at 1 DAT and 7 DAT with 40 kg ha^{-1}. At 14 DAT, the need for dose was much greater (about 80 kg ha^{-1}) for 80% weed control.

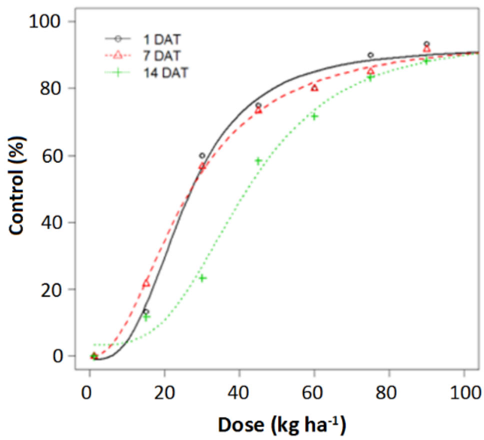
The doses applied in the field were similar to the doses used in previous studies (Knezevic & Ulloa, 2007; Sivesind et al., 2009) and were enough to control the weeds at different growth stages. Fifty per cent weed control rate was achieved with 17 to 20 kg ha^{-1} at 2–4 leaf stage whereas the dose requirement increased to 26 and 42 kg ha^{-1} at 10–12 leaf stage. For 90% control rate, dose ranges were about 38 to 40 kg ha^{-1} and 55 to 82 kg ha^{-1}, respectively at 2–4 and 10–12 leaf growth stages. Ascard (1995) controlled other weeds at 0–4 leaf stage at a control rate of 95% with 10–20 kg ha^{-1} propane dose and 100% with a propane dose of 20–50 kg ha^{-1}. Kang (2001) found that 40 kg ha^{-1} and greater LPG doses could control 80% of the weeds while 60 kg ha^{-1} dose achieved 90% weed control rate. The differences in the dose requirements compared to other studies may be attributed to the differences in weed species.



a) 2–4 leaf stage



b) 6–8 leaf stage



c) 10–12 leaf stage

Figure 7. Dose-response curves showing the control rates of *C. arvensis* as a function of gas dose at three different growth stages at 1, 7, and 14 day after treatment (1 DAT, 7, DAT, and 14 DAT).

Field capacity

Using the flamer width of 2.0 m and the ground speeds from 1.6 to 8.1 km h^{-1}, the theoretical field capacity of the machine was calculated to be 0.32 to 1.62 ha h^{-1} for the applied doses from 15 to 90 kg ha^{-1}.

In this study, an attempt was made to determine whether applicable operating conditions could be found by studying the thermal camera images of the flames using the side views during flaming in stationary operations. The temperature distributions of the flames showed that the differences in flame temperature and the length of the flame could be visually observed and compared.

CONCLUSIONS

The followings could be concluded as result of this study:

1. Flaming angle of 30°was better than 45°. Increased burner angle reduced the temperatures measured on the ground behind the tractor.

2. Low operating pressures (0.1 and 0.15 MPa) were not sufficient to generate high temperatures near the ground. Furthermore, in the presence of wind, the flame pattern distorted easily resulting in very poor heat distribution over the ground.

3. The best combinations of the pressure and burner height were found with 0.2–0.25 MPa and 200–250 mm, respectively.

4. Thermal camera images were helpful to determine inefficient operating conditions for the given gas nozzle and burner.

5. The field tests showed that a broadleaf weed (*C. arvensis*) could be controlled at 90% level with 40 kg $ha^{-1}$and 82 kg ha^{-1}at 14 DAT, respectively at 2–4 and 10–12 L stages at 0.2 MPa gas pressure at 250 mm burner height.

6. The theoretical field capacity of the weed flamer was calculated to be 0.32 ha h^{-1} for the greatest dose (90 kg ha^{-1}) and 1.62 ha h^{-1} for the smallest dose (15 kg ha^{-1}) applied in the field.

ACKNOWLEDGEMENTS. The authors would like to thank Turkish Scientific and Technological Research Council (TUBİTAK) for financially supporting the project no. 213 O 109. We appreciate the support of İnönü University for providing the experimental field. The workshop of the Biosystems Engineering Department was used at Kahramanmaraş Sütçü İmam University to develop the initial prototype, and Gemciler Tarım Makineleri Co cooperated in building the prototype used in the field experiments.

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Biogas production from sugar rich waste

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Abstract. 56 biogas plants are working today in Latvia. There is need to investigate the suitability of various biomasses for energy production. Sweets production factories by-products are organic waste and wastewater featuring a high sugar content. Wastewater have a high chemical oxygen demand (COD) level and requires special treatment that results in additional input of energy and financial resources.
This article shows the results of two studies evaluating sugar-containing biomass suitability for the production of biogas.
The anaerobic digestion process of damaged jam and sweets factory wastewater was investigated for biogas production in 0.75 L digesters, operated in batch mode at temperature 38 ± 0.1 °C. The average biogas yield per unit of organic dry matter (ODM) from digestion of damaged jam was 1.114 L g^{-1}_{ODM} and methane yield was 0.716 L g^{-1}_{ODM}. Average biogas yield from digestion of sweets production factory wastewater was 1.058 L g^{-1}_{ODM} and methane yield was 0.663 L g^{-1}_{ODM}. All investigated sugar rich wastes can be utilised for biogas production successfully thus providing an environmental solution for wastewater problem of sweets production factories.

Key words: anaerobic digestion, sugar rich wastes, biogas, methane.

INTRODUCTION

The research project aims to find out the potential for biogas production from sweets production plant by-products and from food industrial wastewater (SFW) as raw materials.

Organic biomass wastes utilization via anaerobic fermentation process can be regarded as environmental treatment technology, providing both biogas production for the energy as well as the organic fertilizer production for the plant nutrients recycling. Over the last decade considerable efforts have been invested in developing of biogas production technologies in many countries of the EU (Gomez, 2013). The first purpose for biogas plant is manure treatment for environment advantages, and the second purpose is to meet the growing energy demands in the situation, while prices on fuel and energy are increasing drastically. In recent years the biogas production is booming also in Latvia. 56 biogas plants are working today in Latvia. There is a need to use different raw materials in biogas plants (Dubrovskis et al., 2012). Advantages of biogas technology are as follows:

– the essential ecological advantage of biogas technology is that less greenhouse gases, e.g., methane, nitrogen oxide, carbon dioxide, are emitted. For example, greenhouse gases (GHG) emissions from usage of corn for biogas energy production are by 28.8%, or 3.5 times less compare to GHG emissions from natural gas usage for heat energy production (Dubrovskis & Plume, 2009);

– the anaerobic treatment improves the quality of organic fertilizer obtained from anaerobic digestion of manure. Odours emission is reduced, as the substances with strong odour, such as volatile fatty acids or phenols are effectively decomposed. Both pumping ability and flow ability were improved, due to homogenization in the anaerobic fermentation process, so manure spreading as organic fertilizer in the field can be provided with high uniformity and quality (Dubrovskis et al., 2011a);

– finished digestate after anaerobic treatment still have substantial amount of organic matter (OM) that can be used as a source of plant nutrients. For example, maize biomass digestate contains up to 38% of initial OM after finishing of batch anaerobic fermentation process without mixing (Dubrovskis et al., 2010). Biogas technologies are an ideal solution for local conversion of waste, and for returning of organic by-products from towns and villages into the soil. Fermented organic waste is an efficient substitute of mineral fertilizers and reduces the risks of soil acidification and drinking water contamination from high doses mineral fertilizers application;

– biogas systems contributes to the climate protection goal, as the construction and operation of biogas plants can advance the sustainable development and to disseminate environmentally compatible technologies (Dubrovskis et al., 2011b).

Foreign researchers' results show that the biomass with high sugar content can get a large amount of biogas (Misi & Forster, 2001; Kaparaju et al., 2002; Neves et al.; 2002; Mbohwa, 2003; Yasar et al., 2014). For example Lund University researchers studied the sugar beet co-fermentation (Parawira et al., 2004). Results from this study suggests that potato waste and sugar beet leaves are potential substrates for anaerobic digestion for the production of biogas and could provide additional benefits to farmers in southern Sweden. The general conclusion is that starch rich substrates may potentially be mixed with other biomass rich in nitrogen content and then co-digested.

Biogas production from sugarcane waste has large potential for energy generation, however, to enable the optimization of the anaerobic digestion (AD) process each substrate characteristic should be carefully evaluated. Biochemical methane potential assays were performed to evaluate the energy potential of the substrates according to different types of sugarcane plants. Methane yields obtainable from fresh matter (FM) varied considerably (5–181 Nm^3 ton FM^{-1}), mainly due to the different substrate characteristics and sugar and/or ethanol production processes (Janke et al., 2015).

The previous study (Dubrovskis & Adamovics, 2012) showed that the damaged food products with high sugar content can be successfully utilised in the production of biogas. The raw materials can be by-products, residues or products not more usable for food production.

The research project aims to find out the potential for biogas production from damaged jam and sweets production factory wastewater. Positive results will give confidence on advantages of utilization of food industrial wastewater (FIW) for biogas production instead of entering SFW in the biological treatment plant.

MATERIALS AND METHODS

The volume of biogas production was studied using laboratory equipment consisting of 16 bioreactors. Fermentation temperature was maintained 38 ± 0.1 °C inside containers during batch mode process. Mixture for investigation consists of 500 g inoculum (fermented cow manure) and added biomass sample 20 g damaged jam (Study 1) or 500 g inoculum and 40 g sweet factory wastewater (Study 2) placed into 0.75 L bioreactors for anaerobic fermentation. Dry matter, ash and organic dry matter content was determined for every sample mixture before filling into bioreactor. All bioreactors within each study were placed into large, single-compartment thermostat at constant temperature 38°C for anaerobic fermentation processing during 21-day period. Measuring accuracies were following: ± 0.2 g for inoculum and substrate weight (scales Kern FKB 16KO2), ± 0.001 g for biomass samples for dry matter, organic matter and ashes weight analyses, ± 0.02 pH for pH measurements (accessory PP-50), ± 0.05 L for gas volume, and ± 0.1 °C for temperature inside the bioreactor. Gas volumes were measured help by special gas bags in volume of 2 litres positioned outside of reactor and connected with reactors by plastic pipes. Gases volume measurements and gases analysing were provided during fermentation period regularly.

Biogas composition, e.g. methane, carbon dioxide, oxygen and hydrogen sulphide volume, was measured with the gas analyser GA 2000. Dry matter was determined using specialized unit Shimazy at temperature 105 °C, and ashing was performed in oven Nabertherm at temperature 550 °C using the standard heating program. Standard error was calculated using standardized data processing tools for each group of bioreactors.

RESULTS AND DISCUSSION

In **Study 1** was provided anaerobic fermentation of damaged jam for biogas and methane production using 8 bioreactors for inoculum (IN) and damaged jam production wastes (DJ) mixture and 2 bioreactors for control (IN). Biogas and methane data from all 10 bioreactors were used to calculate the average biogas and methane volume for each group of similar bioreactors filled in with the same sample replications. The results were summarized in Tables 1, 2, and in Fig. 1, below.

Results of analyses of damaged jam (DJ) are determined separately and also together with inoculum in reactors R2-R9, see Table 1. The initial pH value for damaged jam is rather low, probably, due to long storage period and/or storage at elevated temperatures.

Table 1. The results of the analyses of raw materials in Study 1

Bioreactor numbers	Raw material	Substrate pH	TS, %	TS, g	Ashes, %	ODM, %	ODM, g	Weight, g
R1, R16	IN 500	7.25	3.42	17.1	28.71	71.29	12.19	500
	DJ20	4.2	41.3	8.26	13.1	86.9	71.18	20
R2-R9	IN500+DJ20	7.15	4.88	25.36	23.62	76.38	19.37	520

Abbreviations: TS – total solids; ODM – organic dry matter; IN – inoculum. DJ – damaged jam.

Biogas and methane yields from damaged jam are shown in Table 2. Average volume of biogas (1.5 L) or methane (0.276 L) released in control bioreactors R1, R16 is already subtracted from biogas volume obtained from every bioreactor filled in with inoculum and jam biomass mixtures, see in Table 2.

Table 2. Biogas and methane extraction in Study 1

Bio-reactor	Raw material	Biogas, L	Biogas, L g^{-1}_{ODM}	Methane average %	Methane, L	Methane, L g^{-1}_{ODM}
R1	IN500	1.40	0.115	18.32	0.256	0.021
R16	IN500	1.60	0.131	18.52	0.296	0.024
Average, R1, R16		1.50	0.123	18.42	0.276	0.023
R2	IN500+DJ20	8.00	1.115	64.00	5.168	0.720
R3	IN500+DJ20	7.90	1.100	65.05	5.139	0.716
R4	IN500+DJ20	8.10	1.128	64.16	5.197	0.724
R5	IN500+DJ20	7.90	1.100	64.51	5.096	0.710
R6	IN500+DJ20	8.20	1.142	63.55	5.211	0.726
R7	IN500+DJ20	7.90	1.100	64.05	5.060	0.705
R8	IN500+DJ20	7.80	1.087	65.24	5.089	0.709
R9	IN500+DJ20	8.20	1.142	63.11	5.175	0.721
Average. R2-R9		8.00 ±0.2	1.114 ±0.028	64.21 ±0.96	5.142 ± 0.076	0.716 ± 0.011

Abbreviations: L g_{ODM}^{-1} – litres per 1 gram organic dry matter of the original raw material.

Biogas and methane production from damaged jam is shown in Fig. 1

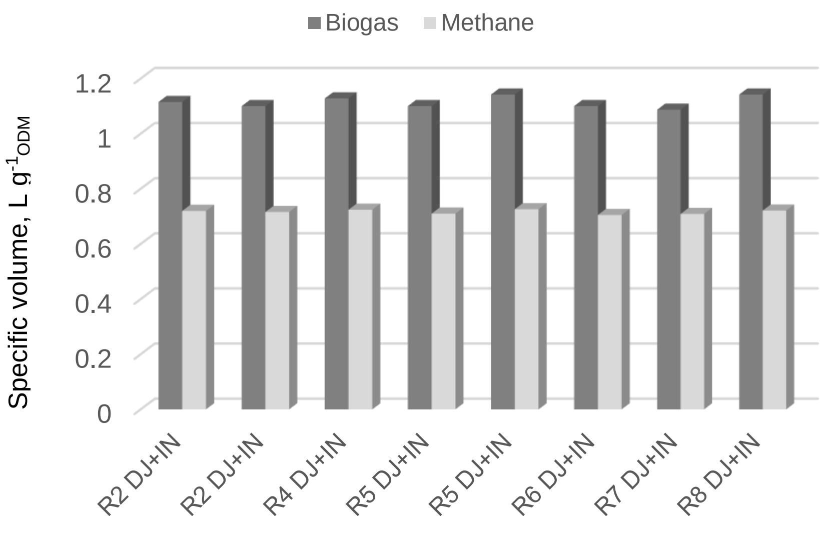

Figure 1. Specific biogas and methane volumes from bioreactors with damaged jam and inoculum.

An investigated average methane yield from damaged jam was 0.716 ± 0.011 L g_{ODM}^{-1} and study shows that jam not usable for food still can be successfully utilised for biogas production.

In **Study 2** wastewater from sweet production factory was investigated. The methodology for biogas and methane potential estimation was the same as in Study 1, only difference was number of bioreactors – 12 bioreactors were used in this investigation. Raw material analysis results are shown in Table 3.

Table 3. The results of the analyses of raw materials in Study 2

Bioreactor number	Raw material	Substrate pH	TS, %	TS, g	Ash, %	ODM, %	ODM, g	Weight, g
R1 and R16	IN	7.29	3.05	15.25	21.9	78.1	11.910	500
	SFW	5.95	3.41	2.225	0.60	99.4	2.212	40
R2-R11	IN + SFW	7.22	3.24	17.475	19.19	80.81	14.122	540

Raw sweets factory wastewater (SFW) had low total solid and organic dry matter content (see Table 3). However, SFW is well suited for the production of biogas, as it contains a lot of sugars and juice. This is confirmed by results of finished digestate analyses and calculation of biogas parameters (Table 4).

Table 4. The results of the analyses of digestate

Bioreactor	Raw material	Substrate pH	TS, %	TS, g	Ash, %	ODM, %	ODM, g	Weight, g
R1	IN	7.21	2.90	14.21	23.53	76.47	10.87	490.2
R16	IN	7.16	3.01	14.90	21.40	78.60	11.71	495.2
R2	SFW + IN	7.08	2.69	14.21	23.96	76.04	10.81	528.4
R3	SFW + IN	7.19	2.51	13.29	28.92	71.08	9.45	529.4
R4	SFW + IN	7.10	2.55	13.46	24.93	75.07	10.11	528.0
R5	SFW + IN	7.06	2.46	13.04	30.02	69.98	9.12	530.0
R6	SFW + IN	7.05	2.74	14.26	30.04	69.96	9.98	520.6
R7	SFW + IN	7.08	2.89	15.25	25.82	74.18	11.31	527.6
R8	SFW + IN	7.02	2.69	13.88	27.63	72.37	10.04	515.8
R9	SFW + IN	7.17	2.31	12.11	34.06	66.94	8.12	524.4
R10	SFW + IN	7.11	2.81	14.86	25.65	74.35	11.05	528.8
R11	SFW + IN	7.12	2.45	12.86	26.75	73.25	9.42	525.0

The content of remaining organic dry matter in finished digestate shows, that organic matter was biodegraded in average by 4.181 g (29.6%) or 0.62 g (5.2%) in mixture (SFW + IN) or in inoculum (IN) respectively. Assuming, that organic matter from sweet factory wastewater (2.212 g) is degraded almost completely, the only logical explanation of excessive biodegraded organic matter in mixture (SFW + IN) is that mixing of wastewater with inoculum causes additional biodegradation of inoculum (IN) by 1.249 g (11.3%) in average, compared to biodegradation of pure inoculum. Surprisingly good results of methane production in reactors R2-R11 can be explained by uniform distribution of raw biomass (favourable for anaerobic fermentation microorganisms) and the chemical composition of raw SFW substance (a lot of sugar and juice) as well as with the above mentioned co-digestion effect of inoculum.

Specific biogas and methane production per 1 g organic dry matter of raw material, average results and standard error were calculated using standard statistical methods. Biogas and methane volumes for bioreactors R2-R11 are shown with already subtracted an average biogas and methane volumes obtained from control reactors (R1, R16) in Table 5.

Table 5. Biogas and methane extraction in study 2

Reactor	Material	Biogas, L	Biogas, L g^{-1}_{ODM}	Methane aver. %	Methane, L	Methane, L g^{-1}_{ODM}
R1	IN 500 g	0.90	0.076	26.11	0.235	0.02
R16	IN 500 g	1.10	0.092	28.82	0.317	0.027
R2	SFW 40 g + IN 500 g	1.70	0.769	54.24	0.922	0.417
R3	SFW 40 g + IN 500 g	2.30	1.040	63.78	1.467	0.663
R4	SFW 40 g + IN 500 g	2.30	1.040	63.48	1.460	0.660
R5	SFW 40 g + IN 500 g	3.30	1.492	60.82	2.007	0.907
R6	SFW 40 g + IN 500 g	2.40	1.085	61.42	1.474	0.666
R7	SFW 40 g + IN 500 g	1.80	0.814	70.83	1.329	0.601
R8	SFW 40 g + IN 500 g	3.10	1.401	58.65	1.818	0.822
R9	SFW 40 g + IN 500 g	2.30	1.040	59.22	1.362	0.616
R10	SFW 40 g + IN 500 g	2.00	0.904	69.70	1.394	0.630
R11	SFW 40 g + IN 500 g	2.20	0.995	65.45	1.440	0.651
Average (R2-15)		2.34 ± 0.51	1.058 ± 0.23	62.76 ± 5.05	1.467 ± 0.29	0.663 ± 0.13

Biogas and methane specific volumes per 1 g organic dry matter from sweets factory wastewater (SFW) from each bioreactor is shown in Fig. 2.

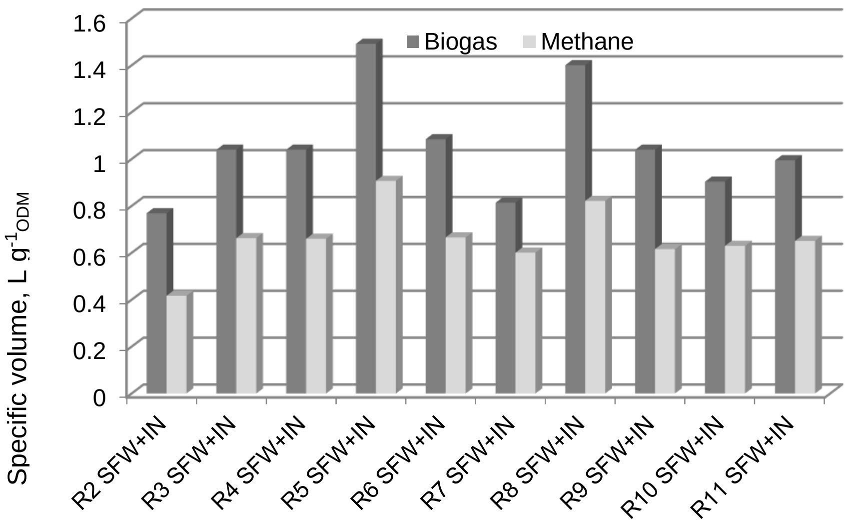

Figure 2. Specific biogas and methane volumes from sweets factory wastewater.

The average methane content of biogas from each bioreactor with wastewater is shown in Fig. 3. High methane content can be explained by the fact that sweets production factory wastewater have a large quantity of organic acids, including acetic acid (acetic acid is consumed foremost by the bacteria in methane production process).

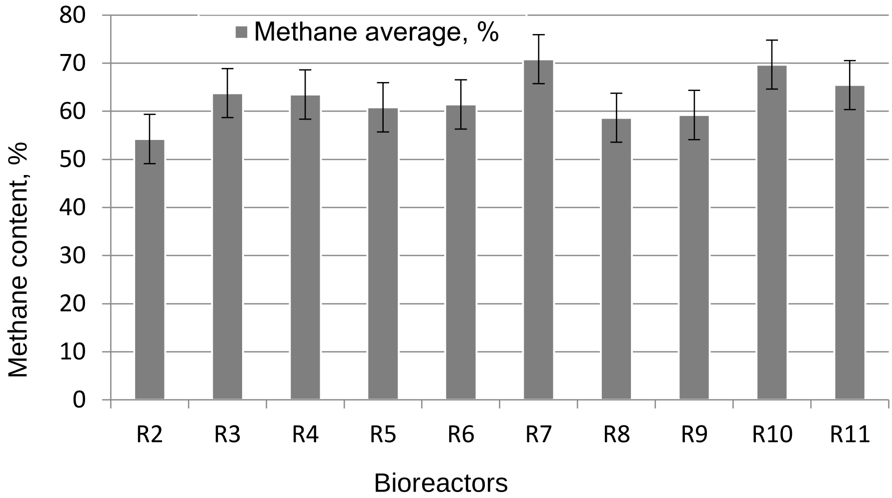

Figure 3. Average methane content in biogas from sweets factory wastewater mixtures with inoculum.

There can be estimated from Table 5 that one kg sweets factory wastewater mixtures with inoculum (weight of mixture before treatment) produces 36.75 L methane (58.5 L biogas) or 1 t produces 36.75 m^3 methane (58.5 m^3 biogas). Approximately 2 kWh of electricity and 3 kWh of heat can be produced from 1 m^3 of biogas (with methane content 63%).

CONCLUSIONS

The average biogas yield per unit of organic dry matter added (ODM) from digestion of damaged jam was 1.114 L g^{-1}_{ODM} and methane yield was 0.716 L g^{-1}_{ODM}.

Lots of methane (0.663 ± 0.245 L g^{-1}_{ODM}) is possible to obtain from sweets producing factory waste.

The research results show that the damaged, not usable for food jam is a good raw material for the production of methane.

The addition of raw materials with high sugar and protein content to the inoculum (finished digestate) causes additional methane extraction from digestate, and therefore re-fermentation of digestate by prolongation of fermentation period or by returning of digestate back to the bioreactor can be regarded as useful.

Sweets factory liquid wastes decompose very rapidly and produce a lot of methane in anaerobic fermentation process. Therefore, more methane can be actually obtained from such a liquids compared to mixtures with high concentrations of organic dry matter.

Anaerobic fermentation of sweets factory wastewater can be regarded as most optimal solution, as storing of untreated wastewater results in sharp decline of its pH value. If acidification was ongoing, it is recommended to raise pH value in mixture for anaerobic treatment help by additives to create more favourable conditions for microorganisms.

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Effect of cow traffic system and herd size on cow performance and automatic milking systems capacity

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Abstract. The objective of the current study was to investigate automatic milking systems (AMS) to find relationships between cow traffic system and efficiency of the AMS use. Milking records of cows from 11 Estonian dairy farms (46 AMS units) as well as data coming from four Latvian (7 AMS units) and two Polish (4 AMS units) dairy farms were analyzed to determine the system capacity. The highest capacity (milk yield per AMS unit per day) for Feed First cow traffic system (mean ± SD) 1,817 ± 276 kg was indicated in Estonian dairy farms. 142 and 255 kg more milk was obtained, respectively, compared with Milk First and Free cow traffic systems. Overall, average milk yield per cow per day was the highest with Milk First cow traffic system – 31.4 kg. It was 3.3 kg higher than with Feed First and 3.5 kg than Free cow traffic systems. The average machine-on time for milking was highest with Feed First traffic system, i.e. 85.3 ± 6.1%. However, the lower percentage of machine-on time for milking was observed for Free and Milk First cow traffic systems (76.4 ± 10.1% and 73.3 ± 7.2%, respectively).

Key words: AMS capacity, milk production, cow traffic system, Feed First, Milk First, Free cow traffic.

INTRODUCTION

It is possible to give many examples showing dynamic technical and technological progress, which is implemented in agriculture. Automatic milking system (AMS), known also by the acronyms VMS (voluntary milking system) and RMS (robotic milking system) can be named as a most important solutions expressing advance in modern dairy farm. To develop and discuss problems associated with the use of AMS various aspects are taken into consideration in research studies.

The first ideas about fully automated milking process were generated in the mid-seventies and focused on technical improvement of milking system. Topics included in the program of specialist conferences, like Automatic milking – a better understanding (Meijering et al., 2004) confirm that current problems concerning AMS cover socio-economic aspects, farm and milking system hygiene, animal health, milk quality and abnormal milk, welfare, grazing, farm and herd management (Kic & Nehasilova, 1997; Kic, 1998). All of the mentioned problems and the other ones are the field of detailed research works and assessments to develop knowledge about automatic milking as an integrated system in the dairy farm (Rossing et al., 1998).

One of the most important aspects of the AMS assessment it is efficiency, which can be estimated under current operating and functional conditions (Laurs et al., 2009; Castro et al., 2012). The efficiency constitutes objective of many investigations, where AMS assessment is associated with its capacity (De Koning & Ouweltjes, 2000; Meskens et al., 2001; Artmann, 2004) and expressed by profitability of automatic milking at dairy farms (Cooper & Parsons, 1999; Bijl, 2007).

The efficiency of AMS depends on many factors including technical and technological solutions, like forced traffic in AMS (Bach et al., 2009). The review of cow traffic and milking capacity aspects (Ipema, 1997; Laurs & Priekulis, 2010) can be inspiration to look for higher efficiency of AMS use.

The objective of the current study was to investigate AMS to find relationships between cow traffic systems and efficiency of the AMS use.

MATERIALS AND METHODS

Milking data were obtained from 46 single AMS units placed on 11 dairy cow farms in Estonia. Proper data were also collected in three Latvian dairy farms (equipped with 7 single AMS units) and two Polish dairy farms with four automatic milking systems. One of the Polish dairy farms was equipped with three AMS units (Lely, two A3 Next models and one A4 model) and the second farm with DeLaval VMS model. However Estonian and Latvian dairy cow farms were equipped with only DeLaval VMS model.

Five farms in Estonia had Feed First cow traffic, the rest of four had Free cow traffic and two farms had Milk First cow traffic system. Three Latvian farms had Feed First, while one farm – Milk First cow traffic system. However, one Polish farm had Feed First and the second (with three AMS units) Free cow traffic system.

The computer program DelPro was used to collect data over the period of 14 days per AMS from March 2015 to April 2015 in Estonian farms. Data were recorded over the period of two weeks in 2009 in Latvian dairy farms, while in Polish dairy farms – two weeks in December 2015.

The following records per farm were collected and included into the analysis: number of AMS units, number of cows at milk and total milk yield harvested per day. The data obtained per AMS unit per day were: number of operated cows, milk yield harvested, milkings performed. The results calculated per cow per day were: number of milkings and milk yield harvested. Dataset contained also milking time per one cow (including cows entering the unit, teat cleaning, teat cup attachment, milking, disinfection of the teats and leaving the milking unit) in each dairy farm. Moreover, share of on-time for milking, washing as well idle time were determined. Data gathered in all farms were used to find relationship between capacity of AMS and percentage of on-time for milking. Factors associated with assessment of AMS efficiency were taken to estimate for other relationships in the field of AMS use, i.e. relationship between percentage of on-time for milking and capacity and herd size and milking frequencies.

Acronyms were used to denote proper cow traffic system in the investigated Estonian, Latvian and Polish dairy farms including three groups: FF – Feed First cow traffic system, FT – Free cow traffic system, MF – Milk First cow traffic system.

For each group of dairy farms and particular indices the mean values ± SD were calculated.

Statistical analysis of all collected data was performed using the Statistica v.12 software. Analysis of variance (ANOVA) for main factors was conducted. The statistical model for cow performance included the fixed effects of cow traffic system (Feed First / Free cow traffic and Milk First cow traffic system) and country (Estonia / Latvia / Poland). Significance level was $\alpha = 0.05$. A multiple range test for comparing means in the analysis of variance, i.e. Duncan test was used. Homogeneous groups identified by Duncan test were denoted by a, b and c letters.

RESULTS AND DISCUSSION

Considering data for Estonian dairy farms equipped with AMS (Table 1) it is possible to indicate that the highest capacity expressed by milk yield per AMS unit per day was with Feed First cow traffic system 1817 ± 276 kg (mean ± SD). It was by 142 and 255 kg more than with Milk First and Free cow traffic. The average milk yield per cow per day was the highest with Milk First cow traffic – 31.4 kg. In comparison with Feed First and Free cow traffic it was respectively 3.3 and 3.5 kg higher milk yield. The average AMS on-time for milking was highest with Feed First traffic system – 85.3 ± 6.1%. The lower percentage of on-time for milking was observed for Free and Milk First cow traffic systems – 76.4 ± 10.1 and 73.3 ± 7.2%, respectively.

Comparison of data from Estonian dairy farms (Table 1) showed considerable larger herd size of dairy cows operated by AMS integrated with Feed First traffic system (64.5 ± 4.0 cows) in contrast to the farms with Free and First Milk cow traffic systems (55.7 ± 2.4 and 53.3 ± 4.6 cows, respectively). This can be one of the factor, which explain the highest yield of milk obtained by AMS units per day in farms with Feed First cow traffic system.

The comparison of Estonian dairy farms confirms high production potential of AMS with Feed First cow traffic system. However, the results from Latvian dairy farms equipped with the same cow traffic system and AMS (Table 2) showed that small herd size of cows was operated by AMS (48.0 ± 1.0 cows) as well as low yield of milk gained by AMS units per day – 1,141 ± 159 kg in contrast to 1,817 ± 276 kg in Estonian dairy farms. As a result, it is concluded that Latvian farms don't utilize full potential of AMS and such situation can lead to low effectiveness of AMS and cause therefore financial losses. This is particularly important due to high costs of AMS implementation in dairy farms (Gaworski et al., 2013).

The Polish dairy farm FF1 (Feed First cow traffic system) (Table 3) is comparable with the same characteristics (number of cows per AMS and yield of milk obtained by AMS per day) concerning the same traffic system (Feed First cow traffic) in the Estonian dairy farms. Percentage of time for milking was only variable lower in Polish farm FF1 in comparison with mean value for corresponding Estonian farms FF(1–5) (78.8 vs. 85.3%). The percentage of milking time differs widely between individual farms in all countries. The lowest value (67.7%) was obtained in the Estonian farm FT2 (Free cow traffic system), while the highest value (91.6%) was observed in Estonian farm FF3.

Table 1. Characteristics of different cow traffic systems in the observed Estonian AMS dairy farms

Traffic system / Farm	Number of		Cows AMS^{-1}	Milkings cow^{-1} day^{-1}	Milking time min	Milk yield		Percentage of time for		
	cows	AMS units				kg AMS^{-1} day^{-1}	kg cow^{-1} day^{-1}	milking	Idle	washing
FF1	234	4	58.5	2.55	7.55	1,514	25.9	89.9	6.4	3.7
FF2	253	4	63.3	2.20	7.88	1,741	27.5	76.1	17.9	6.0
FF3	196	3	65.3	2.39	7.65	1,760	27.1	91.6	3.8	4.6
FF4	347	5	69.4	2.23	7.72	2,268	32.7	85.7	10.8	3.5
FF5	132	2	66.0	2.52	7.20	1,802	27.2	83.3	12.3	4.5
(mean ± SD)			**64.5 ± 4.0**	**2.38 ± 0.16**		**1,817 ± 276**	**28.1 ± 2.7**	**85.3 ± 6.1**	**10.2 ± 5.5**	**4.5 ± 1.0**
FT1	218	4	54.5	2.56	7.28	1,434	26.2	71.2	23.2	5.7
FT2	212	4	53.0	2.42	7.50	1,416	26.6	67.7	27.3	5.0
FT3	233	4	58.3	2.59	7.50	1,673	28.6	76.2	17.2	6.7
FT4	456	8	57.0	2.55	7.82	1,724	30.2	90.6	4.9	4.5
(mean ± SD)			**55.7 ± 2.4**	**2.53 ± 0.08**		**1,562 ± 160**	**27.9 ± 1.9**	**76.4 ± 10.1**	**18.1 ± 9.7**	**5.5 ± 1.0**
MF1	200	4	50.0	2.82	6.93	1,541	30.7	68.2	27.3	4.5
MF2	226	4	56.5	2.71	7.33	1,809	32.0	78.4	17.8	3.8
(mean ± SD)			**53.3 ± 4.6**	**2.77 ± 0.08**		**1,675 ± 189**	**31.4 ± 0.9**	**73.3 ± 7.2**	**22.6 ± 6.7**	**4.1 ± 0.5**

FF(1–5) – Feed First cow traffic system, FT(1–4) – Free cow traffic system, MF(1–2) – Milk First cow traffic system.

Table 2. Characteristics of different cow traffic systems in the observed Latvian AMS dairy farms

Farm	Number of		Cows AMS^{-1}	Milkings cow^{-1} day^{-1}	Milking time min	Milk yield		Percentage of time for		
	cows	AMS units				kg AMS^{-1} day^{-1}	kg cow^{-1} day^{-1}	milking	idle	washing
FF1	97	2	48.0	2.71	8.69	1,177	24,5	78.0	18.0	4.0
FF2	94	2	47.0	2.73	8.07	967	20,6	72.0	24.0	4.0
FF3	49	1	49.0	3.00	8.47	1,278	26,1	84.0	10.0	6.0
(mean ± SD)			**48.0 ± 1.0**	**2.80 ± 0.20**		**1,141 ± 159**	**23.7 ± 2.8**	**78.0 ± 6.0**	**17.3 ± 7.0**	**4.7 ± 1.2**
MF1	108	2	54.0	2.89	7.30	1,052	19.5	79.0	15.0	6.0

FF(1–3) – Feed First cow traffic system, MF1 – Milk First cow traffic system.

Table 3. Characteristics of different cow traffic systems in the observed Polish AMS dairy farms

Farm	Number of		Cows AMS^{-1}	Milkings cow^{-1} day^{-1}	Milking time min	Milk yield		Percentage of time for		
	cows	AMS units				kg AMS^{-1} day^{-1}	kg cow^{-1} day^{-1}	milking	idle	washing
FF1	63	1	63.0	2.60	6.48	1,820	28.7	78.8	18.3	2.9
FT1	200	3	66.0	2.50	7.00	1,848	28.0	80.0	15.9	4.1

FF1 – Feed First cow traffic system, FT1 – Free cow traffic system.

Table 4 presents results of analysis of variance for cow and AMS performance, which included the fixed effects of cow traffic system (Feed First / Free cow traffic and Milk First cow traffic system) and country (Estonia / Latvia / Poland).

Table 4. Analysis of variance for cow and AMS performance including all dairy farms

		Cows AMS^{-1}	Milkings cow^{-1} day^{-1}	Milking time min	Milk yield kg AMS^{-1} day^{-1}	Milk yield kg cow^{-1} day^{-1}	Percentage of time for milking	Percentage of time for idle	Percentage of time for washing
Traffic system	FF	58.8	2.55^{a}	7.75^{a}	1,592	26.7	82.2	13.5	4.3
	FT	57.8	2.52^{a}	7.42^{a,b}	1,619	27.9	77.1	17.7	5.2
	MF	53.5	2.81^{b}	7.19^{b}	1,467	27.4	75.2	20.0	4.8
	p-value	0.1631	0.0496	0.0185	0.2769	0.7330	0.2700	0.3393	0.1526
Country	Estonia	59.3^{a}	2.50^{a}	7.49^{a}	1,698^{a}	28.6^{a}	79.9	15.3	4.8
	Latvia	49.5^{b}	2.83^{b}	8.13^{b}	1,118^{b}	22.7^{b}	78.2	16.8	5.0
	Poland	64.5^{a}	2.55^{a}	6.74^{c}	1,834^{a}	28.4^{a}	79.4	17.1	3.5
	p-value	0.0045	0.0082	0.0004	0.0006	0.0072	0.7773	0.8084	0.1023

FF – Feed First cow traffic system, FT – Free cow traffic system, MF – Milk First cow traffic system
$^{a, b, c}$ – denoted homogenous groups; the different letters a, b and c refer to the significance of difference between the values in column at the level of at least 95%.

Results of analysis of variance show significant difference of mean values ($p < 0.05$) for two factors (milkings per cow per day and milking time) included in the group of compared cow traffic systems. However, results of analysis of variance for cow and AMS performance were significantly differentiated for five factors in cross-section of three compared countries. The percentage of milking time can be recognized as one of the factor characterizing efficiency of the AMS use. It was also pointed out in the investigation performed by Castro et al. (2012), where the capacity of an AMS was expressed in terms of its occupation rate, defined as the percentage of hours the AMS is actually milking per day. It is possible to raise hypothesis that higher percentage of on-time for milking represents higher efficiency of automatic milking system(s) in the farm.

To develop such formulated problem some of the data from the investigated dairy farms were extracted and analysed. Relationship between capacity of AMS (kg of milk milked per day) and percentage of on-time for milking (%) was expressed with a coefficient R^2 (°).

The results show relatively low R^2 values for the analysed relationship between capacity of AMS and percentage of on-time for milking. Only for herds operated by AMS with Free cow traffic system (FT) showed the R^2 value 0.62. Due to low R^2 values of FF and MF systems the overall R^2 value amounted only to 0.15. Such results, especially low R^2 values suggest considerable differences between investigated herds and cows within the herds. The differences can include cow milk yield and cow individual ability to be adapted and operated effective way by AMS.

To estimate AMS effectiveness, it was proposed to find relationship between herd size and percentage of on-time for milking (Table 5). The results indicate on low R^2 values for the analysed relationship between cow herd size operated by AMS unit and percentage of time for milking. Only for herds with Milk First cow traffic system (MF) it was found higher R^2 value (0.83). Another hand there were only three farms with such cow traffic system, therefore, to confirm the relationship it seems to be important to include more records into the analysis.

Table 5. The coefficient R^2 for the relationship between percentage of on-time for milking and capacity and herd size

Solution	No of farms	No of AMS	percentage of on-time for milking	
			capacity of AMS (kg of milk per day)	herd size operated by AMS unit
FF	9	24	0.27	0.24
FT	5	23	0.62	0.23
MF	3	10	0.08	0.83
Total	17	57	0.15	0.25

FF – Feed First cow traffic system, FT – Free cow traffic system, MF – Milk First cow traffic system.

Results of the current observations become part of general discussion on AMS effectiveness, where on-time for particular kind of activities is one of the most important element of the AMS assessment. Relatively low R^2 values concerning the analysed relationships can be effect of many factors (at the same time), which may have effect on AMS milking time. According to Komiya et al. (2002) the milking time depend on milk flow and the milk yield per milking of an individual cow. Moreover, according to the same authors, the milking capacity, (the number of cows which milking robot is able to milk), is determined by the individual performance of the cow and the settings of the system parameters.

Considerable number of factors associated with assessment of AMS efficiency inspires to estimate for other relationships in the field of AMS use. Including data gathered from the 17 farms with AMS in three European countries (Estonia, Latvia and Poland) an effect of cow herd size on milking frequency was found (Fig. 1).

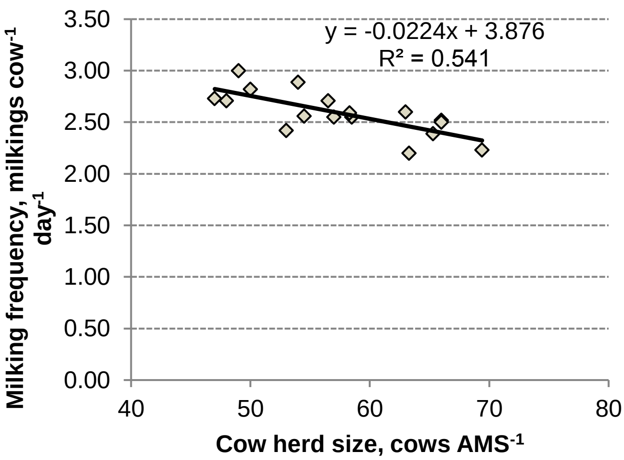

Figure 1. Relationship between herd size and milking frequency.

According to Fig. 1 it is possible to indicate decrease in milking frequency when herd size operated by AMS is increasing. The herd size can explain 54% ($R^2 = 0.54$) from the variability of milking frequencies values. Slightly higher R^2 value ($R^2 = 0.66$) was obtained for the relationship when only farms with Feed First cow traffic system were taken into account (data not presented).

The milking frequency of the cow is quoted as one of the most important factors, which express profits gained from the AMS operation at dairy farms. Higher number of milkings per cow per day lead to increase in annual milk yield per cow (Erdman & Varner, 1995). The milking frequency investigated in current study ranged from 2.20 until 3.00 milkings per cow per day. Obtained range was wider than observed by Gygax et al. (2007), who reported it from 2.38 until 2.56 milkings per cow per day. To compare the frequencies of milkings in more detailed way it must consider the conditions of cow at milking. Bach et al. (2009) found 1.7 until 2.2 and 2.4 until 2.5 milkings per cow per day for Free and Forced cow traffic, respectively. The number of milkings per day per cow ranged from 2.42 to 2.59 for Free cow traffic in Estonian and Polish dairy farms. However, increase in the number of milkings per cow doesn't necessarily mean a greater milk yield per AMS unit (Castro et al., 2012). This finding was confirmed in current study, where dairy farms with Feed First cow traffic system were associated with decrease in capacity of AMS, when number of milkings increasing per cow per day ($R^2 = 0.58$). Many management factors, such as feeding strategy, may determine the success of cow traffic. Such factors might be more important in order to obtain successful cow traffic, than the type of traffic system (Markey, 2013).

CONCLUSIONS

Results of the current study showed that some of the EU countries dairy farms are characterized by high technical and biological potential expressed by number of AMS used per farm and amount of milk produced.

It was possible to indicate the highest capacity, i.e. milk yield per AMS unit per day for Feed First cow traffic system for Estonian dairy farms. The average milk yield per cow per day was the highest with Milk First cow traffic. The average AMS on-time for milking was highest with Feed First traffic system.

The Latvian dairy farms with Feed First cow traffic system operated with small size of cow herds as well as the milk yield by AMS unit per day was low. It is possible to conclude that Latvian farms don't utilize full potential of AMS and this can lead to the low effectiveness of AMS and financial losses.

The Polish dairy farm with Feed First cow traffic system was comparable with mean values (number of cows per AMS and amount of milk milked by AMS per day) concerning the same cow traffic system (Feed First) used in the Estonian dairy farms.

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Spatial overlapping in crop farming works

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Abstract. A good driving accuracy and a proper machine input control are essential in sustainable farming. The goal is to work on the field exactly according to the plan, for example spraying a certain amount of fungicides evenly to the field. However, without modern assisting systems the farmers tend to overlap their driving lines. So far there have not been quantitative tests to present how mark able this overlapping is in real conditions. To solve this, we collected data from regular farming practices during four years in 17 different fields by recording GNSS (Global navigation satellite system) positions and a relative working status of the implement. We developed data mining methods of finding out the average overwork percentages of regular crop farming practices within different complete field plots. Based on the cumulative work distance, we measured the minimum overlapping percentage of different field works. The average minimum overlapping percentages for different machinery were: sprayer 15.7%, combine driller 7.7%, combine harvester 1.7%, spin disk fertilizer 9.5%, cultivator 19% and roller 59%. To understand reasons for great deviation between similar works, we determined different overlapping components for the spraying work: 2/3 of the spraying overlap was because of the driving line inaccuracies while the remaining 1/3 happens in the headland turns. This detected overlapping leads to the over consumption of pesticides, seeds, fertilizers, fuel and time but it can be minimized by applying accurate steering assistance and by adapting automatic section controls.

Key words: GPS, spatial accuracy, steering assistance, section control, data mining.

INTRODUCTION

In traditional crop farming the fields are aimed to be threaded evenly. In irregularly shaped fields this means, that the driver aims to work evenly the entire field, first by circulating the field a few times near field boundaries to produce headlands and then by driving parallel straight lines back and forth. The spatial accuracy of these driving lines is very important: roughly it causes null or double treatments producing unwanted effects. It has been assumed that farmers have a tendency to overlap their work about 10% of the implements width (Nieminen & Sampo 1993; Griffin et al. 2005). Shockley et al. (2011) simulated the overall automatic steering net profits in the farm scale. They assumed that the spraying overlap in unassisted crop farming would be between 1.5 m – 3.0 m, being 9.5% – 19.1% with 16 meter working width. These figures are relatively high in comparison to reported precision farming profits. By using precision nitrogen management for example, the gained overall economic benefits have been at the level of 5% (Nissen, 2012). It is obvious that the effect of overlapping work is very negative to the attempted precision farming acts. Also the overlapping work increases driving distance, takes more time, increases soil compaction, consumes more farming inputs and increases environmental load.

The overlapping work can be reduced by improving the driving accuracy and/or by controlling the implement and its sections more accurately. Different methods for improving the consecutive driving accuracies have now been developed almost a century. Currently, these methods include different track marking devices, using the same tracks (controlled traffic) and using an electronic steering assistance or an automatic steering, typically by applying GNSS positioning based systems. These electronic steering automation methods have widely been developed (Mousazadeh 2013). On top of the improved work quality and increase in productivity, these guidance systems could reduce farming costs, driver's fatigue and impact on the environment and they could improve safety and make it possible to work at night and when visibility is poor (Cordesses et al. 2000; Dunn et al. 2006). The accuracy of these systems is well understood and there are existing standards (ISO 2010; ISO 2012) to produce comparable results. Also these systems have already been adopted by many farmers. However, it is not well known that how much these systems could actually improve the farming results.

Kvíz et al. (2014) found that the regular overlap of passes was in the range between 1% and 6% of machine's working width with drivers who were aware of the test setup. They also found that value can be significantly minimized by utilizing precise guidance systems and the working width had a significant influence on the accuracy of field operation. They measured pass-to-pass deviations with different implements by measuring the distance between the tire tracks of two neighbouring passes with the help of a laser rangefinder by using a matrix method (Bell, 2000). They concentrated on nominally straight driving parts in the field and not measured the headland parts. However, the shape and size of a field significantly affect the number of machinery passes (Galambosova & Rataj, 2011; Oksanen, 2013) complicating the even coverage of the work.

The current problem is that there are no quantitative measures about the unassisted work accuracy in traditional farming in real field conditions. In this study, the unassisted driving means that there are no electronic guidance or steering systems involved. Since 2008, internet based service infrastructure named Cropinfra (Pesonen et al., 2014) has been developed among others to collect and maintain quantitative data from typical Finnish farming practices. Data is collected with GNSS (Global Navigation Satellite System) based measurement systems implemented in all grain farming machines at the research station. This data forms a good source for quantitative analyses. In this study, we developed data mining methods of finding out the average overwork percentages of regular grain farming practices within different complete fields. This overwork amount is practically the minimum overlapping amount in the field. The overlapping work is done by accident and in the optimal case it does not exist at all. Using spatial analyses we also determined the sources of overlapping in spraying works to be able to estimate the positive impact that can be gained with technology adaptation. The research questions of this study are as follows: 1) how much is the average overlapping in regular farming practices? 2) What is the structure of the overlapping and how significant are the different components?

MATERIALS AND METHODS

In this study, we used Cropinfra data from the year 2011 to 2015. For each selected work, we calculated the travelled distance while implement was working. This distance multiplied by the working width was compared with the detected size of the field producing the overwork percentage of the work under the study. This corresponds to a minimum overlapping percentage. These procedures are presented in detail in the following chapters.

Data collection

GNSS positioning, usually GPS positioning is a straight forward way to be used to determine spatial movement. We installed Garmin 19x GNSS receivers in all of the tractors in the test farm. These low-cost NMEA2000 receivers are capable of using GPS, GLONASS and Egnos correction. The measured accuracy in field conditions has been 1.1 metres including a 30 cm standard deviation (Kaivosoja & Linkolehto, 2015). The general drawback of the low cost positioning is the possibility of a position drifting. However, speed detection with a low-cost GPS has been accepted for several studies: Witte & Wilson (2004) studied 1 Hz non-differential GPS for speed determination and concluded that it was accurate enough for biomechanical and energetic studies especially in relatively straight courses. They found that good speed determination was preserved even when the positional data were degraded. Keskin & Say (2006) concluded that low-cost GPS receivers can be confidently used to measure the ground speed in agricultural machinery operations. With the accurate time and speed measurements from the GPS, the travelled distance can be detected.

To determine the work coverage, the implement's working status for each GNSS position was needed. We recorded the status of the implement: power take-off RPM (revolutions per minute) *PTO*, valve status (on/off) *ON*, lifting status sensor voltage (ground level or above) *Lift. V* and the GNSS information simultaneously from the CAN bus with 5 Hz interval (Table 1). All data were recorded from ISOBUS process data messages. All data were synchronized and gathered with developed applications working in LabVIEW environment on a docked laptop.

Table 1. Sample data logging of a spraying work

Time PC	ON	PTO	Lift. V	LAT	LON	Speed	Direction	Elevation
75757.0	0	302	54.8	60.450895	24.346639	1.116	335.07	83.01
75757.2	0	311	54.4	60.450895	24.346639	2.304	335.07	83.01
75757.4	0	317	54.4	60.450895	24.346641	2.808	335.07	83.01
75757.6	1	320	54.8	60.450894	24.346644	2.916	335.07	83.01
75757.8	1	314	54.0	60.450892	24.346646	4.860	335.07	83.01
75758.0	1	317	54.4	60.450890	24.346648	4.680	335.07	83.00
75758.2	1	329	54.8	60.450888	24.346651	4.500	336.93	83.00
75758.4	1	346	54.0	60.450885	24.346653	4.852	338.21	83.00
75758.6	1	361	54.0	60.450883	24.346656	5.304	339.33	83.00

If there were no new GNSS data available, the sensor data would be collected at 2 Hz interval. For those, the speed data was calculated afterwards being the average of five earlier and five later successful speed measurements. If there were over 5 km h^{-1}

deviations between consecutive speed measurements, the speed will be set to be the average of three earlier measurements. Data having less than 0.5 km h^{-1}driving speed was excluded. On average, this method corrected 12 driving speed measurements per each complete field work. The GNSS unit was on top of the tractor. We determined the posture of the implement from the GNSS data and calculated an estimated location of the implement for each record and used that position in our analyses.

We examined only data that did not include any deviances such as work interrupts or log failures due to driver or the system. Based on that, about 1/6 of data were rejected. In total, we evaluated 140 drives driven in 17 different fields. The average size of those fields was 5.3 ha. We used data from a 16-metre sprayer (92 drives), combine driller (22 drives), combine harvester (8 drives) and a roller, a cultivator and a spin disk fertilizer (each six drives) representing a wide scale of farm machinery. We focused on spraying and combine drilling works since those works are often done by avoiding especially gaps but also overlaps.

There were three different drivers producing field data, one having decades of experience, second having nearly a decade experience of farming and the third having about two years of experience. The drivers planned their driving path according to traditional farming practices: work efficiently and evenly the entire field, avoid gaps and overlaps and prefer straight driving lines. The headland drives were used in each work. The spraying and fertilizing drives were matched to earlier sowing tracks if possible. The section control was not used. The cultivating, sowing, rolling and harvesting driving lines were matched to the parallel driving lines.

The driver's awareness of the driving accuracy test could have an effect on the driving result giving too good accuracy results. To minimize the effect, this test setup has been part of our regular field operation practices since 2010 and it has not been related to any accuracy evaluations. First, the farmer turns on the laptop and then starts the logging program from the desktop. Then the driver fills the basic information about the driver, field, machinery and tractor. Then data logging is turned on. While driving, the data logging program indicates that the data logging is progressing successfully. The logging and the laptop are turned off after the task is completed.

To evaluate our findings, we compared one combine drilling work driven with automatic steering system (AGI-4 TopDock) with a cm level positioning accuracy in 2015 to identical work made without steering assistance in 2014. The field plot, the driver and the machine were the same in both cases.

Work amount calculation

After data collection, we calculated the worked area of each work. When the implement status was indicating that the machine was doing work, we calculated the distance based on the detected GNSS speed and time interval. The total worked area was the calculated heading distance multiplied by the known working width of the used implement. We used the working widths that were assumed by the drivers and not concentrated on the detailed machine structure.

There are some challenges on determining the actual field size. There are official field parcel borders in Finland that are annually corrected from digitized ortophotos. These borders define the official size of the field plots; however those polygons do not take into account the surrounding or intra-field ditches so the actual farming size is somewhat smaller. Also many fields are divided into different growing parcels. We defined the actual field area to be the spatial work coverage of the annual sowing work based on our data logging. We calculated the coverage by using a buffer zone method for driving lines (Kaivosoja, 2008), where conscious measurement points forms a vector line. Then for each vector, a surrounding polygon is calculated with the distance corresponding to the working width of the machine. In practice the outer buffer zone line of the headland driving path formed the field boundary.

The sowing data from different years were compared and the biggest area was selected to represent the actual size of the field. The average standard deviation of these buffered areas was 0.03 ha. We used 38 sowing works in total. The determined field sizes were 0.14 ha smaller than the official field polygons in average. The used 17 test fields and single buffered sowing areas are presented in Fig. 1. The fields numbered as 10, 24 and 29 had intra-field ditches.

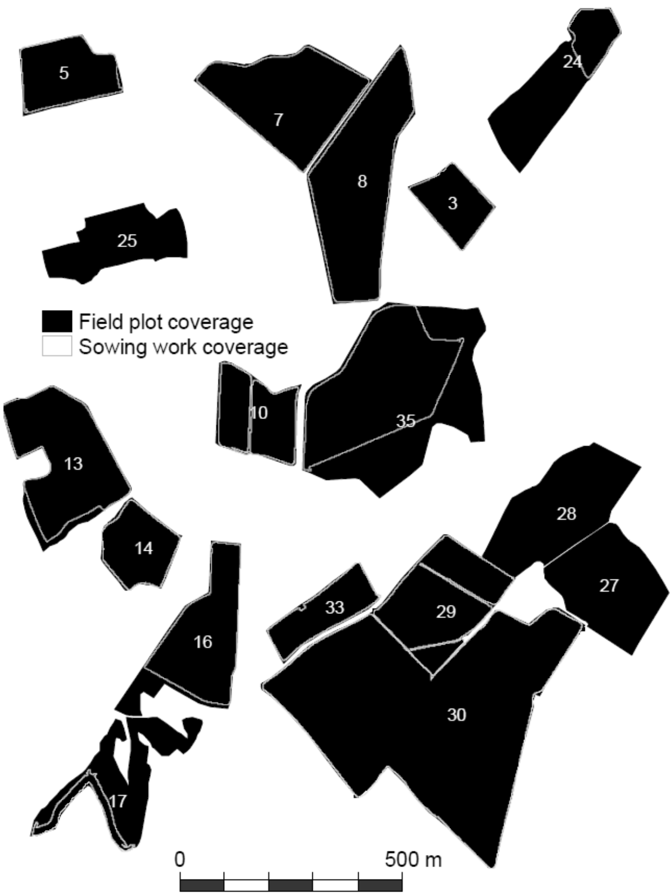

Figure 1. Field parcel borders of the seventeen study fields and the buffered sowing work areas.

The overwork amount of a single work was the total worked area divided by the determined field size. For the statistical analysis of data, we calculated the overwork percentage of each data and then calculated an overall average and the standard deviation of the overwork amount.

Overwork classification

Different overlapping elements for the spraying work were determined to be able to find out the meaning of the determined overwork. We used the buffer zone method to visualise field works (Fig. 2) and to see the characteristics of the overlapping work.

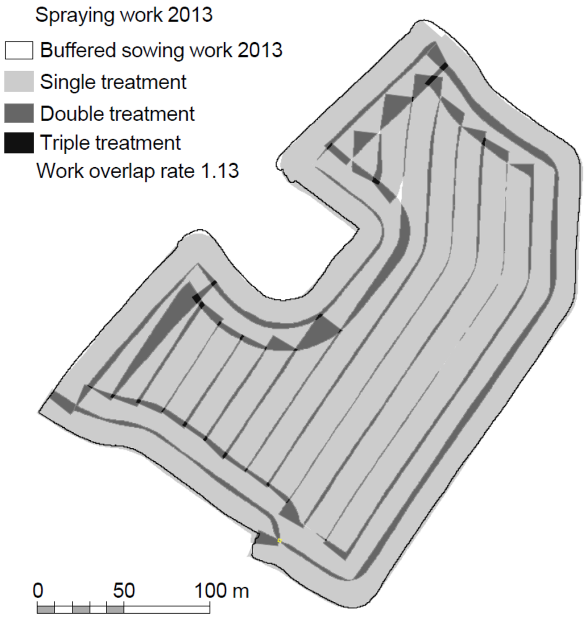

Figure 2. Visualized double and triple overlapping work in the field number 13.

Based on the visual analysis, we evaluated that the detected overwork consist of five main different types of working inaccuracies: 1) overlapping the parallel driving lines, 2) overlapping last driving line, 3) working outside the field boundaries (spraying ditches), 4) overlapping before and after the headland turns, 5) headland overlap because of the gentle enter/exit angle (over 45 degrees). These elements for spraying work are presented in Fig. 3.

We used the following methods to determine the overwork elements (Fig. 3):

1) Overlapping the parallel driving lines: the buffer zone method and the number of passes versus the width of the field.

2) Overlapping last driving line: the length of the last driving line when the machine was working versus the size of the buffered gab between surrounding driving lines.

3) Working outside the field boundaries: buffer zone method to calculate the footprint of the worked area.

4) Overlapping before and after the headland turns: buffer zone calculation for headland drives and the driving distances within that area when machine was working.

5) Headland overlap because of the gentle enter/exit angle: calculate the amount of over 30 degree approaches to headland and using the previously presented method.

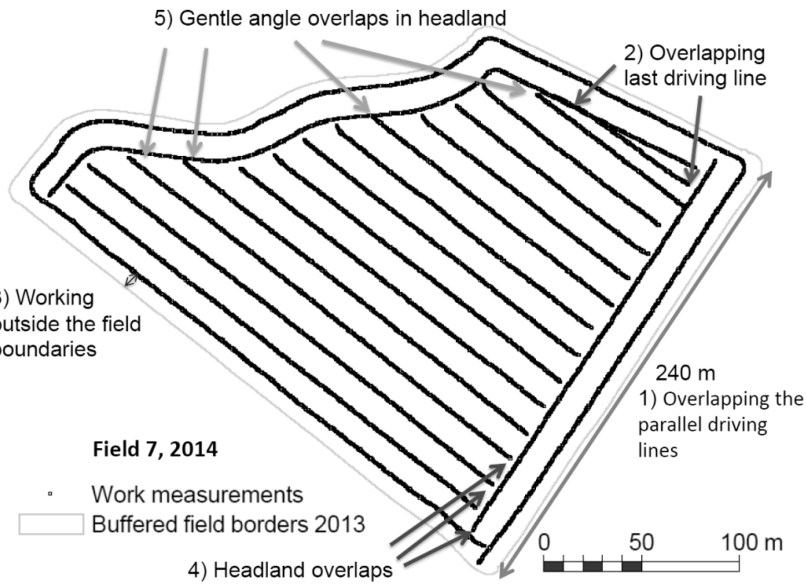

Figure 3. Spraying driving lines and the detected overwork elements.

We adapted the presented methods in order to visually evaluate three different spraying drives (Figs 2, 5 and 6) and made analyses to all of the 17 fields. We used Microimages TNTgis software to map the overlappings, and manually classified the types of overlaps. The software calculated the areas for each overlap.

RESULTS AND DISCUSSION

The selected 92 spraying work drives from four years made in 17 different fields by two experienced drivers result 15.9% overlap on average (Table 2). The overlap rates for different drivers were: most experienced 16.3% (67 drives), other experienced driver 15.5% (14 drives) and rookie 12.7% (13 drives). The rookie's lower overlap rate was due to imprecise work meaning that there were often gaps in the fields. The average standard deviation of all these drives was 9.0%. This was mainly caused while working the headlands. The average overlap of 22 combine driller drives was 7.7% and the standard deviation was 2.1% (Table 2). The measured harvesting work was very close to the sowed area being only 1.7% bigger. The roller and cultivator works produced great overlap with large standard deviation since the nature of the work. The determined overwork of the spin disk fertilization was much smaller than the overwork of the spraying with the equal working width. The following Table 2 shows the details of the used machines, the determined overwork and standard deviation amounts and the measured average overlaps in meters.

Our study revealed that without modern guiding systems, the work overlapping is significant. Each farming work has its own overlapping in different locations. This causes uncertainties to the field knowledge and may greatly weaken the effect of precision farming acts. The measured over consumption of pesticides (16%), seeds (8%) and fertilizers (10%) is significant. The case is similar with fuel and time consumption.

The automatic steering comparison to combine drilling was made in the field plot number 13. The overwork amount in 2014 without automatic steering was 8.3% and with automatic steering in 2015, the overwork was 4.3%. The number of parallel driving line passes was 57 in 2014 and 54 in 2015.

Table 2. Calculated average overwork and the standard deviation of different field works

Machine	Machine type	Width meters	Drives	Overwork %	Std. %	Overlap meters
Hardi Twin Track	Sprayer	16.0	92	**15.7**	9.0	2.54
Junkkari Maestro	Combine driller	4.0	22	**7.7**	2.1	0.31
Sampo Comia	Combine harvester	4.2	8	**1.7**	3.3	0.07
Kire	Roller	5.2	6	**59.1**	13.7	3.07
Amazone BBG Carrier	Cultivator	3.0	6	**19.0**	7.5	0.57
Bögballe DZ Trend	Spin disk fertilizer	16.0	6	**9.5**	8.8	1.52

In the following Fig. 4, the overwork of the spraying and sowing are presented for each field. The X-axis presents the field plot numbers in organized by the field size. In both cases, the entire overwork was overlapping work. There is no direct relation between the size of the field plot and the amount of overlapping. There was only a small correlation between the sowing and spraying overlap in the same fields being 0.51. The difference between the official field area and the buffered field size did not have any correlation with the calculated overwork percentage; this would indicate that our field size determination was successful.

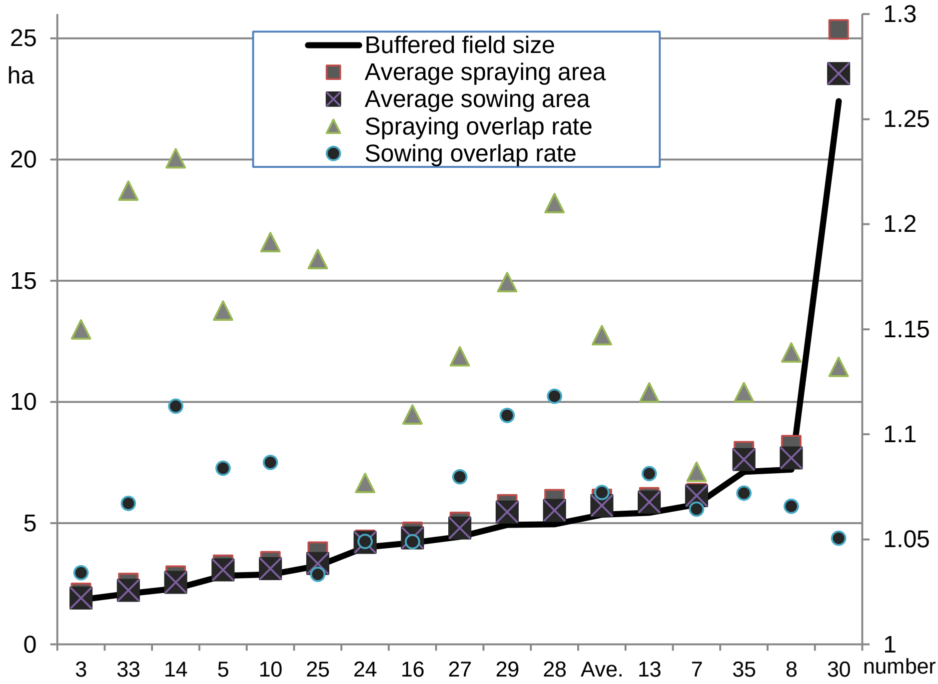

Figure 4. Spraying and sowing work overlap rates compared to field plot size.

Overwork classification results

Our overwork classification studies revealed in that case of field number 13 (Fig. 2), the total 13% overlapping consist of following elements: overlapping the parallel driving lines 8.8%, overlapping last driving line 1.1%, working outside the field boundaries 0.6%, overlapping before and after the headland turns 1.3%, and headland overlap because of the gentle angle 0.8%.

In the following Fig. 5, the different overlapping components are visualized. The dominant grey colour represents successful spraying, all other colours are representing different types of work overlapping. The role of inaccurate headland driving is huge in this small 2.8 ha field causing nearly 15% overlap.

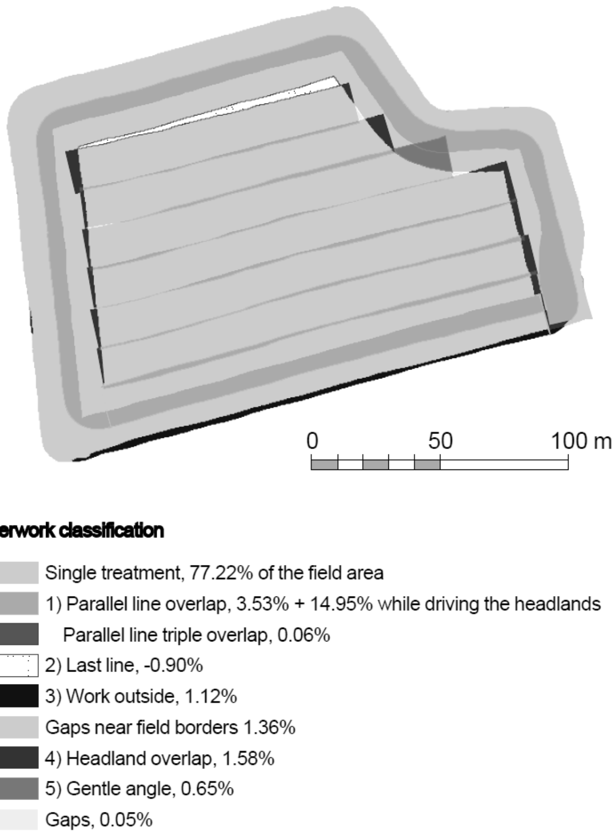

Figure 5. Classified overlapping of the performed spraying work.

The role of headland driving is smaller with bigger fields (Fig 6.) but there are still many different sources for inaccurate spraying work. In this field, relatively great amount of overlapping was caused due to inaccurate section control in each pass causing a 3.4% overlap. Pass-to-pass overlapping in the middle of the field was less than 5% being 75 cm in practice.

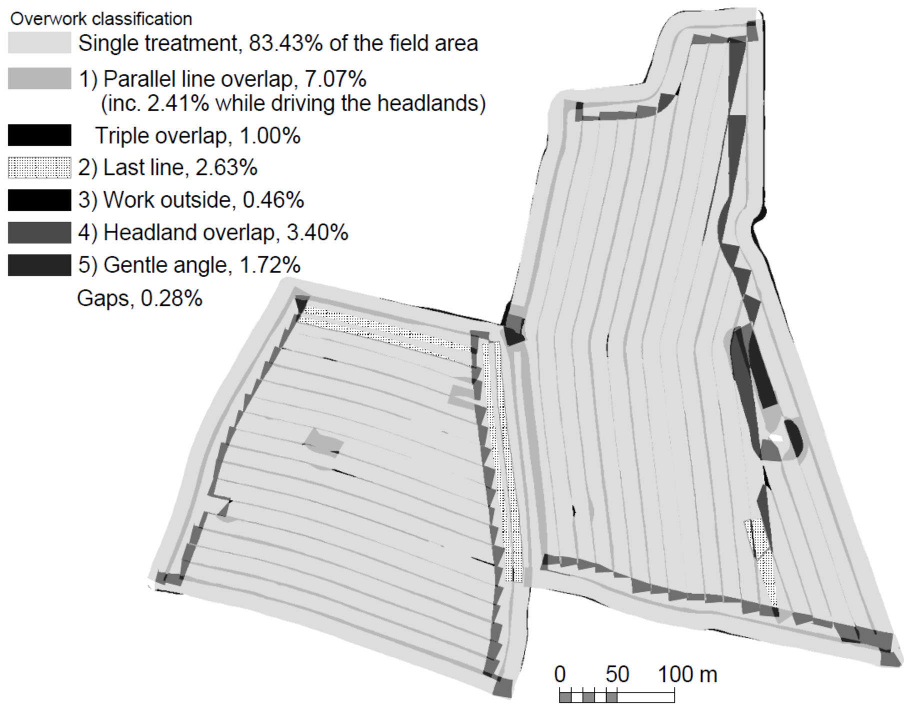

Figure 6. Classified spraying overlap on a large field.

Different overlapping classes for spraying are shown in Table 3 for the presented fields 5, 13, 30 and on average for all the 17 fields. The *OK* class in Table 3 presents the area that got a single treatment according to the plan. The inaccurate parallel driving caused 10.3% overlap on average in the spraying while the headland overlapping was less than 2%.

Table 3. Classified overlapping types in different fields

		Overlap class						
Field No.	Size (ha)	OK (%)	**1** (%)	**2** (%)	**3** (%)	**4** (%)	**5** (%)	Gaps (%)
5	2.8	77.6	18.5	-0.9	-0.2	1.6	0.7	0.1
13	5.4	88.5	8.8	1.1	0.0	1.3	0.8	0.0
30	22.4	83.4	8.1	2.6	0.5	3.4	1.7	0.1
17 fields ave.	**5.4**	**85.3**	**10.1**	**1.4**	**0.0**	**1.7**	**1.4**	**0.0**

In practice, the overlapping happens because the drivers want to avoid gaps that can easily be seen, the irregularly shaped fields are impossible to threaten evenly with big machinery, and the edges of headland areas are often difficult to be seen.

This determined overlapping can be minimized by applying accurate steering assistance and by adapting automatic section control. A plain steering assistance with 15 cm pass-to-pass accuracy would decrease the overall spraying work overlapping amount from 15% to about 7%. Depending on the mapping capabilities, it might also reduce the overlapping in headland turns. According to our automatic steering test, the overlapping in combine drilling work decreased from 8.3% to 4.3%. In practice, this decrease meant 54 kg of seeds and 77 kg of fertilizers, saving about 10 € per hectare with the current market prises.

The assumption that farmers tend overlap their work about 10% of the implements width matched very well to our finding of the spraying line overlapping of 10.3%. This value included the overlapping while driving the headlands and overlapping caused by obstacles in the field. When comparing with Kvíz et al. (2014) who found that the regular overlap of passes was in the range between 1% and 6%, we got bigger values. However, when focusing only our pass-to-pass spraying accuracy in the middle of the field (Fig. 5. and Fig. 6.) we got similar values: 3.53% and 4.66%. This would indicate that using steering automation only in the middle of the field would not significantly reduce the overlap amount.

With better positioning systems and shaft angle measurements the overlapping measurements would have been more reliable in relation to individual fields. By focusing on the driving distance measurements and the averaging, we fairly managed to overcome this drawback. We were focusing on the sowing and spraying and those works are commonly done by avoiding gaps. The overlapping with spin disk fertilization was almost half compared with the spraying. This could happen because the driver is not trying to avoid the gaps more than the overlapping.

The shapes of the test fields were not very regular but they were typical Finnish fields. When comparing the fields with the highest and the lowest amount of overlapping, it is very difficult to draw any conclusion based on field sizes and shapes. Also the high standard deviations of the overwork percentages with different machines are indicating that the overworking is not always happening in the same way. This can also be seen in Figs 5 and 6: the farmer is overlapping the headland driving or headland turns or different obstacles are causing overlap.

Based on our results, the usage of GNSS assistance would easily cut the amount of overlapping in half. The section control was calculated to decrease the overlap by 30%.

CONCLUSIONS

In this study, we managed to calculate the overlapping percentage for spraying, sowing, harvesting, rolling, cultivating and fertilizing works by using the low-cost GPS and the implement status information. We determined different elements for overworking and measured them for spraying works. Our main findings in this study were:

- based on 92 field drives, the spatial overlapping in regular spraying works was 15.7% with 16 meter implement,
- the difference between two experienced drivers were only 0.8%,
- the overlapping happens near headlands and on parallel tracks,
- measured overlapping in combine drilling work was 7.7% on average,
- accurate automatic steering system decreased the overlapping in combine drilling work from 8.3% to 4.3%,
- there is no direct connection between the amount of overlap and the size and shape of the field.

Regular grain farming field operations are not very accurate without any modern steering assistance and machine control. The 15% average overlapping on spraying works is huge. Also overlapping with other machinery is significant and causes a lot of unwanted variation to the fields greatly complicating the precision farming acts. Simultaneously the farmer's time and pesticides, fertilizers, fuel and other matters are wasted. This was a successful study and showed one way how to exploit data from our Cropinfra-platform.

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Assessment of the economic value of cattle slurry and biogas digestate used on grassland

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Abstract. Concentration of dairy production and development of manure handling technologies has led to large amounts of cattle slurry produced as a by-product. Slurry can be used directly for fertilisation or input for biogas production. As a result of added organic materials, the nutrient content of the by-product of anaerobic digestion (biogas digestate) differs from nutrient content of slurry. The data from the 2012 to 2014 field experiment designed to evaluate the use of local organic fertilisers on grassland were used for the current study. The objective of this research is to present an approach for the fair reflection of the economic value of organic fertilisers. The approach is based on substitution relationships between mineral and organic fertilisation on a certain yield level of grass dry matter production. The economic value was assessed based on the nutrient content of cattle slurry and biogas digestate, application costs, and the cost of mineral fertilisation. Two categories of economic value were calculated: the total and the actually realised value. The total economic value shows the potential value of nutrients available for plant production. The actual realised value is formed through the nutrient usage by plants. The economic value of the biogas digestate used in the experiments appeared to be higher than the value of slurry, due to the equal application of ammonium nitrogen (NH_4-N), the higher content of potassium and lower application rates.

Key words: cattle slurry, biogas digestate, economic value, grassland.

INTRODUCTION

Several aspects of fertilisation with organic fertilisers are gaining importance, such as the emission of atmospheric gases (Webb et al., 2010; Rodhe et al., 2015), minimisation of transportation and application costs (Tamm & Vettik, 2011; Tamm & Vettik, 2012) and the fertiliser value of liquid manure and biogas digestate (Schröder et al., 2007; Alburquerque et al., 2012; Möller & Müller, 2012; Tampere & Viiralt, 2014).

In line with the development of technologies in animal husbandry and biogas production, as well as with the shift of animal production from smaller production units to larger ones, the need for consideration of the economic value of by-products has arisen. Farmers and biogas producers often consider animal manure and biogas digestate as wastes that create disposal costs (Keplinger & Hauck, 2006; Alburquerque et al., 2012). In the periods of economic recession, the fertiliser value of organic fertilisers is clearly perceived, but the marketing distance of these goods is limited by high transportation costs.

The economic value of products is formed through market transactions. In European markets, animal slurry and biogas digestates are valued differently, based on the local needs for plant nutrients and availability and prices of mineral fertilisers. In Estonia, the value of animal manures has been treated in multiple ways: accounting with zero value (Koik et al., 2009; Rebane, 2015) or considering the value of manure nutrients equal to the mineral fertiliser nutrients (Vettik & Tamm, 2013). To date, the market for cattle slurry and biogas digestate is still limited in Estonia. Thus, the value of liquid organic fertilisers has to be obtained through an alternative way – using the component prices and associating costs for application and transport (Kässi et al., 2013; Naglis-Liepa, 2013). Disposal prices of biogas digestate for biogas producers can vary from negative to positive, depending on the regional nutrient availability, season, feedstock and other factors (Dahlin et al., 2015).

The agronomic and economic value of organic fertilisers depends on several factors, including ammonia volatilisation, which is affected by the application method (Rodhe et al., 2015). The farm survey titled ´The main production resource efficiency of agriculture in Estonia´ in 2013, reviewed the main technologies in agriculture. It was found that 33 % of dairy farmers who had liquid manure system at their farm used trailing hose application; 24.7% indicated usage of broadcasting with mixing into soil. Within larger dairy farm (>100 cows) groups, in addition to injection technologies, the share of trailing hose and broadcasting systems used is still quite large (Fig. 1). Among other factors, the choice of fertilising machinery depends on the dry matter (DM) content in the liquid manure, where the trailing hose and trailing shoe application are suitable for grassland application of manure DM content in between 6 to 9 % (Vettik &Tamm, 2013).

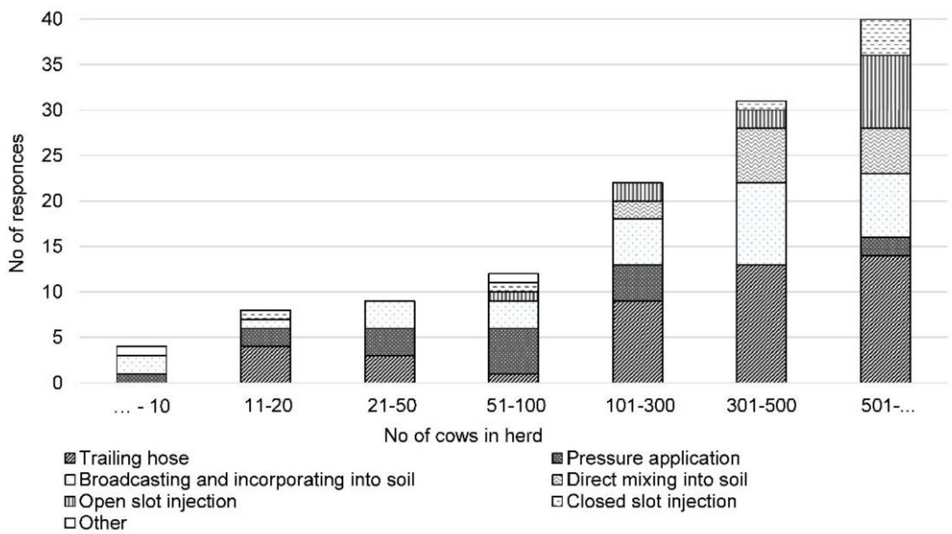

Figure 1. Liquid fertiliser application technologies at Estonian Dairy Farms in 2012 (The main…, 2013).

The application of liquid organic fertilisers on grassland allows reduction of the aggregate emission from storage and application of fertilisers during the summer period due to high temperatures (Rodhe et al., 2015). The timing and choice of application machinery for grassland fertilisation in the vegetation period is still limited because of the risk of grass contamination and crop damages (Laws et al., 2002; Rodhe & Halling, 2014), especially in case of shallow injection systems.

In practice, organic fertilisation is necessary to compensate the amounts of nutrients carried away with grass yield, since the farm financial budget constraints often limit the usage of mineral P and K on grassland. While the official statistics (EN17) shows the negative balance of phosphorus (P) per hectare of total agricultural land in Estonia, no official information about the balance of potassium (K) is available. In terms of global resource supply, it is pointed out that the scarcity of phosphorus and potassium is increasing (Kässi et al., 2013; Vaneeckhaute et al., 2013); thus, appropriate usage of organic fertilisers should help to balance the usage of these nutrients. Therefore, it is necessary to analyse the contents of organic fertilisers; however, not often done by farms.

The aim of the current study is to evaluate the economic value of biogas digestate and cattle slurry on the example of their use as organic fertilisers on grassland (consistent of grass species only). Analysis is based on field experiment data from 2012 to 2014.

MATERIALS AND METHODS

Field experiment data

The data for the assessment of the economic value of cattle slurry and biogas digestate originate from a field experiment conducted at the Erika Experimental station, Estonian University of Life Sciences (58°23`32``N, 26°41`31``E). Experiments were conducted in four replicates in a randomised complete block design. In 2012–2014, the grass sward consisted of smooth meadow grass (*Poa pratensis*) and red fescue (*Festuca rybra L.*), previously also perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*), which had disappeared during unfavourable winters (Tampere & Viiralt 2014).

The primary objective of the trial was to investigate the yield effect and grass silage quality under fertilisation with cattle slurry and biogas digestate (composed of cattle slurry and agricultural residues). These fertilisers were compared to barely mineral nitrogen applied to grass-only mixtures, which is a common practice in Estonia. Grass yield, dry matter (DM) and nutrient content of grass were measured and several measurements of silage content made.

The fertiliser rates in trial were set up to meet NH_4-N levels of 180 kg ha^{-1} for all fertilised treatments (Table 1), divided into three applications. The total amounts of nitrogen (N_{tot}) reached the level of 300 kg ha^{-1} at the treatments with organic fertilisers, containing 26% (digestate in 2012) to 40% (slurry in 2012, digestate in 2013) of nitrogen in organic form. One third of organic nitrogen is estimated to be released in the year of application, the rest during the following years.

Table 1. Amounts of plant nutrients applied with fertilisers and measured in yield

Year	Treatment	Fertilisation, kg ha^{-1}					Yield in DM* t ha^{-1}	Nutrients in cut grass, kg ha^{-1}		
		N_{tot}	NH_4-N	NO_3-N /org-N	P	K		N_{tot}	P	K
2012	Control	0	0	0	0	0	7.52^1	122	n.m	n.m
	NH_4NO_3	180	90	90/0	0	0	8.76^2	203	n.m	n.m
	Digestate	247	183	0/64	44	131	10.59^3	210	n.m	n.m
	Slurry	308	180	0/128	55	150	11.61^3	222	n.m	n.m
2013	Control	0	0	0	0	0	4.70^1	93	13	104
	NH_4NO_3	180	90	90/0	0	0	5.52^2	147	18	131
	Digestate	312	181	0/131	57	252	6.44^3	137	19	152
	Slurry	299	180	0/119	51	199	7.08^4	140	20	159
2014	Control	0	0	0	0	0	5.09^1	109	14	55
	NH_4NO_3	180	90	90/0	0	0	8.22^2	246	29	108
	Digestate	288	182	0/106	51	176	11.20^3	243	35	164
	Slurry	294	180	0/114	53	162	11.05^3	219	33	143
Mean	Control	0	0	0	0	0	5.76^1	108	14	80
	NH_4NO_3	180	90	90/0	0	0	7.50^2	199	24	120
	Digestate	282	182	0/100	54	214	9.41^3	197	27	158
	Slurry	300	180	0/120	52	180	9.92^3	194	26	151

* DM – dry matter; indexes express significant difference in yield ($P < 0.05$); n.m – not measured; N_{tot} – total amount of nitrogen; org-N – nitrogen bound in organic matter.

Factors of the economic value of organic fertilisers

To assess the economic value of organic fertilisers, several factors have to be taken into account that are connected to the machine technologies used, the plant need for nutrients in the year of application and the following years in crop rotation, soil nutrient content, availability of the land, etc. (Fig. 2).

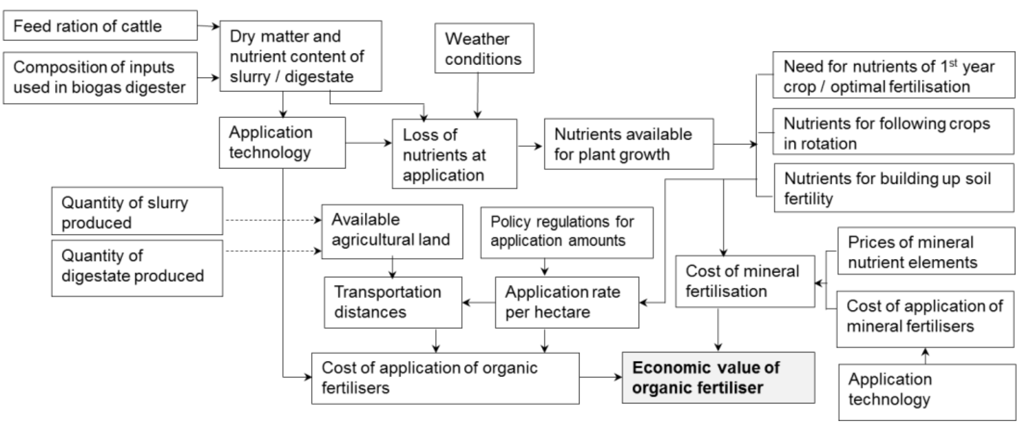

Figure 2. Factors influencing the economic value of cattle slurry/ biogas digestate.

The value of organic fertilisers is not based on the total nutrient content but rather on the amount of nutrients that become available for plants when applied to the soil. Loss of nutrients during and directly after application depends on the application machine technology (Webb et al., 2010), weather conditions and dry matter content of the fertiliser. The higher the temperature and the higher the DM content, the higher is the total ammonia emission from the fertiliser (Sommer & Hutchings, 2001).

Crop needs for nutrients and nutrient availability in an organic fertiliser determine the upper limit for application rates per hectare that has an effect on the application costs. At low soil nutrient content and at crop rotation, where the following crops use the carry-over effect of fertiliser nutrients, higher rates of potassium and phosphorus than the need of the first year crop are reasonable. The very low application rates typically reflect the shortage of fertilisers that cause an inefficient use of labour, machinery and materials (fuels) and the high cost of application.

Based on the price level of mineral fertilisers used at the farm, the monetary value of nutrients in manure and digestate can be calculated. Since the application costs of an organic fertiliser exceed substantially the spreading costs of a mineral fertiliser, the value of the organic fertiliser must be adjusted.

Weather conditions

The utilisation of nutrients is dependent on weather conditions. In 2013, plant growth was influenced by unfavourable weather conditions at the experimental area. The precipitation during the period from May to September (294.4 mm) was 22% lower than long term average (376.9 mm). In the second fertilisation period of the experiment plots in 2013, the precipitation was only 2.2 mm, average temperature 19.5 °C (Table 2). In such conditions, the infiltration of fertilisers into soil is slow and ammonia volatilisation rates are high (Huijsmans et al., 2001). In some cases, conversely NH_3 losses increase if infiltration is reduced by a high water content (Sommer & Hutchings, 2001). The precipitation at the field trial site was above the long term average at the second fertiliser application in 2012 and 2014 (35.6 mm and 44.6 mm, respectively), which improved the infiltration of nutrients, but also increased the risk of losses through leaching (Tampere et al., 2014).

Table 2. Weather conditions on the fertiliser application decades (I, II and III application)

Indicator	Period	2012	2013	2014
Average temperature, °C	I	9.9	6.1	7.3
	II	12.2	19.5	12
	III	14.1	17.9	21.9
	April – September	12.6	13.7	13.3
Precipitation, mm	I	9.8	15.2	7.8
	II	35.6	2.2	44.6
	III	24	27.2	15.2
	April – September	443	294.4	407.2

Ammonia emission from surface-applied slurry at the temperatures of 9–10 °C is presumably at the level of 10% (slurry dry matter content 8%), at the temperature 20 °C, emission can reach 20–30%, at the temperature 30 °C up to 50% (Sommer & Hutchings, 2001; Huijsmans et al., 2001). The trailing hose application allows up to 51% reduction in emission compared to splach plate application technique (Häni et al., 2016). Different factors, like dry matter content, soil infiltration rate, air temperatures, rainfall etc. with varying relative importance, affect the nitrogen emission, therefore the actual emission rates are not predictable (Sommer & Hutchings, 2001).

Nutrient content of organic fertilisers in the experiment

Nutrient content of slurry varies considerably, depending on the nutrient content of raw manure, type of slurry storage system, time since excretion etc. The content of biogas digestate depends on the input ingredients, the speed and anaerobic fermentation process in the digester.

The exact chemical content of cattle slurry and biogas digestate was analysed at the Laboratory of Plant Biochemistry of the Estonian University of Life Sciences (Tampere & Viiralt, 2014). Dry matter content of biogas digestate was 3.5% in 2012 (Table 3), since the input to the digester was cattle slurry with no considerable added organic material. Additional input of organic material led to higher dry matter levels of the digestate in 2013 and 2014. The higher content of NH_4-N in biogas digestate (mean value of three years 2.8 kg t^{-1} compared to 2.56 kg t^{-1} in cattle slurry) determined the lower average application rates per hectare compared to cattle slurry. The high share of ammonium nitrogen in the digestate increases the potential volatilisation of total nitrogen as compared to undigested cattle slurry.

Table 3. Data for the calculation of the economic value of organic fertilisers used in the experiment

Factor	Cattle slurry				Digestate (digested cattle slurry)			
	2012	2013	2014	**Mean**	2012	2013	2014	**Mean**
Quantity applied. t ha^{-1}	67.1	76.0	68.3	**70.5**	57.3	71.8	68.2	**65.8**
Application cost € t^{-1}	2.98	2.84	2.98	**2.93**	3.14	2.90	2.96	**2.99**
DM yield. t ha^{-1}	11.61	7.08	11.05	**9.91**	10.59	6.44	11.2	**9.41**
DM and nutrient content measured in fertilisers								
DM. %	8.3	8.2	8.8	**8.4**	3.5	8.1	6.8	**6.2**
N_{tot}. kg t^{-1}	4.60	3.93	4.30	**4.28**	4.31	4.32	4.23	**4.29**
NH_4-N. kg t^{-1}	2.68	2.36	2.63	**2.56**	3.20	2.51	2.68	**2.80**
P. kg t^{-1}	0.83	0.68	0.79	**0.77**	0.76	0.79	0.76	**0.77**
K. kg t^{-1}	2.23	2.60	2.37	**2.40**	2.28	3.48	2.59	**2.78**
Amount of nutrients reached into yield*								
N_{tot}. kg t^{-1}	3.31	1.84	3.21	**2.75**	3.66	1.91	3.56	**2.99**
P. kg t^{-1}	0.49	0.27	0.48	**0.41**	0.52	0.26	0.51	**0.43**
K. kg t^{-1}	2.25	2.09	2.09	**2.14**	2.13	2.12	2.40	**2.22**

* the amount of nutrients in cut grass, kg ha^{-1} (Table 1) divided by the applied amount of slurry / digestate, t ha^{-1}.

The amounts of nutrients that reached the yield were measured in cut grass and were in accordance with the fertilisation recommendations in Estonia at acquired grass yield. The average amounts of total nitrogen (N_{tot}) in 2012–2014 measured in cut grass were 64.3% of N_{tot} applied with slurry and 69.7% of N_{tot} applied with biogas digestate (Table 3).

Calculation of the economic value of organic fertilisers

In order to establish the relations between the factors of economic value of cattle slurry and biogas digestate, a model was built up by using Lindo™ software for linear programming. The value of an organic fertiliser is expressed as a shadow price through the substitute relationship between organic and mineral fertilisation. It is dependent on the available amounts of nutrients in cattle slurry (X_S) and digestate (X_D), the costs of application of the organic fertiliser (C_S, C_D) and the alternative costs of fertilisation: with mineral fertilisers. The cost of mineral fertilisation (C_{NPK}) includes the purchase and application costs of mineral fertilisers (€ kg^{-1}). Both the organic and mineral fertiliser amounts have to meet the requirement of nutrients (R_{NY}, R_{PY}, R_{KY}; kg ha^{-1}) by the crop grown at an expected yield level (Q_Y, t ha^{-1}). The value (shadow price) of organic fertilisers is expressed through the following relation:

$$Min \quad C_N * Q_N + C_P * Q_P + C_K * Q_K + C_S * Q_S + C_D * Q_D - P_Y * Q_Y$$

Subject to

$$R_{NY} - - X_{SN} * Q_S - X_{DN} * Q_D < 0$$
$$R_{PY} - Q_P - X_{SP} * Q_S - X_{DP} * Q_D < 0$$
$$R_{KY} - Q_K - X_{SK} * Q_S - X_{DK} * Q_D < 0$$

$$Q_S < A_S$$
$$Q_D < A_D$$

where: Q_{NPK} – quantity of nutrient elements in mineral fertilisers (kg ha^{-1}); Q_S , Q_D – quantity of organic fertilisers (t ha^{-1}); P_Y – value of grass dry matter yield (€ t^{-1}); Q_Y – amount of grass dry matter produced (t ha^{-1}); A_S, A_D – availability of slurry/digestate (t).

Characteristics of the calculation

To calculate alternative costs of mineral fertilisation, the plant requirement for nutrient elements (NPK) per hectare of fertilised area was taken into account. The 2012–2014 average prices of mineral nutrient elements were N 0.94 € kg^{-1}, P 0.96 € kg^{-1} and K 0.91 € kg^{-1}. The average cost of three applications of mineral NPK per kilogram of nutrient (depending on loading, transportation and application of mineral fertilisers) ranged from 0.10 € kg^{-1} to 0.12 € kg^{-1} according to the total amount of nutrients applied. The cut grass was ensilaged, thus the price of grass dry matter yield (74.29 € t^{-1}) was obtained through the market price of a ton of grass silage.

The cost of cattle slurry and digestate application (Table 3) was calculated according to the machine technology implemented in field trials, using machinery cost calculation algorithms from Estonian Crop Research Institute (Machinery cost …). The slurry and digestate were spread to the field with 20 cm spacing, implicating the trailing hose application technology. The transportation distance for the application costs shown in Table 3 was assumed to be 1 km, performed by application equipment. The total application cost of three applications was divided by the quantity of the applied organic fertiliser. For transportation beyond two kilometres from storage facilities, it is economical to involve a separate tank (Tamm & Vettik, 2012).

The data of the experiment with high rates of organic fertilisers used on permanent grassland, allow us to show the potential economic value of the used organic fertilisers and the actual value, realised through the fertilisation of particular grassland mixture with high rates on continuous years.

The contents of nutrient elements in slurry and digestate were involved in the calculations as follows:

1) **To calculate the total economic value of a fertiliser**, the total available amounts of nutrients in manure were considered after ammonia losses through emission. The estimation of potentially available nitrogen was at similar level than the nitrogen amounts reached into grass yield.

2) **To show the actual realised value of a fertiliser at the current yield level**, the amount of nutrients were used by crops in the current year. It was presumed that the possible uptake of the nutrients (in available form) from soil was compensated by the organic fertilisers through nutrient mineralisation; thus, the stock of nutrients in soil would not be reduced. In the experiment variants of control and mineral nitrogen, where the PK was not applied (Table 1), the formulation of yield was a result of decreasing the soil nutrient reserves. Carry-over (residual) effect of organic nitrogen in organic fertilisers used on grassland has cumulative nature (Schröder et al., 2007), which means that the currently applied organic nitrogen has an effect on developing the yield in the following years.

RESULTS AND DISCUSSION

The economic value of organic fertilisers depends on farm-specific conditions presented in Fig. 2. The conditions of field experiments in 2012–2014 enabled the calculation of the value of fertilisers at two levels: a) the total economic value at maximum usage of nutrients in an organic fertiliser; b) the value actually realised at the level on nutrient application to the soil (Fig. 3).

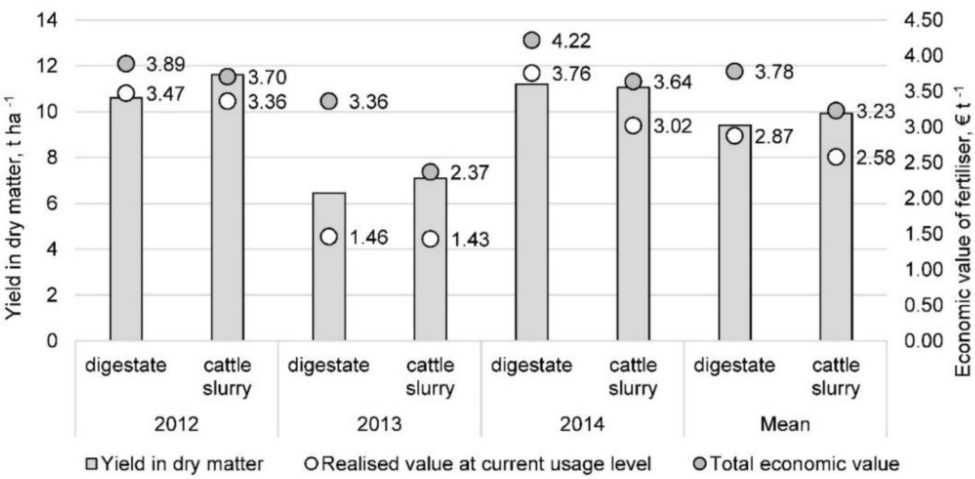

Figure 3. The economic value of cattle slurry and biogas digestate in the grassland experiment.

Since the experiment continued for several years at the equally high rates of fertilisation, the phosphorus and potassium levels exceeded the crop needs. The soil element supply at experimental plots was at high (P) and medium (K) level, thus there was no need to rebuild the soil element stock. Even if the leaching of phosphorus from grassland is marginal, potassium appears to be more mobile, especially from the grass-only mixtures (Tampere et al., 2014). Thus, it is not economical to apply excess nutrients.

The yield levels of treatments fertilised with slurry and digestate were at a comparable level in 2012 and 2014 and differed significantly ($P < 0.05$) only in dry 2013 (Table 1).

Based on the 2012–2014 average data, the total economic value of biogas digestate used at grass-only mixture was 3.78 € t^{-1}, the value of cattle slurry 3.23 € t^{-1} (Fig. 3). These levels are reachable when fertilisers are used at high application rates for a crop with high need for nutrients. The value actually realised at the current fertilisation level reached respectively 2.87 € t^{-1} and 2.58 € t^{-1}.

In 2012, the dry matter content of digestate 3.5% and the high NH_4-N content kept the total application amounts of nitrogen lower compared to the following years, which had an effect on the application costs and on the total value of nutrients per ton of digestate.

The NH_4-N content of cattle slurry was low (2.36 kg t^{-1}) in 2013, therefore the total application amount of slurry was 76 t ha^{-1}, which increased the costs of application and decreased the total economic value of slurry (2.37 € t^{-1}). The same ground caused lower total economic value of the digestate in 2013. In addition, the phosphorus content of slurry was low in 2013.

The difference between the value actually realised and the total economic value of organic fertilisers was largest in 2013, where the uptake of nutrients was lowest due to dry weather (total precipitation 270.2 mm), and probably high ammonia emission. The actual value of fertilisers received in 2013 was respectively 1.46 € $t^{-1}$and 1.43 € t^{-1}.

As the contents of slurry and digestate were similar in 2014, the yields were at the same level. The difference in total economic value relates to the differences in the application rates of slurry between the application times. The different application quantities were caused by the variation in NH_4-N content in slurry.

The effect of fertilisation with organic fertilisers on grassland depends on the botanical composition of the grass sward. The agronomic effect of organic nitrogen is expected to be higher on swards that consist of grass mixtures compared to legume-grass mixtures. Grassland mixtures with no legumes use high amounts of nitrogen (180–220 kg ha^{-1}) (Kässi et al., 2013) that gives a higher value to manure compared to legume-grass mixtures. The effect of additional fertilisation with organic fertilisers at the legume-grass mixtures, where the need for nitrogen is covered with atmospheric fixation, compensates scarce phosphorus (P) and potassium (K) amounts. (Viiralt et al., 2015). On the other hand, the potential leaching of potassium appears to be higher at grass-only swards, depending on the precipitation and water uptake with higher yields (Tampere et al., 2014).

Policy regulation before 2014 instructed the usage of organic fertilisers through the allowed amount of 30 kg ha^{-1} phosphorus on the average of total agricultural land. That led to high volumes of slurry used on the fields near storage facilities. Current policy restricts the application rates to 25 kg ha^{-1} of phosphorus per fertilised hectare (Water Act of Estonia), thus increasing the fertilised area. Shortage of suitable land nearby storages increases the transport distances, leading to the reduction of the economic value of the fertiliser (Fig. 4). Therefore, suitable land is an important availability factor or restriction, which is farm- and site-specific.

Restricting the excess application of nutrient elements, the regulations increase the share of nutrients used for that purpose and diminish the share of nutrients lost through leaching. Adjustments in crop rotation could enhance the maximum usage of the organic fertiliser potential and decrease the dependence on mineral fertilisers.

The effect of transportation distance depends on the choice of the transportation vehicle. For our calculations, the assumption of a separate transportation tank was taken for distances over three kilometres. That enables keeping application productivity per hectare stable compared to the case of transportation with a trailing hose manure distributor. Based on the 2012–2014 average data, the total economic value of biogas digestate decreases from 3.78 € t^{-1} to 2.57 € t^{-1} reaching the 10 km distance. Similarly, the total economic value of slurry decreases from 3.23 € t^{-1} to 2.00 € t^{-1} until the 10 km distance (Fig. 4).

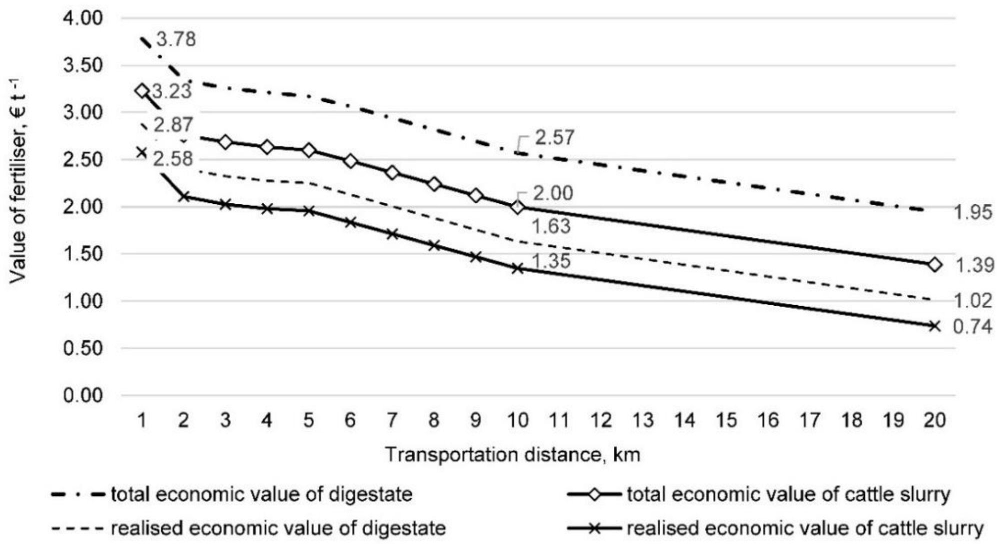

Figure 4. The 2012–2014 average total economic value (€ t^{-1}) and realised economic value (€ t^{-1}) of cattle slurry and biogas digestate depending on the transportation distance.

The total value calculated at the distance of 20 kilometres is ca 50%, actually realised value is ca 30% compared to the value at nearby fields (the other conditions remain the same). The changes in value are farm-specific, depending on the machinery used, but still give an overview of the relations between the value of the fertiliser and the distance.

The economic value of the biogas digestate used in the experiment was higher than the value of cattle slurry mainly due to the higher content of NH_4-N, thus the needed amount of digestate to reach the target nutrition level was smaller. The content of organic fertilisers varies considerably between farms, animal species, feed rations, seasons and years; therefore, the numerical results of our analyses are not extendable to different types of slurry and digestate. The results are also dependent on the value of alternative fertilisation with mineral fertilisers, which are in practise farm specific.

The estimation of production efficiency through unit production costs of grass dry matter (data not presented) shows that the three-fold application of organic fertilisers with higher total nutrient amount than plants can use increases the production costs over the market value of grass production. The surplus costs of fertilisation lead to inefficiency from the economic point of view, compared to the treatments of mineral nitrogen and controls.

The effect of advanced application technologies on the economic value of liquid organic fertilisers should be assessed in the future on the same methodological basis. Injection of the slurry or digestate to grassland with the intention to decrease ammonia losses (Webb et al., 2010; Häni et al., 2016) might result in decreased yield levels, especially in the case of spring fertilisation (Rodhe & Halling, 2014) and will increase simultaneously the costs of fertilisation.

The appraisal of the economic value of fertilisers used for forage crops should also include the quality aspects of the final product – silage. The added value of forage crops appears through milk quality and yield. The effect of the chemical and microbiological properties, metabolisable energy content of silage (MJ) and total energy production per hectare (GJ) to the performance of milk production is worth of analysing.

CONCLUSIONS

In this research, the cattle slurry and biogas digestate as organic fertilisers used on grassland were examined in order to estimate their economic value.

Based on the available nutrient content and the associating costs of fertilisation, the total economic value at a certain transportation distance on average of 2012–2014 was 3.23 € t^{-1} for cattle slurry, 3.78 € t^{-1} for biogas digestate. The actually realised value through usage of nutrients applied was respectively 2.58 € t^{-1} and 2.87 € t^{-1}, depending on the yield level and plant nutrient requirements of particular years. The difference between the total and the realised economic value is the result of the high level of fertilisation during all three experimental years, where not all of the applied nutrients were utilisable by the crop. Sources for economic values of biogas digestate higher than those to cattle slurry were the higher NH_4-N and potassium content accompanied with lower application rates.

The results of the actual economic value based on one grassland mixture (smooth meadow grass, red fescue) which uses high amounts of nutrients are not extendable to other field crops.

A general conclusion drawn from the current analysis is that attributing zero value to organic fertilisers, which is the prevalent approach in Estonia, is unjustified. The value of organic fertilisers forms through actual usage of these fertilisers at farms, depending on the nutrient requirements, range of crops fertilised and application technology.

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Pilot study of variability on demand and knowledge concerning organic food on an example of two Polish regions

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Abstract. The paper focuses on showing variability of knowledge and demand for organic food in two regions of Poland, i.e. Świętokrzyskie and Mazovian provinces. The selected for detailed investigations Polish regions differed in society wealth. Mazovia province with capitol (Warsaw) is reach as opposed to Świętokrzyskie – mountain province with dominance of more difficult conditions for comfort and affluent life. Basing on questionnaire the group of respondents' attitude towards organic food was recognized and compared. The problems included in the questionnaire there were factors influencing the organic food buying, factors which influence about the resignation of organic food buying, the availability of information about organic food, availability of organic food in selected regions, requirements for organic food, most frequently purchased organic products, place where consumers buy organic food, consumption frequency of organic food, factors influencing the choice of organic food. The comparison of two provinces indicated differences within the meaning of organic food as well as autonomy in consumer behaviour. Polish society is characterized by a growing interest in organic food. The production industrialization and mass food processing causes people to look for some alternatives. Organic farming gives people that chance. In the conclusions, we have formulated a term mean that due to the consumption of organic products – 'we are what we eat'.

Key words: consumer, demand, knowledge, organic food, Poland, production.

INTRODUCTION

The organic agriculture has constantly expanded world-wide in the last years including developed as well many developing countries. The international market of organic food has rapidly increased as well. An important factor behind the organic success is the positive consumer awareness on health and environmental issues, including the resistance towards GMO farming and genetically modified food produces (Defrancesco & Rossetto, 2007). This way the organic food products constitute one of the significant alternatives within the global food market. Food markets have become more global over recent decades as retailers and manufacturers source and distribute food products, raw and processed worldwide (Fulponi, 2004).

The organic food products and production can be included as a part of sustainable agriculture and food production system. The term sustainability has become omnipresent: It obviously can no longer be excluded from any statement or discussion that is in any way oriented towards development, progress and our common future

(Knaus, 2007). Sustainable agriculture may be broadly defined as ecologically sound agriculture and narrowly defined as eternal agriculture (Heitschmidt et al., 1996). Sustainable development is today often used and broadly accepted in science, politics and nearly all societal groups as a guiding principle for societal development (Meyer, 2006).

The agricultural and environmental conditions in Poland, as well as biological variety are favourable for organic farming development. Transition of the Polish economy towards market system has initiated many discussions on criteria taken into account to assess the changes observed in all stages of food chain (Gaworski, 2006).

Changes in agricultural practice over the past 50 years have increased the world's capacity in order to provide food for its people through increases in productivity, greater diversity of foods and less seasonal dependence. Food availability has also increased as a consequence of rising income levels and falling food prices (Kearney, 2010). Major advances in sustainable food production and availability can be achieved with the concerted application of current technologies and the importance of investing in research sooner rather than later to enable the food system to cope with both known and unknown challenges (Godfray et al., 2010).

In the field of food system development is possible to indicate many significant, current problems, like food quality as well as food availability. Access to food varies substantially across households because of the various factors affecting food prices. The mentioned factors include environmental dimensions, such as geographic region of the country; urban versus rural setting; types of stores available (supermarkets, convenience stores, mass merchandisers etc.); and types of foods available, such as healthier versus less healthy (Caswell & Yaktine, 2013).

The short review of food system development can be inspiration to put general scientific problem concerning consumer attitude to some kind of food products. To precise the scientific problem it is possible to phrase the following question: Can consumer attitude to some food products result from consumer knowledge and access to these products?

Aim of the research was to show effect of regional conditions and variability on consumer behaviour referring to some food products.

Scope of the research included two Polish regions, where access as well as consumer demand and knowledge concerning food organic products were investigated.

As a result of the research it was expected to develop problem, how sustainable development of national food system include variability of regions translating into consumer approach to organic products.

MATERIALS AND METHODS

To find differences in consumer behaviour referring to organic food products, two Polish regions were selected to carry out the investigations. The selected for detailed investigations regions differ in many respects: geographical, social and economic. Mazovia with the capital (Warsaw) is a region of relatively high quality of life, in contrast to the Świętokrzyskie province – mountain area of domination of difficult living conditions.

The consumer behaviour, knowledge and assessment of access to organic food products were investigated on the base of a questionnaire. The model questionnaire included 10 basic questions, each of them with few optional answers. Questions at this part of questionnaire included information, how many answers was possible to give. Structure of the questionnaire was supplemented with 6 questions concerning: dwelling place (options: big city, small city and village), education (primary, secondary and higher education), monthly income (per family), expenses for food per month (including four ranges), expenses for organic food per month (including four ranges), and general assessment of own financial situation (very good, good, average, bad and very bad).

The research problems highlighted in the questionnaire were:

- factors influencing the purchase of organic foods,
- factors for canceling the purchase of eco-food,
- availability of information on organic food,
- availability of organic food in selected regions,
- requirements for organic food,
- most frequently purchased organic products,
- place where consumers buy organic food,
- frequency of consumption of organic products,
- factors influencing the choice of organic food.

General procedure of the data collection on the base of questionnaire included at first step the sent inquiry to potential respondents about possible participation in the research on organic food problems. When the participation was approved the printed or electronic version of the questionnaire was sent to the respondents. During one week we have received the filled questionnaires from respondents. At this period we had the contact with respondents to explain some doubts, when it was necessary. At the next step answers given in questionnaires were verified in respect of completeness. Together 40 completely filled questionnaires were taken to further analyses.

Questionnaire was directed only to the women carrying a house and responsible for grocery shopping. The definition of consumers as a specific group in which women played a predominant role is even more relevant in the context of policy making (Terragni, 2007).

Group of 20 women represented Mazovian region, while 20 women were investigated in Świętokrzyskie region. The selected respondents belonged to the age bracket of 25–45 years old.

Including basic criterion of analysis, i.e. Polish region, differences in structure of respondents was possible to indicate. Group of women representing Mazovian region was dominated by big city dwellers (95% of respondents), while distribution of respondents from Świętokrzyskie region included: 45% – country dwellers, 35% – small city dwellers and 20% – big city dwellers.

Considering education status of respondents slight differences were possible to find. The group of respondents living in Mazovian region included the same percentage (45%) of persons with higher and secondary education, while 10% of women had primary education. However, respondents in Świętokrzyskie region were characterized by the following education status: higher – 40%, secondary – 40% and primary – 20% of investigated population.

Statistical analysis of data concerning respondents was performed using the Statistica v.12 software. Analysis of variance (ANOVA) for main factors was conducted. The statistical model included the fixed effects of region (Mazovian / Świętokrzyskie region). Significance level was $\alpha = 0.05$.

Results of the investigation were presented in descriptive form. Detailed answers given by respondents in questionnaires were taken to discuss some problems of organic food consumption and differences between consumers and their behaviour in two considered Polish regions, i.e. Mazovian and Świętokrzyskie provinces.

RESULTS AND DISCUSSION

Results of analysis of variance showed significant difference ($p < 0.05$) between respondents from Mazovia and Świętokrzyskie region for one main factor, i.e. dwelling place (Table 1). The dwelling place included three options: big city (more than 50 thousand of inhabitants), small city (less than 50 thousand of inhabitants) and village.

Table 1. Analysis of variance for investigated respondents from two Polish regions (Mazovia and Świętokrzyskie region)

Effect	*SS*	*df*	*MS*	*F*	*p*
Education status	0.5846	2	0.2923	3.0613	0.0622
Dwelling place	2.2888	2	1.1444	11.9844	0.0002
Incomes	0.5759	3	0.1920	2.0104	0.1345
Expenses for food	0.5272	3	0.1757	1.8403	0.1619

For other main factors (educational status, incomes and expenses for food) it wasn't found significant difference ($p>0.05$) between respondents investigated in Mazovia and Świętokrzyskie region.

Knowledge of organic food

Women living in large cities both in Mazovian and Świętokrzyskie know organic food. Respondents representing villages or smaller towns in the area Świętokrzyskie mostly not heard of organic food. Participants were from secondary and vocational mostly never heard of organic food, in the case of women with higher education – the situation is vice versa. Eleven of the twenty surveyed in Świętokrzyskie heard of organic food, which gives 55% in the Mazovian until nineteen twenty people familiar with organic food (95%).

Availability of organic food

Respondents in accordance match that organic food is expensive. None of the women indicated no answer: I do not like organic food, which indicates that these products are considered tasty. But the problem arises when issues related to the availability of that food. It turned out that in Świętokrzyskie eleven women indicated the answer – 'I do not know where to buy it', and in the Mazovian only one. This shows that in Świętokrzyskie organic food is not very common and exposed, it is difficult to find the point where you can buy eco-food.

Knowledge of products and their availability

The respondents most frequently indicated that organic food is healthy and without harmful substances. The information the respondents most often acquire in the store with this type of product. The ladies of Mazovian indicated in addition to exhibitions and fairs during which they can gain proper knowledge about the products, often to try the products and also buy merchandise.

In Świętokrzyskie province up to 75% of the respondents answered that they misjudge the availability of organic products, 20% was medium and only 5% – well. On the contrary, the results show up in Mazovia, where the availability of good estimates 55% on average – 40% and only 5% – bad. These results are justified by the requests indicated in the introductory part of the paper. Świętokrzyskie province is poorer compared to the Mazovian, few industrialized and incomes of the population are mainly generated through farming. We can indicate a relationship here that say the fact that the population of the Świętokrzyskie region trust the products produced by themselves, on their farms, without requiring processing. They recognize that only these products are healthy. Such approach confirm important aspect named regional food system. Regional food systems face high expectations: from regional economic development perspective, they are seen as a means to produce regional value added – an expectation which induces the creation of regional brands for food and other products in almost every region with active regional management (Kaliwoda et al., 2007).

Opinions and konowledge about organic food

Quite disturbingly present the results concerning the knowledge of the respondents about organic food. In Świętokrzyskie province they fell the most common response from these products are made naturally and without preservatives. However, in the Mazovian portfolio answer it turned out to be much broader namely: less processed, with a shorter shelf life, appropriately marked and certificated and rich in nutrients. In Świętokrzyskie nobody paid attention to the response of labeling and certification process and once selected answer with a short shelf life. It provides with a little knowledge of organic products in general. Ignorance of signs and certificates resulting in limited ability to search for organic products.

Behaviour of the investigated consumers can result from their attitude and identified psychographic-motivating profile of the Polish consumer. A type of the consumer being mature as regards dietary behaviours predominates in two groups of eco-consumers: a group of those being health-motivated and a group of those having futuristic motivation. Two types of the consumer represent an ecological motivation for eco-consumption: sceptic and traditionalist (Cichocka & Grabiński, 2009).

Consumer behavior

With the Świętokrzyskie province 50% of respondents buys organic food. According to them, the most widely purchased products include eggs, vegetables and bread. None of the women do not buy fruit and vegetable preserves and fruit. In Mazovian district organic food bought fifteen of the twenty surveyed women, i.e. 75% of respondents. Most buy bread, eggs, vegetables and also gave further grits, flour, spices, herbs and olive oil. There is more interest in dairy products and meat and fruit preserves. It should be noted that awareness of the existence of products, do not reach for and availability. In Mazovian district is greater access and choice of organic food, and in Świętokrzyskie people are unaware that such products exist. In Świętokrzyskie province people face the problem of misinformation and ignorance that organic food can be purchased.

In Świętokrzyskie province 50% of all respondents buying organic food, usually as much as 80% make their purchase from the manufacturer, 20% of organic food store. None of the women not purchasing over the Internet. This is due to ignorance that such foods can be purchased over the Internet. Most buys from the manufacturer because they have better access, a small portion is shopping in stores with organic food, which is caused by a limited number of the shops. In the Mazovian district 75% of all respondents buy organic food. From this 80% is supplied with organic food stores, because they are public. Through the Internet buys 13% and the producer only 7%. The indicator of direct purchases from the manufacturer is low and associated with low availability-proximity to public areas where food is prepared is that – as a rule, are a type of tourism are places where outside activities of a typical tourist, it is also produced food from local organic producers.

Consumption of organic food

Another important issue is the frequency of consumption of eco-food. In Świętokrzyskie province answer was given by 50% of all respondents. Several times a month organic food consumed 60%, less 30% and the answer 2–3 times a week marked 10%. No one answered that eats organic food every day. In Mazovian district answered 75% of all respondents, of which every food that consumes 20%, 2–3 times a week – 47% and 33% several times a month. No one answers rarely indicated. The above-mentioned differences result from the wealth of people in both provinces.

Factors determining purchase organic food

The last important issue is the choice of organic food and the factors influence the choice. In Świętokrzyskie district this question answered 50% of all respondents. Most often marked answers, i.e. motive for the choice of organic food are: price of product, manufacturer, appearance and suggestions dealer. Suggesting a producer is understandable, since most respondents buy food directly from him. Nobody pointed labeling, which indicates ignorance in this regard. In the Mazowieckie voivodship answer was given by 75% of all respondents. In the majority of answers they were falling price of the product, as well as the expiry date, ingredients, labeling and manufacturer. Consumers from Mazovia show more interest in healthy food kitchen. It was in Mazowieckie voivodship the last five years created the majority of culinary blogs that promote living in harmony with the trend ‘fit’. They also have a greater knowledge of the labeling of organic products, know how to distinguish from conventional.

You are what you eat ... this saying testifies to attempt to show users how important the daily diet and knowledge of the products consumed.

Awareness about organic food of Polish respondents participated in the research is growing. We want to eat healthy and from a reliable source. The industrialization of mass production and food processing causes people to look for alternatives. Organic farming gives us that chance. Derived from the production it is healthier and more secure.

Availability of natural products derived from crops, in which no artificial fertilizers are used and the processing is carried out without preservatives is high. Their purchase is not limited to specialty health food stores or stalls in markets and residential shelves in stores. Organic food has become more available and ‘for everyone’ thanks to the visibility of its hypermarkets and the possibility of purchasing over the Internet.

The guarantor providers that buy organic food, is the certificate that recovery is very difficult. This ‘green leaf’ testifies to the fact that the production / food was carried out without any artificial and harmful substances. This applies to the entire production chain - from the farm after a company engaged in the processing. As a result, we are confident about the naturalness of a product and we can expect the highest quality.

It can be important to treat organic food consumption as a part of ecological system. The preferred direction is making by households ecologically oriented choices in terms of acquisition, use of goods and then waste disposal. It is possible to show the impact of some patterns and styles of consumption (like consumerism, sustainable consumption) on the demand for environmental resources and to high-light the greening processes of household consumption as a factor positively associated with the efficient resources management (Rumianowska, 2013).

In Poland, the market for organic food is still a small percentage of the entire industry. In 2015 it reached 770 million PLN. We can say with full awareness that it is a developing market with an upward trend. If we were to compare yourself to our western neighbors, that’s for sure a lot of us still missing. Some statistical data show that the Polish inhabitant a year on eco-food seems approximately 4 euros and in Western Europe it is from 90 to 195 euros (Kowalska, 2015).

At the current time and in the future, the problem of access to some kind of food, including organic food can be considered in the field of ethics. ‘Food Ethics’ is a discipline, which tries to examine the whole spectrum of ethical aspects of nutrition in an interdisciplinary way (Bambauer & Meinhardt, 2004).

CONCLUSIONS

The carried out investigations confirm effect of dwelling place on consumer behaviour concerning organic food. Women living in large cities in two considered regions know organic food. Respondents representing villages and smaller cities in the poorer region (Świętokrzyskie province) mostly not heard of organic food. In practice the results of investigation indicate needs to improve access to organic food, especially in small cities. The country dwellers have more possibilities to have contact with some kind of organic food, when they are owners of small farms. Such approach confirm important aspect named regional food system.

The regional food system, especially in small cities and villages can be partly equated with organic food system and it is chance to have access to high quality food products in some, especially poorer regions.

The undertaken problem of variability in access, consumer demand and knowledge concerning food organic products in regional scale can be developed for international comparisons. As a result it can be expected to find differences in consumer behaviour concerning organic food in some countries.

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Dust pollution in the sport facilities

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Abstract. The aim of this paper is to present the results of microclimatic research focused on the dust pollution in several buildings and different rooms used for sport activities at the University. The attention is paid mainly to the problems of dimensions of space, capacity and activity of sportsmen, and influence of space ventilation. In the frame of this research the concentration of air dust was measured by the exact instrument DustTRAK II Model 8530 aerosol monitor. Using the special impactors the PM_1, $PM_{2.5}$, PM_4, PM_{10} size fractions were also measured. Obtained results of measurements were evaluated and concentrations of different size of dust particles were analysed. Results of different indoor conditions were generalized. Based on the results of measurements practical recommendations for the design, use and ventilation of these types of buildings were summarised in the conclusions.

Key words: air, dust fractions, gyms, indoor environment, swimming pool, ventilation.

INTRODUCTION

Dust is one of the most common pollutants, which people face in everyday life and in their work activities. By dust we understand air pollution particles of matter that dispersed in the air create aerosols. Dust is characterized by a concentration, size and properties of dispersed particles. On all of those characteristics depends the influence on health. The harmful effect of dust on humans is very wide. Evaluation of dust depends on the origin, nature and size of the dust particles, on its concentration in the air, but also on the length and conditions of action, and on the human individual sensitivity to dust.

The attention to dust is paid in many research works, e.g. Skulberg et al. (2004), Bouillard et al. (2005), Mølhave (2008), Mølhave et al. (2009), Buchholz et al. (2011), Nõu & Viljasoo (2011), Brodka et al. (2012), Traumann et al. (2013), Traumann et al. (2014), Kic (2015). The methodology and the results of measurements correspond to the research topic, especially to factors that are specific to studied space. There are studied e.g. the impact of outdoor particulates transferred into the indoor space, the impact of processed and handled material, the influence of floor surface, the influence of sports equipment (climbing chalk), particles released from special plastic materials used indoor etc.

Particles of internal dust are generated primarily by internal surfaces and devices of buildings, textile materials used in the interior, sloughing skin cells from people, etc.; part of household dust comes from atmospheric dust outside. The problems of the dust in gym air were studied e.g. by Carignan et al. (2013), Alves et al. (2014), La Guardia & Hale (2015).

Over many years of research, it was found that the effect of solid dust particles on health depends mainly on their size. Particles bigger than 100 µm have relatively little importance for human health, because due to its considerable weight quickly settle. The size of dust particles is 1 to 100 µm, particles larger than 30 µm, are known as coarse dust in the environment and in normal conditions also quickly settle. In terms of human respiratory tract larger particles do not cause major problems, since they are recorded on the hairs in the nose and do not penetrate further into the airways (Hollerova, 2007).

Inhalable fraction of dust means a set of airborne dust particles that can be inhaled through the nose or mouth. Respirable fraction means the weight fraction of inhaled particles which penetrates into the respiratory tract where is no ciliated epithelium and in alveoli.

Particles smaller than 10 µm (Particulate matter PM_{10}) are of great biological importance because they can penetrate behind the larynx into the lower airways. Therefore these particles are called inhaled particles or thoracic particles. These particles can settle in the bronchial tubes ($PM_{2.5}$), or penetrate into the alveoli (PM_1) or to the blood (nanoparticles) and cause health problems (Hollerova, 2007).

The use of PM_4 is not as common as the previously mentioned PM. According to Boac et al. (2009) the American Conference of Governmental Industrial Hygienists has defined three particular mass fractions in relation to potential health effects: inhalable fraction (particulate matter (PM) with a median aerodynamic diameter of 100 µm that enters the airways region), thoracic fraction (PM with median aerodynamic diameter of 10 µm that deposits in the tracheobronchial regions), and respirable fraction (PM with a median aerodynamic diameter of 4 µm that enters in the gas exchange regions), herein referred to as PM_4.

Weschler et al. (2008) the particle concentration calculated from total airborne concentration and the concentration of airborne particles PM_4. According to the Standard of dust concentration in Japan for the protection of people´s health includes especially for the ambient air, the indoor air quality control and for health standard for office in construction site PM_{10}, and for the workplace assessment standard PM_4.

Ehrlich et al. (2013) focused his measurements on the crystalline silica in occupational health and recognised that most of those respirable particles are smaller than four microns (PM_4).

Fromme et al. (2007) evaluated indoor air quality and dust particle fractions (PM_{10} and $PM_{2.5}$) in 64 schools during the winter and summer. The winter concentrations $PM_{10} = 91.5$ µg m^{-3} and $PM_{2.5} = 19.8$ µg m^{-3} were significantly reduced in summer $PM_{10} = 64.9$ µg m^{-3} and $PM_{2.5} = 12.7$ µg m^{-3}. Herdorf et al. (2009) measured PM_{10} in classrooms with objective to study impact of cleaning. Intensified cleaning showed a significant decrease in all classrooms from 79 ± 22 µg m^{-3} to 64 ± 15 µg m^{-3}.

Problems of dust inside the houses and rooms are also as the dust can be source of house dust mites which are present indoors wherever humans live. Positive tests for dust mite allergies are extremely common among people with asthma. According to the WHO (2000) and Hurley et al. (2005) long-standing increased concentration of dust particles PM_{10} results in an increase in total mortality.

As the university students as well as the staff should be active not only in the study or research but also in the sport activities, it is important to know what the situation inside the sport facilities is. Due to the fact that during sport activities people breathe very intensively, the air inside the rooms should be very clean. The aim of this paper is to present results of microclimatic research focused on the dust pollution in several rooms used for physical education and sport activities at the Czech University of Life Sciences Prague.

MATERIALS AND METHODS

This research work and measurements of the actual values were carried out in buildings and rooms of Department of Physical Education at the Czech University of Life Sciences Prague. All rooms are situated in two buildings, three of them in the same building (two conventional gyms GA, GB and one fitness centre GC). The first gym GA has the following dimensions: floor area about 540 m^2, volume 4,320 m^3 and it is used mainly for different ball games. The second gym GB has the following dimensions: floor area about 216 m^2, volume 1,728 m^3 and it is used mainly for sports games, floor exercise, aerobics, table tennis, etc. The third gym GC has the following dimensions: floor area about 92 m^2, volume 240 m^3 and it is used as a fitness centre. The last building is swimming pool centre SP (pool is 25 m long), which has the following dimensions: floor area about 640 m^2, volume 4,018 m^3.

The dust measurements were carried out first when all rooms were empty, without students and without ventilation, several days without cleaning the floors. The same dust measurements were carried out during the normal function of rooms, with students and with standard ventilation. There were following number of persons during the measurement inside the rooms: GA 20 students play floorball, GB 27 students doing aerobic exercise, GC 18 students in fitness training, SP 20 students swim.

The total concentration of air dust was measured by special exact instrument Dust-Track aerosol monitor. After the installation of different impactors the PM_{10}, PM_4, $PM_{2.5}$, PM_1 size fractions of dust were also measured. The 90 data of dust concentration for total dust as well as of each fraction size in each room were collected, in several representative and available places, which can be used for measurement without technological problems. The position of measuring instrument was usually at 115 cm above the floor.

Measuring devices and equipment technology environment continues to improve and provide a larger volume and more accurate results. New studies are constantly providing fresh information, but there are still many uncertainties. Maybe, new and more precise ideas about the influence on the human health can be discovered.

Very helpful and also important is to know the details about the composition and size of dust particles from the point of view of technical equipment and technology of indoor environment. This is important among other things for the selection of appropriate filters, scheduling maintenance and cleaning, and overall management options how to reduce the dust inside the buildings.

There are the reasons why the measurements have been provided not only according to the prescribed normal national or international standards (e.g. PM_{10} and $PM_{2.5}$), but it was also measured the total dust concentration and particulate matter by all available impactors PM. Larger amounts of information allow to obtain more detailed information on the composition and percentage of size fractions of dust.

According to the Air Protection Act No. 201/2012 PM_{10} limit value in 24 hours is 50 μg m^{-3}, 1 year limit value is 40 μg m^{-3} and 1 year limit value $PM_{2.5}$ is 25 μg m^{-3}. The 90 data of dust concentration for total dust as well as of each fraction size in each room were collected. The obtained results of dust measurements were processed by Excel software and verified by statistical software Statistica 12 *(ANOVA* and *TUKEY HSD Test*). Different superscript letters (a, b, c) in common are significantly different from each other in the rows of the tables *(ANOVA; Tukey HSD Test;* $P \leq 0.05$*)*, e.g. if there are the same superscript letters in all the rows it means the differences between the values are not statistically significant at the significance level of *0.05*.

RESULTS AND DISCUSSION

Principal results of dust measurement are summarized and presented in the Tables 1, 2, 3 and Figs 1, 2. The measurements in the empty, but not ventilated rooms (Table 1) show us that total dust concentrations and also concentrations of all dust fractions was in all rooms higher than 0.050 mg m^{-3}, which is dangerous for the human health. The lowest concentration of dust was in the swimming pool, which can be explained by the large area of the water surface inside. The worst situation was in the area of large gym GA and fitness GC.

Table 1. Total dust concentration and concentration of dust fractions PM_{10}, PM_4, $PM_{2.5}$ and PM_1 in the empty rooms without ventilation. Different superscript letters (a, b, c, d) are the sign of high significant difference (*ANOVA; Tukey HSD Test*; $P \leq 0.05$)

Room	Total	PM_{10}	PM_4	$PM_{2.5}$	PM_1
	μg m^{-3} ± SD	μg m^{-3} ± SD	μg m^{-3} ± SD	μg m^{-3} ± SD	μg m^{-3} ± SD
GA	80 ± 3^{a}	79 ± 3^{a}	77 ± 1^{a}	75 ± 2^{a}	70 ± 2^{a}
GB	74 ± 2^{b}	74 ± 2^{b}	73 ± 1^{b}	72 ± 1^{b}	66 ± 1^{b}
GC	81 ± 5^{a}	80 ± 3^{a}	78 ± 2^{c}	76 ± 2^{a}	72 ± 4^{a}
SP	56 ± 2^{c}	56 ± 2^{c}	54 ± 2^{d}	53 ± 2^{c}	50 ± 2^{c}

SD – Standard deviation

Table 2. Total dust concentration and concentration of dust fractions PM_{10}, PM_4, $PM_{2.5}$ and PM_1 in the rooms with students and with ventilation. Different letters (a, b, c) in the superscript are the sign of high significant difference (*ANOVA; Tukey HSD Test*; $P \leq 0.05$)

Room	Total	PM_{10}	PM_4	$PM_{2.5}$	PM_1
	μg m^{-3} ± SD	μg m^{-3} ± SD	μg m^{-3} ± SD	μg m^{-3} ± SD	μg m^{-3} ± SD
GA	33 ± 7^{a}	29 ± 4^{a}	25 ± 1^{a}	23 ± 1^{a}	20 ± 1^{a}
GB	41 ± 13^{b}	32 ± 5^{b}	25 ± 1^{b}	25 ± 1^{b}	22 ± 1^{b}
GC	34 ± 8^{a}	$30 \pm 5^{a,b}$	25 ± 1^{b}	23 ± 1^{a}	21 ± 1^{c}
SP	25 ± 2^{c}	24 ± 1^{c}	24 ± 1^{c}	23 ± 1^{c}	$21 \pm 1^{a,c}$

SD – Standard deviation

The measurements carried out during the normal function of rooms, with students and with standard ventilation (Table 2), show us that the limit level 0.050 mg m^{-3} of the dust concentration has not been exceeded in any room. The worst situation was in the area of gym GB which was probably caused by the bigger number of sportsmen. The limit value $PM_{2.5}$ 25 µg m^{-3} was exceeded only in this gym. The lowest concentration of dust was again in the swimming pool.

From the Table 3 it is apparent a very significant effect of ventilation on dust reduction. It can be assumed that, the dust concentration in tested rooms with students will be higher than in the empty rooms. From the comparison in Table 3 is obvious that the intensive ventilation contrary significantly reduced dust levels.

Table 3. Reduction of dust concentration due to the ventilation

Room	Total	PM_{10}	PM_4	$PM_{2.5}$	PM_1
	%	%	%	%	%
GA	41.25	36.71	32.47	30.67	28.57
GB	55.41	43.24	34.25	34.72	33.33
GC	41.98	37.5	32.05	30.26	29.17
SP	44.64	42.86	44.44	43.40	42.00

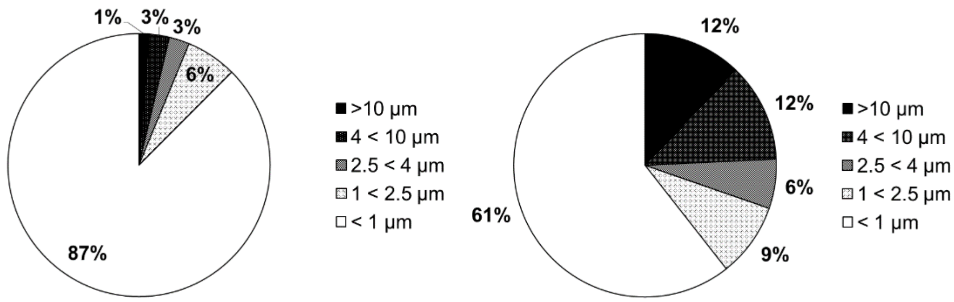

Figure 1. Percentage of dust fractions inside the empty gym GA without ventilation (left) and with students and ventilation (right).

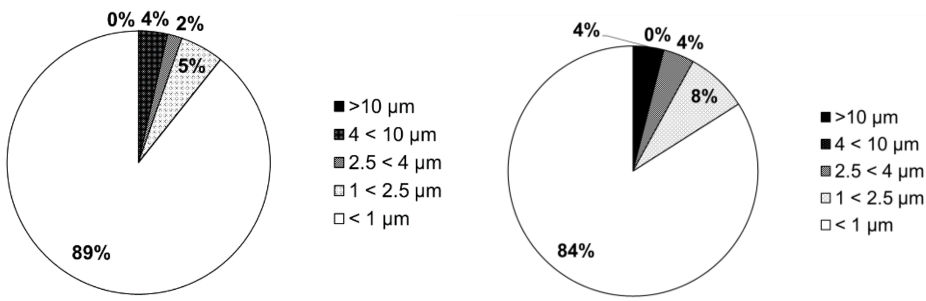

Figure 2. Percentage of dust fractions inside the empty swimming pool SP without ventilation (left) and with students and ventilation (right).

The Fig. 1 presents an example of the distribution of dust size of particles inside the gym GA without and with the ventilation. The main parts (87%) of the dust in the empty gym without ventilation are the particles smaller than 1 µm (size fraction PM_1). The air contains the biggest dust particles in very low percentage (1% of the particles bigger than 10 μm, and 3% of the particles smaller than 10 μm bigger than 4 μm). It is obvious that the small particles can move around freely in the air and the large particles settle down.

The use of the ventilated gym with students changed the percentage of dust fractions. There are 61% of the particles smaller than 1 μm and the percentage of big particles is higher (12% of the particles bigger than 10 μm, and 12% of the particles smaller than 10 μm bigger than 4 μm). This fact can be explained by the discharge of small particles due to the intensive ventilation. Similar situation is also in the other gyms.

The Fig. 2 presents the distribution of dust size of particles inside the swimming pool SP without and with the ventilation. Also in this case without ventilation the biggest part (89%) of the dust is created by particles smaller than 1 μm. During the intensive ventilation has been increased the percentage of the bigger dust particles, but not so much in comparison with the situation in the gyms. It is thanks to the generally lower concentration of the dust inside the building with swimming pool and also due to moisture and wet conditions which enable fixing the dust to the wet surfaces and humid air.

CONCLUSIONS

The results of measurements in the University sport facilities showed that:

- average concentrations of dust in all gyms as well as in the swimming pool without students and without ventilation was over the level 0.050 mg m^{-3},
- the biggest percentage of dust particles are small size particles PM_1,
- very big influence on the indoor air cleanness and reduction of air pollution by dust has the intensive ventilation, which can reduce the total dust concentration and therefore also the concentration of all dust particles, mainly the small size particles PM_1,
- intensive ventilation is more important if the room has small dimensions and number of sportsmen is high,
- the problem of dust is not so important for swimming pools, due to moisture conditions, humid air and intensive ventilation.

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Microclimatic conditions in the poultry houses

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Abstract. The aim of this paper is to present the results of microclimatic research focused on the indoor conditions in several agricultural buildings used for fattening of chicken broilers. The attention is paid mainly to the construction of the building and its position in the farm area, which together with technological equipment of the building, floor covering, and system of ventilation, can influence the microclimatic conditions inside the halls. In the frame of this research main parameters of internal and external properties of climate were measured and evaluated. The measurement results of the air temperature, humidity, globe temperature, concentration of CO_2, dust pollution and surface temperatures show rather important role of the overall layout of buildings, influence of the wind and solar radiation together with surroundings. The research results show that to the improvement of internal microclimate can contribute significantly the use of principles of passive air conditioning. The acquired new knowledge can be useful not only to improve the current situation on the farm, but mainly for the improvement of the building constructions in similar new farms.

Key words: air temperature, air pollution, solar radiation, passive air conditioning.

INTRODUCTION

Poultry housing technology, external climatic conditions and weather influence the indoor microclimate during different periods of the year, which needs different methods of ventilation control (Kic et al., 2007a; Kic et al., 2012). Creation of internal environment in the halls for poultry housing in summer is complicated mainly because of the high biological load of indoor environment, resulting from the large number of chickens per 1 m^2 of the floor area and high heat gains due to solar radiation. Problems occur particularly towards the end of fattening. Chickens have a large mass, they produce large quantities of pollutants (Aarnink et al., 2009; Kic & Růžek, 2014) and a lot of metabolic heat. Usually this problem is solved by intensive ventilation and sometimes by cooling of supplied air (Šottník, 2007; Zajíček & Kic, 2013a).

Technological equipment including the ventilation, heating and lightening is energy consuming which should be reduced by different approaches (Kic et al., 2007b; Rajaniemi & Ahokas, 2012). To improve microclimate conditions inside the buildings can help different methods for reduction of pollution (Kic & Liška, 2009; Liška & Kic, 2010; Liška & Kic, 2011), but for thermal state of the air the use of principles of so-called passive air conditioning systems that are energy-saving, could be useful like in the other buildings (Zajíček & Kic, 2014). Some of publications present the methods of calculation of main parameters of ventilation system (Gűrdil et al., 2001;) and simulation indoors conditions (Mistriotis et al., 1997; Mutai et al., 2011; Zajíček & Kic, 2012; Zajíček & Kic, 2013b; Zajíček & Kic, 2013c).

The aim of this paper is to show the measurement results of internal environment in poultry houses and verify the influences on the indoor climate of the halls in summer, particularly the possibility of influencing the inside thermal comfort with shading the buildings by surrounding vegetation and appropriate solution of the ventilation system.

MATERIALS AND METHODS

This research work and measurements were carried out in three buildings for fattening of broilers. All poultry houses are situated in one farm (Fig. 1), and they have the same internal dimensions: length 100 m, width 11.5 m, height 2.7 m, and inside each hall is housing of 23,000 chickens on the floor. The measurements were carried out during the 26th to 33rd days of fattening when the chicken have average weight about 1.5 kg.

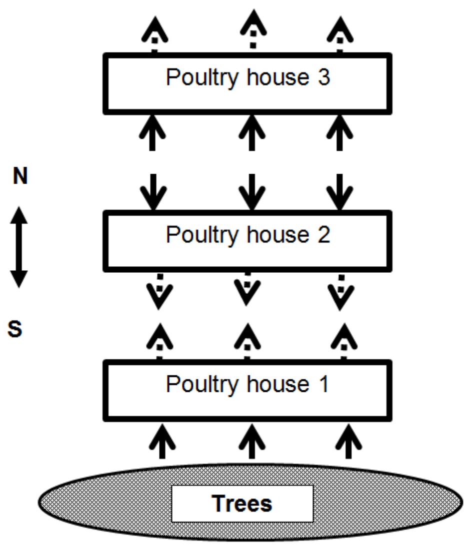

Figure 1. Ground plan of the poultry farm with three poultry houses, where N is the north; S is the south; → is the air inlet; and - - → is the air outlet.

Air temperatures and relative humidity were measured by data loggers ZTH65 outside and inside the poultry houses with registration at intervals of 15 minutes during one week (long-time measurement). Parameters of ZTH65 are: temperature operative range –30 to +70 °C with accuracy ± 0.4 °C and operative range of relative humidity 5–95% with accuracy ± 2.5%.

The thermal comfort in the space was continuously measured during the short-time experiments by globe temperature which includes the combined effect of radiation, air temperature and air velocity (measured by globe thermometer FPA 805 GTS with operative range from –50 to +200 °C with accuracy ± 0.1 °C and diameter of 0.15 m) together with temperature and humidity of surrounding air measured by sensor FHA

646–21 including temperature sensor NTC type N with operative range from –30 to +100 °C with accuracy ±0.1 °C, and air humidity by capacitive sensor with operative range from 5 to 98% with accuracy ±2%. Furthermore the concentration of CO_2 was measured by the sensor FY A600 with operative range 0–0.5% and accuracy ± 0.01%. All these data were measured continuously in the poultry houses 1 and 2 as well as outdoor in the installed meteorological station and stored at intervals of one minute to measuring instrument ALMEMO 2590–9, ALMEMO 2690–8 and ALMEMO 5990–2 during approximately five hours (short-time measurement).

The surface temperatures outside and inside the poultry houses were measured by thermographic camera IR Flexcam Pro with operative range from –30 to + 350 °C with accuracy ± 2 °C. Instantaneous values of surface temperatures (thermograms) were stored in the device memory and then analysed in a PC using a special software Infrared Solutions FlexView 1.2.2 designed for this thermographic camera.

The concentration of air dust was measured by special exact instrument Dust-Track aerosol monitor. After the installation of impactors the PM_{10} and PM_1 size fractions of dust were measured and compared in all three poultry houses. The 90 data of dust concentration PM_{10} and PM_1 size fractions in each building were collected. The position of measuring instrument was usually at 30 cm above the floor.

RESULTS AND DISCUSSION

The main objective of this article is a presentation of results of measurement of main microclimatic parameters in poultry houses, a comparison of obtained results with values recommended in relevant standards, and an analysis if the use of principles of passive air conditioning can contribute to the improvement of internal microclimate.

The results of long-time measurement of temperature and relative humidity of the air in three poultry houses are presented in Table 1. The results of this measurement show that the most favourable conditions in terms of air temperature in summer are in the poultry house 1 with an average temperature of 28.7 °C.

Table 1. Average values and standard deviation of the air temperature t and relative humidity RH in three poultry houses and outside in meteorological station during the long-time measurements

Place of measurement	t	RH
-	°C ± SD	% ± SD
External	21.6 ± 3.1	72.7 ± 13.5
House 1	28.7 ± 0.9	66.2 ± 1.8
House 2	30.9 ± 1.0	57.3 ± 3.2
House 3	32.5 ± 1.2	46.4 ± 3.5

SD – Standard deviation

The air temperature in this hall was during the whole measured period lower than in the other two halls (the average temperature in the house 2 was 30.9 °C and in house 3 was 32.5 °C). The optimal temperature for chickens during the period 4^{th} to 6^{th} week of fattening is usually recommended between 19 to 22 °C, which has not been reached in this period even during the cooler outdoor air in the night. The course of the air temperature and relative humidity of air during the whole long-time measurement is in Figs 2 and 3.

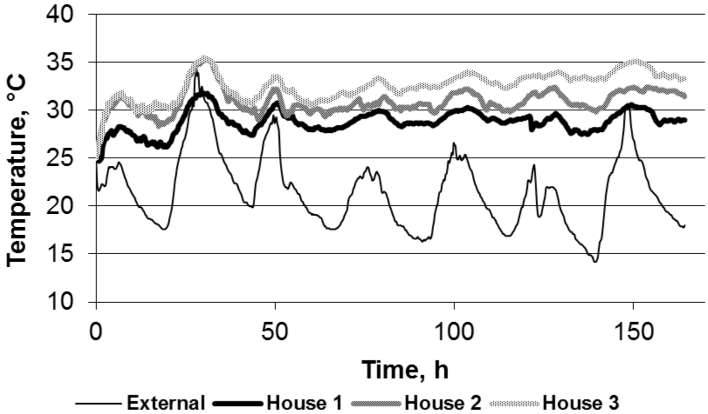

Figure 2. The course of the air temperature outside and inside the poultry houses 1, 2 and 3.

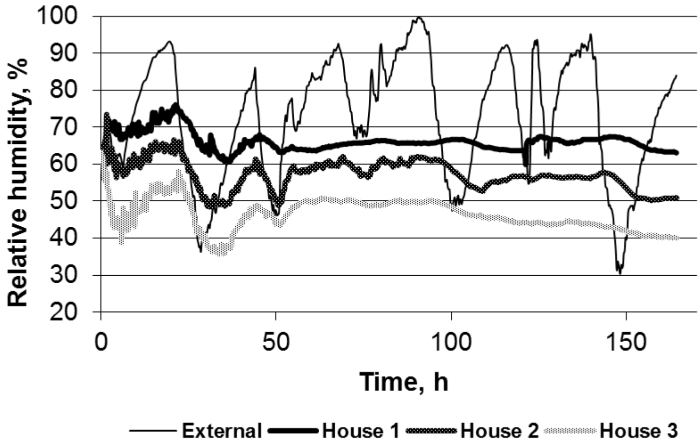

Figure 3. The course of the air relative humidity outside and inside the poultry houses 1, 2 and 3.

The courses of relative humidity correspond to the internal conditions in halls and to the changes in external and internal environment. As in other farms with similar technological equipment, the air moisture does not cause major problems in terms of microclimatic comfort. Recommended maximum relative humidity 70% was exceeded only in exceptional cases and for a short time in the house 1.

Average values and standard deviation of the globe temperature, internal air temperature, relative humidity and concentration of CO_2 in poultry house 1 and 2 during the short-time measurements are presented in Table 2. The results of short-time measurements in houses 1 and 2 confirm the results of long-time measurements. There is a very positive effect that the fresh air sucked into house 1, is from the cold zone near the house 1, which is shaded by trees. Therefore it is cold and fresh air, although it is on the south side of the hall. This also reflects a greater difference between the average globe temperature and the average air temperature in the house 1 than in the house 2.

Table 2. Average values and standard deviation of globe temperature t_g, air temperature t, relative humidity RH and concentration of CO_2 in two poultry houses and outside in meteorological station during the short-time measurements

Place of measurement	t_g	t	RH	CO_2
-	°C ± SD	°C ± SD	% ± SD	% ± SD
External	-	24.2 ± 1.2	59.4 ± 2.8	0.033 ± 0.000
House 1	25.1 ± 0.9	24.7 ± 0.1	63.1 ± 1.5	0.044 ± 0.006
House 2	25.3 ± 0.6	25.3 ± 0.7	62.8 ± 1.2	0.060 ± 0.020

SD – Standard deviation

From the measurement results it is evident the positive effect of suction of fresh air from the cold shaded part of the farm. To maintain better thermal comfort inside the house 1 significantly contributes partial shading by trees on the south walls and also partly shading the roof of this building. This contributes to reduce the impact of solar radiation on the indoor thermal comfort and reduce the inside temperature during the highest external temperatures. The comparison of the surface temperatures of terrain near air inlets measured by thermographic camera is summarized in Table 3.

Table 3. Surface temperatures of the soil (terrain) in the place of the fans suction into the poultry houses 1, 2 and 3

Suction area of	House 1	House 2	House 3
-	°C ± SD	°C ± SD	°C ± SD
Average temperature	23.29 ± 0.38	29.45 ± 1.60	29.52 ± 1.19

SD – Standard deviation

The worst conditions in terms of the air temperature are in the poultry house 3. This is mainly due to the fact that the air is sucked from the middle part of a farm, from the south side of the house 3 which is not overshadowed and therefore the supplied air has a higher temperature than the air supplied into the house 1 or 2. Ventilation air which is supplied into the hall 2 is also sucked from the middle of the farm, but is drawn from the north side, partially shaded by the hall 2. Therefore, the temperature in the house 2 is higher than in the house 1, but lower than in the house 3. Therefore it can be said that even in this case, shading of buildings helps to improve indoor thermal comfort of the internal microclimate.

The thermograms of the surface areas inside the poultry houses 1 and 2 are shown in Fig. 4. The results of surface areas of chickens on the floor, south wall, north wall and ceiling selected from thermograms in Fig. 4 are summarised in Table 4. There is obvious lower temperature of surrounding surfaces in the house 1 than in the house 2. Thanks mainly to the lower temperature of the inlet air and the surface areas inside the building also the average surface temperature of the chickens on the floor in the house 1 (33.39 ± 1.40) is lower than in the house 2 (34.15 ± 1.57).

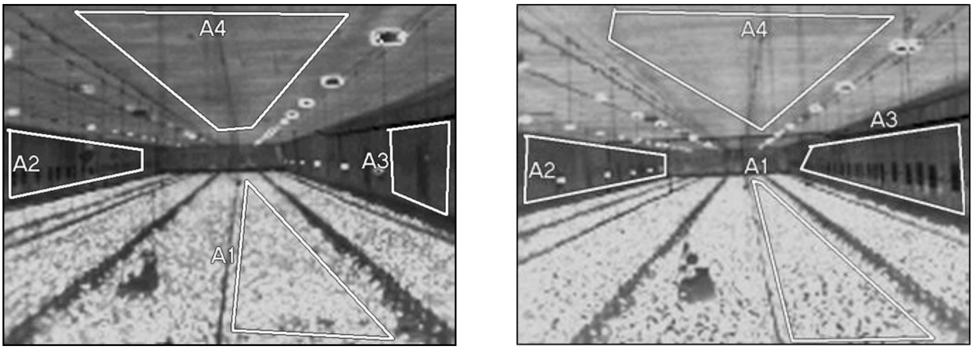

Figure 4. The thermograms of the surface areas inside the poultry house 1 (left) and 2 (right). Where A1 is the evaluated surface area of the chickens on the floor; A2 is the south wall; A3 is the north wall; A4 is the ceiling.

Table 4. Average surface temperatures inside the poultry houses evaluated from the thermograms according to the Fig.4

Surface	Area	House 1	House 2
-	–	°C ± SD	°C ± SD
Chickens on the floor	A1	33.39 ± 1.40	34.15 ± 1.57
South wall	A2	27.57 ± 0.60	28.08 ± 0.69
North wall	A3	27.73 ± 0.41	27.73 ± 0.70
Ceiling	A4	29.31 ± 0.64	30.58 ± 0.38

SD – Standard deviation

The results of measurement of the CO_2 concentration in houses 1 and 2 (Table 2) are quite surprising. The recommended maximum concentration of 0.25% was not exceeded in any house, but this was measured in the summer season with a maximum flow of ventilation air. Surprising is the difference between the CO_2 concentration measured in these two buildings. This can be explained partly by the fact that chickens produce more CO_2 in the house 2 due to the stress from higher temperatures and generally less favourable microclimate conditions.

Furthermore, lower average CO_2 concentrations in house 1 can be due to the fact that the air is sucked into the hall clean and colder from the area of surrounding trees and fields. Houses 2 and 3 have a common zone from which the air is supplied into the halls. Therefore, the higher average concentration of CO_2 in house 2 can be explained partly by the fact that this suction zone of air is in the centre part of the farm. This area is partly influenced by the overall environment of farms, and exhausted air from outlets of poultry houses could be partly sucked by inlets again into the houses 2 and 3.

These conclusions correspond with the results of dust measurements (Fig. 5 and 6). Concentrations of PM_{10} and PM_1 size fractions of dust were the lowest in the house 1 and the biggest in the house 3. From the viewpoint of dust pollution, the problems of the hall 2 and hall 3 can be explained also by the outside recirculation of air which is partly contaminated by dust particles.

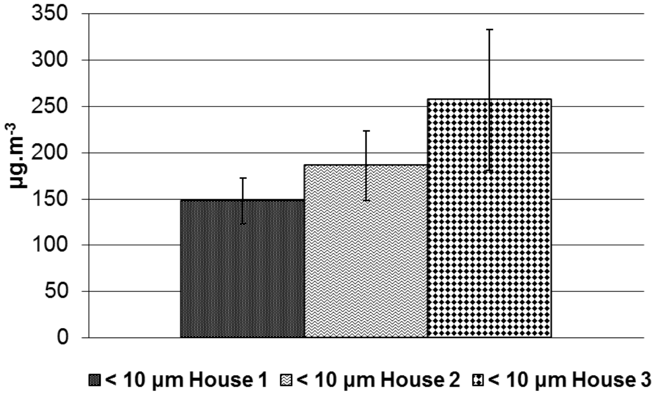

Figure 5. Concentrations of measured dust fraction PM_{10} inside the poultry houses 1, 2 and 3.

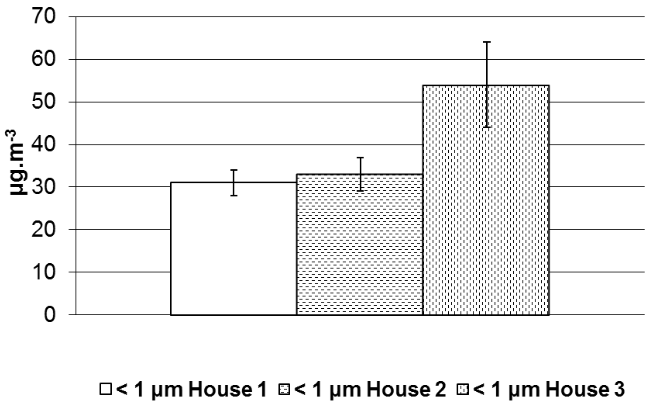

Figure 6. Concentrations of measured dust fraction PM_1 inside the poultry houses 1, 2 and 3.

CONCLUSIONS

The results of measurements in the poultry houses showed that principles of passive air conditioning can contribute significantly to the improvement of internal microclimate, especially:

- high trees growing around the poultry houses significantly reduce external heat load of construction, reduce heat gains and improve the summer heat balance of the building,
- air intake from the places protected from direct sunlight e.g. by shading trees significantly reduces the temperature of the inlet air to the hall and contribute to the thermal comfort in the building during the summer months,

- regarding to the orientation of building, the best solution is to situate the air inlets on the north side of the building, because the assumption is that it will be sucked cold air into the hall in summer,
- a significant effect on air cleanliness in terms of gaseous pollutants and dust has the air intake from areas protected against external pollution,
- a suitable location of air outlets should prevent undesired recirculation of exhaust air from the poultry house.

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The construct of value in knowledge-intensive business service from customer's perspective. An example of a long-term training activity

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Abstract. Value is considered to be the driver, as well as the main purpose, of relationships between customers and service providers. Despite the topicality of the subject, service marketing literature provides little information about the process of value creation. The question of how is value formed is topical for a broad scope of services, from healthcare to beauty services, but it is especially relevant for knowledge-intensive business services (KIBS). KIBS are complex offerings that aim to solve customer's problem by applying competence of service provider (for example consultancies and training services). It happens quite often that those types of services fail to meet the expectations of the customer regarding service value. This mismatch between service value and price charged might come from a broad variety of reasons. This ambiguity of value creation process leads to the research question of the current article: how do clients identify, what the service is actually worth? The current article presents the results of longitudinal qualitative research on service value formation from the customer's perspective. It aims to provide insights both for researchers as well as practitioners on elements of service, based on which client forms the perception of the value of KIBS and also illustrated the dynamics.

Key words: service value, customer value, value creation, co-creation, value-in-experience, KIBS.

INTRODUCTION

It is rather hard to identify the value of the service due to its intangible nature. The complexity and ambiguity of this concept have provoked a lot of discussion among scholars. The significance of research in the field of service value has grown rapidly over the last few decades. The shift of dominant logics in marketing literature from goods-dominant (G-D) to service-dominant (S-D) (Vargo & Lusch, 2008) has increased the importance of comprehension of customer value (Monroe, 1991) in the majority of business fields. Understanding what does actually create value for the client and delivering accordingly is the primary key to competitiveness in the modern business environment (Osterwalder et al., 2015).

Marketing theory, which is the primary domain of value-related body of knowledge, has faced several shifts of dominant logics (Vargo & Lusch, 2008). The transition from G-D towards S-D logic has entirely transformed scholars' view on the process of value formation. In addition to that, the rise of experience in management and marketing literature (Pine & Gilmore, 1999) has provoked a new wave of in-depth research not only on the essence of value but also on value constituents. For the past two decades marketing literature has mainly been discussing the experiential construct of value (Boswijk, 2013; Sundbo, 2015).

Naturally, academic research on service value constituents is of great interest to practitioners as well as the scholars. Every service field has its specifics and challenges in customer value creation. In the case of knowledge-intensive business services (KIBS) value identification is even more complicated, than in other fields. The reason for this is the fact that there tends to be a significant informational imbalance between the parties involved (Gummesson, 1978; Thakor & Kumar, 2000; Ojasalo, 2001; Aarikka-Stenroos & Jaakkola, 2012; Kukk et al. 2014).

In a nutshell – KIBS are companies that sell knowledge-based services to clients, who lack the competence to solve a problem using internal resources only (OECD, 2006). Consultancies and training are a typical example of such services. In this type of KIBS customer does not just purchase a solution, he buys external competence to assist him in the creation of the solution. In other words, the outcome of such KIBS is co-created by the service provider and the customer.

Unfortunately, existing body of knowledge fails to describe based on what does the KIBS customer evaluate the service. As this is a very topical issue both for scholars and practitioners, we find it essential to locate the answer to the question *'how do clients identify, what the service is actually worth?'*

To fill this gap in the body of knowledge research was conducted with the key purpose to *determine the construct of value in KIBS from customer's perspective*. In our study, we aim not only to identify concrete constitutes of value but also to see how they change in the dynamics throughout the service delivery process. Current article gives the overview of the results of this research.

CONCEPTUAL FRAMEWORK

Service value

The value in general and service value, in particular, is a rather abstract concept with meanings that vary according to context (Sweeney, 1994). It can be defined both by the service provider and customer, and the results may be quite different from each other (Grönroos, 2011). The shift of the dominant logic of the economy from the G-D logic to S-D logic has made the customer the key identifier of the value. It is still an open question, based on what do consumers evaluate a service.

Eggert and Ulaga (2002) state that among different definitions of perceived service value, a list of three common elements can be outlined:

1) Multiple components of perceived value; since value is often described as a trade-off between benefits and sacrifices, the key elements that play a role in forming service value perception are both physical and intangible attributes of the service and monetary or another sort of sacrifice.

2) Subjectivity of value perceptions; different clients may rate the value of the service differently according to their personal background. In addition to that, when business services are considered, then different members of the service buying organisation may perceive the value differently.

3) The importance of the competition; perceived value may be shaped in relation to the services that other providers are offering.

Classic view on service value formation is that the main aim of services is to change the state of people, artefacts, or of information and knowledge, rather than produce artefacts themselves (Miles, 2005). This means that one may judge value of a service primarily based on their effects on the buyer rather than how they are produced (Wood, 2005).

Alternative view of value creation that emerged after the emergence of the theory of experience economy (Pine & Gilmore, 1999) sees value creation as a more holistic process. In the context of experience economy value is perceived not only based on the functional evaluation of outcome but also based on the hedonistic assessment of the process (value-in-experience) (Kukk & Leppiman, forthcoming).

There are also a variety of opinions in the marketing literature regarding who is the primary creator of value. Grönroos (2011) points out that value can be created either in provider's sphere of influence (value-in-exchange), in customer's sphere of influence (value-in-use) and as an all-encompassing process across those two spheres of influence. Scholars generally agree that in complex services (KIBS definitely among them) value is created in cooperation between service actors and throughout the whole service life cycle (Aarikka-Stenroos & Jaakkola, 2010; Leppiman, 2010; Aarikka-Stenroos & Jaakkola, 2012; Heinola, 2012) and therefore, value co-creation process takes place.

Value creation specifics in KIBS

When it comes to value creation in KIBS in particular, there are a few extra factors that have to be taken into account. A significant feature of KIBS is the high level of customization and intense interaction with the client (Sawhney, 2006; Cova & Salle, 2008; Aarikka-Stenroos & Jaakkola, 2010). The value in KIBS is being co-created by service stakeholders (Kukk et al., 2014). The main challenge of such co-creation within business services is the asymmetry of the information and competence possessed by the stakeholders (Gummesson, 1978; Thakor & Kumar, 2000; Ojasalo, 2001; Kukk et al. 2014). This fact also has an impact on the evaluation of the effect of the service (utilitarian approach to value), as the customer may often lack the appropriate knowledge or skills to estimate the value of service provided. In this case, the customer determines service value by evaluating service encounter as a process (Pine & Gilmore, 1999) (hedonistic approach to value).

Our previous empirical research confirms that the experience of co-creation process and perception of the value of the service are very much dependent on each other. Also, the client's engagement in the value creation process can influence the perceived value both positively and negatively (Kukk & Leppiman, 2013; Kukk et al., 2014). Generally speaking, there are four main stages of a service that customer perceives (see Fig 1).

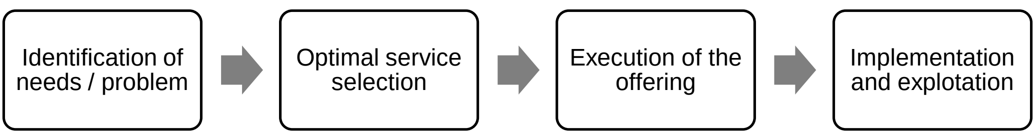

Figure 1. Phases of KIBS according to clients' perceptions (Kukk et al., 2014).

The evidence from previous research on value co-creation (Kukk et al., 2014) points out two main ideas that serve as a departure point for current research. First of all, it is evident, that during the four stages of the service there is a dynamics of customer's expectations. It applies both to the elements of the service and to the amount of contribution which the customer expects to have in the value co-creation process. For this reason, we find it essential to explore the value constitutes not just throughout the service, but also in all the service stages separately.

Second, data (*ibid*.) shows that not just *what* is being done, but also *how* it is done has impacted on the service value from the customers' perspective. Therefore, we may assume that *experience* (and potentially *meaningful experience*) (Leppiman & Same, 2011) has an impact on business service value for the customer. This statement, however, contradicts with the general utilitarian view on business service value formation that dominates KIBS-related literature (Aarikka-Stenroos & Jaakkola, 2012; Lessard, 2014). For this reason, we have chosen to conduct qualitative research on service value aiming to identify the construct of value from customers' perspective.

RESEARCH DESIGN AND METHODOLOGY

A two-stage qualitative research was conducted to answer the research questions.

In the first stage of the research, the data was gathered via the longitudinal multi-touchpoint process. We studied the perception of KIBS value of the participants of an international long-term professional development programme. The duration of the training programme (excluding the preparatory part) was six months from May until November 2015. There were 33 participants in the sample. Participation in the research was voluntary and the participants gained no material or immaterial benefits by submitting the responses.

Demographic overview of the sample is presented in Fig. 2.

Figure 2. Demographic overview of the research sample.

Purposeful strategic sampling (Mason, 2002, 120–125) was used to select the participants. The sample can be described by the following criteria of the participation in the training programme (and therefore in the research):

– the participant has professional interest towards the topic of the training;

– the participant is in a managerial position, meaning he has the mandate to execute changes (if he finds it necessary) in the work process of the organisation he represents based on the learning;

– the participant is able and motivated to participate in the whole programme.

The design of the study followed the structure of KIBS perceived by the customer (Kukk et al., 2014), the long-term nature of the service allowed us to approach the participants several times, without it becoming overwhelming. The data gathering was organically integrated into service delivery process. It had started before the beginning of the programme and finished after a few weeks after the programme had ended.

Two different methods were used in data gathering process:

– electronic form with supporting questions to gather written narratives on value perception;

– focus-group interviews to get a deeper understanding of willingness for value co-creation in various stages of the service delivery.

The detailed overview of the research is presented in Table 1.

Table 1. The design and the time-line of the research

Service stage	Aim of the interaction	Interaction	Tools used	Time of interaction
Identification of the needs	pre-service needs and interests identification	A	written narrative (with support questions)	April 2015
Selection of the optimal service solution	mapping of expected value constituents	B	written narrative (with support questions)	May 2015
		C	focus-group interview	June 2015
Execution of the offering	mapping of perceived value constituents	D	written narrative (with support questions)	July 2015
Implementation and exploitation of the created solution	identification of post-service perceived value constituents	E	focus-group interview	November 2015
		F	written narrative (with support questions)	December 2015

Gathering of the narratives (interactions A, B, D, F) was arranged via an electronic form. The form included an introductory text that explained the self-refectory nature of the survey as well as the purpose to gather data on the value of the programme. Due to the fact, that the nature and methodology of the programme included other elements and tools of self-reflection, the form was well blended in into the process.

The form also contained supporting questions. The phrasing of the questions varied depending on the stage of the service. Nevertheless, throughout the process the questions targeted value perception from three different angles: the value created by service provider prior or during the service (value-in-exchange), the value created (or potentially created) by customer during or after the service (value-in-use), and the value co-created by involved stakeholders throughout the process (value-in-experience).

To ensure detailed feedback from the respondents, there was a minimum limit of 350 words per question.

The focus groups (interactions C and E) took place during the training sessions and focused on the value of the programme while still at the beginning of the process (interaction C) and in the very last stage of the programme (E). The purpose of the focus groups was the enrichment of the qualitative data gathered via electronic forms and taking advantage of the opportunity of reactive discussion development to gather more detailed information. To gather maximum insights focus groups were performed in three smaller groups. Each focus group interview lasted for around one hour. All of the focus groups were facilitated according to the same manual.

The quality of the gathered data depended very much on communication and language skills of the participants. As the group was multinational, the participants had an opportunity to submit their answers in English, Estonian, Latvian or Russian language. Several participants did not choose to present replies in their mother tongue but preferred either English or the national language of the country they represented instead. Due to this, some of the responses are laconic and more general than the others.

In the focus group interviews data was gathered in the national languages (Estonian and Latvian), except one sub-group (interaction F), that was conducted in English.

In the second stage of the study, a qualitative content analysis (Flick & Gibbs, 2007; Leppiman, 2010; Schreier, 2012; Bazeley, 2013,) of the gathered data was performed to extract and systematise valuable information.

The qualitative data analysis was conducted in two separate stages. First the data collected during the four service stages was analysed separately to identify the separate constituents that are part customer's value estimation in different stages of the service. In the second phase, the generalising analysis of the full data was performed to unify the categories that were identified during the first stage of the analysis and to create a general picture on value construct.

The qualitative analysis provided us with new categories that are described below in the sections of the article dedicated to the four stages of KIBS respectively.

As the data gathering via electronic form was optionally anonymous, we do not have the opportunity to track all the responses of a particular person. In the results representation below we use the following coding for the quotes: letter (A; B; C; D; E; F) indicates the interaction via which it was obtained (see Table 1); the number (1–33) shows the number of the response.

RESULTS

Identification of the needs

The first stage of the service aims to specify, what are the concrete needs and issues that have to be solved by KIBS. In some training programmes, participants sign up for a particular course, which has been developed and prepared before gathering any insights from the customers. In other cases (also in consultancy service) trainings are tailor made, and respond to the specific needs and interests of the client.

In our case, we adapted and integrated the general principles of service design (Kukk & Leppiman, 2013), involving customers in defining appropriate service content as much as possible throughout the whole process. The first step of such interaction was gathering data on the specific needs of the selected participants on the announced topic of the programme. In addition to that gathered data provided some significant insight on what are the main constituents of value, that customers expect prior to service delivery.

Qualitative analysis of the data provided us with two main categories (with five sub-categories): 1) performance improvement and 2) interaction with other practitioners. Table 2 lists the categories and subcategories with the examples of keywords and phrases found in data.

Table 2. Examples of key words and phrases addressing categories 1 and 2

NR	Category	Example quote
1	**Performance improvement**	
1a	improving personal professional performance	*'Continues professional development allows me to improve how I do my job. I expect this programme to be a contribution to this'. (A29)* *'Participation in the programme should allow me to learn, how to share my knowledge and skills with youngsters'. (A14)* *'I think I should be able to improve my skills in giving feedback'. (A3)*
1b	improving performance of the organisation	*'We need to engage our youngsters more into activities we offer at the centre, we are also looking to expand our audience in 2016'. (A6)*
2	**Interaction with other practitioners**	
2a	collecting knowledge on experience of other practitioners	*'Training is a perfect place to share my experience and knowledge with other practitioners, but also to get practical tips from them as well'. (A6)*
2b	sharing information on personal experience	*'I am expecting meeting and discussing the topic with other professionals of the field. I also look forward to sharing my experience on international level.' (A14)* *'The importance of sharing experiences cannot be overlooked.' (A9)*
2c	contact making for further cooperation	*'Every new contact is extremely valuable. I am looking forward to meeting Latvian colleagues. (A14)* *'I expect to broaden my cooperation network'. (A24)*

The pre-service narratives on expected value seem to be surprisingly homogeneous. The most mentioned value constituents could be categorised as elements of improving personal professional performance. The vast majority of the informants identified that they expect to acquire or develop specific *professional skills*, or *learn* new information on the topic. Even though a broad variety of keywords were used by the informants to describe this category, the pattern of skill and competence improvement-orientation is evident. Only a few of the informants mentioned the value of the training programme in the context of organisational level.

Though in reality organisational performance improvement is closely linked to personal performance, in the process of value estimation distinguishing those two elements is crucial. As seen in the examples above, nevertheless the aims and topic of the programme were communicated as organisational (or even field best practice improvement orientated), most of the informants have replied in a self-centered manner.

Another value-shaping element of the service that was often mentioned in the problem-defining phase of the programme development was the fact, that training should be a place to interact with other professional individuals. It is noteworthy that even though most of the responses clearly value the input from the others, there are also quite a few of evidence indicating, that they are looking forward to *contributing* as well.

The interpretation we would like to suggest here is that as clients themselves are already established and in most cases quite experienced professionals, they see the value also in spreading their knowledge to the larger audience. At the same time, it unfortunately remains unclear, if this happens due to the desire of genuine contribution to the development of the field or in order to get recognition and credit.

Some of the informants saw the interaction with other professionals as a potentially longer-lasting value factor. There were several references, that important element of value would be the after-training cooperation with individuals and organisations met during the programme.

We also find it important to highlight, that several informants also expressed they particular interest and willingness for co-creation of the value during the programme delivery:

'I am ready to participate in the creation and execution of the new programme'. (A3)

To summarise the results of the analysis of the first stage of the service we can say, that in this phase the informants were clearly leaning towards utilitarian approach to service value, focusing on elements that are (directly or indirectly) contributing to improvement of professional performance.

Selection of the optimal service solution

In the second stage of KIBS service provider (in co-operation with the customer) develops the solution that will be implemented during the service delivery stage. In the case of current study, this meant specifying the final schedule, content focus and methods of the training programme. The main difference between the first two phases of the programme is that in the first ones the customers were only aware of the general field and topic of the training programme, in the second stage they became more conscious of the complex process that was being designed exclusively for them.

Data analysis showed that in this stage the categories, that were defined in the first phase of the service remained present. The notable difference is that subcategory 1b (improving the performance of the organisation) was represented in the data much less compared to stage one.

In addition, we also highlighted new categories, that were not present in the identification of the needs stage of the service. The two categories that have added up to the list mentioned above were: 3) motivation and 4) experience. The quotes and keywords illustrating those categories are described in Table 3.

Table 3. Examples of key words and phrases addressing categories 3 and 4

NR	Category	Example quote
3	**Motivation**	*'[The result I expect the most] from the training programme is that in the end I have gained new ideas and feel encouraged in my work.' (B11)* *'I think it [the main result] will be my own inspiration and ideas that will come up after participating [in the programme]. '(C13)* *'I see it [value] in not loosing motivation after the programme.' (B3)*
4	**Experience**	*'[It is valuable for me] that it is a new project with a wide range of a new extraordinary experiences and different participants. Experiences can be actually mutually shared and explored during the programme'. (B10)* *'I see this programme as experience, and therefore it can only be valuable in any case'. (B19)*

Though the general picture both from the narratives (B) and the focus-group interview (C) follows same pattern of value constitutes as in the first step of the service, the data also includes a clear evidence, that as soon as the participatory nature of KIBS became clearer to the participants, the additional expected elements added up.

Several times motivation is being mentioned as one of the most valued potential outcomes. In the narratives, there's also a significant pattern, where motivation is mostly referred to in relation to personal performance improvement (subcategory 1a), as illustrated in Table 3. The majority informants are confident that the training will complete the task of providing new knowledge, but they see the extra value in also gaining the motivation to apply this knowledge in practice:

'I am hoping to gain knowledge and inspiration to improve how I do things.' (B20)

'[After the training] the motivation within me [to apply new skills] would grow.'(B11)

Another category that compliments the motivation created by the training is the element of experience (Leppiman & Same, 2011). According to the informants, the experience is expected to add value to the programme.

The noticeable pattern when going through the data gathered during the stage of selection of optimal service solution is that the category of performance improvement is a lot less dominant. Also, we noted, that the categories adding up in this service phase can only be evaluated very subjectively.

Execution of the offering

Execution of the offering is the phase, where the service is delivered in accordance with the plan, which was agreed in the previous stage of the service. Therefore, the narrative gathering process was performed after the participants had already had significant experience with the training programme. At the time, they had already experienced an international and a national training session. Also, they had received the task of applying the gained knowledge in their 'practice projects' (contribute effort to the value creation process). In addition to that, some of the participants received personal mentoring in the course of practising their skills.

The data gathered at this stage can be characterised as rich in both emotional reflections and constructive feedback on the service. The usage of keywords and phrases expressing emotions (such as 'love', 'excitement', 'I felt …' etc.) was high. In addition to that, the data was noticeably less homogeneous compared to the previous two stages. Two new categories were adding up to the ones that have been mentioned previously: 5) content relevance and 6) Facilitator. Also, the analysis of the data collected in the stage of service execution allowed us to specify subcategories of the categories 'motivation' (3) and 'experience' (4). The new categories and subcategories are illustrated in Table 4.

Table 4. Examples of key words and phrases addressing categories 3–6

NR	Category	Example quote
3	**Motivation**	
3a	will to implement learning into practice	*'[...] it is important that the our experience and also sharing with colleagues is inspiring, so that I'll definitely continue applying Youthpass process in the future'. (D6)*
3b	re-assurance of one-s competence in the field	*'I have learned about [this] from academia and also on several international seminars, but after the second seminar [of the programme] I have a feeling that i don't have doubts anymore, if i can apply this knowledge. This is the most important outcome so far'. (D3)*
4	**Experience**	
4a	active involvement	*'As it is easy to get tired of learning process, then I appreciate a lot the <u>variety of tools</u> used in this programme". (D16)* *'I like that most of the sessions <u>are not in the form of a lecture, but are arranged as group works, simulations, discussions</u>'. (D28)*
4b	training space comfort (working environment)	*'In order to get a good learning experience one needs a good <u>learning environment</u>. It is important that we have the <u>opportunity to move around the room, use the walls, express ourselves visually</u>'.(D19)*
4c	comfort of supporting facilities.	*'It is good that the <u>accommodation and food</u> are nice, this helps not to be distracted from the <u>learning experience</u>.(D1)*
5	**Content relevance**	
		'I value the <u>tools and working methods</u> introduced during the second training sessions the most. I also appreciate, that there was a possibility to have the introduction of relevant materials to study this information further'. (D18) *'For me it is positive, that we are <u>diving into topic</u>, it is important that we receive <u>so much in-depth information</u>'. (D25)*
6	**Facilitator**	
6a	professional skills of the facilitator	*'It adds a lot that trainers are <u>friendly and available</u>'.(D8)* *'Trainers are very <u>caring and careful</u> towards us'. (D24)*
6b	personality of the facilitator	*'I am very happy about very <u>professional trainers</u>, they are very good'. (D9)* *'Facilitators have done a <u>professional job</u> with the topic, the <u>expertise</u> is very valuable'.(D14)*

It is noteworthy that category of performance improvement (category 1) was not present in the data of this stage of the service. Instead, informants pointed out the particular elements of the programme, highlighting the content relevance and interest to it (5).

The examples above (Table 4) show, how the informants express the appropriateness of the information for them, yet there are no mentions regarding how it is useful in performance improvement.

In addition, informants appreciated a lot the experience of the participation. According to the data, there are three main elements that shape the value of training experience. First of all active involvement of the participant in the process (4a), the second highly appreciated experience-shaping element is the comfort of the training environment (4b). Also, data shows that the environment outside the learning space (4c) also contributes to value perception.

Based on the service experience until that moment, several informants also reflected on how it influences their motivation. It allowed us to determine that there are two main components of this value constitute, that training participants highlight. First of all, it is will to implement learnings into practice (3a) (that also meant by the informants in the previous stages of the service). As a new dimension of motivation, we identified the re-assurance of the competence and capability, which participants received from the programme (3b).

Another interesting insight comes from the following quote:

'I felt really good sharing information and methods and outcomes. I felt like I'm learning even if I was just sharing what I'm doing. I rarely speak about it otherwise. That feels good.' (D3)

The facts described above explain why sharing experience and knowledge (subcategory 2b), which was highlighted a lot in the first two service stages as an expected valuable element of the programme, is of such importance to the service clients.

In addition to deeper exploration of previously mentioned categories, we determined a new category of service element that, according to the informants, added value. It was the facilitator of the activity. More specifically we highlighted two subcategories: facilitator's professional skills (6a) and personal skills (6b).

To summarise the analysis of data gathered the third stage of KIBS we can say, that in this stage the variety of constitutes of value that informants have pointed out is the broadest. It is also evident that compared to previous two stages informants give more detailed and concrete comments on what is valuable to them (often accompanying statements with examples).

Implementation and exploitation of the created solution

During the design of the particular service offering, we took into account the findings from our previous research (Kukk et al., 2014) that showed, that the one of the most complex stages for the customer is the last one, where he applied the gained competence or created solution in practice. As this is often the stage, where service provider's contribution is minimal, the client often feels, that he is left alone without the support of an expert and it would add value if service provider would provide some assistance and feedback at this stage. Therefore, we designed service offering in a way, that there was a planned programme continuation even after the customers have tried the implementation of the new skills in practice ('practice projects').

The second focus group (interaction E) was conducted during this last seminar. The narratives (interaction F) were gathered later, after one month after the programme had ended, to have a better perspective on after-effect on a longer time scale.

Analysis of data collected during the final stage of the service did not provide us with any categories or subcategories that have been not present in the previous three stages. Four out of six categories listed above were present in the last stage of the service. Table 5 illustrates the categories and examples of the quotes addressing them.

Table 5. Examples of key words and phrases addressing categories 1–4

NR	Category	Example quote
1	**Performance improvement**	
1a	improving personal professional performance	*The most important [outcome] for me is that I approach the whole work process differently'. (F3)*
1b	improving performance of the organisation	*'I see the value in the fact that we have included the learning process in the youth work activities'. (F14)*
2	**Interaction with other practitioners**	
2a	collecting knowledge on experience of other practitioners	*'[I value] working on topic with others, hearing what they had to say and share about [their experience]. (F12)*
2c	contact making for further cooperation	*'The important added value of the programme was the opportunity to network with other participants and to start long-term cooperation with some of them.' (F6)*
3	**Motivation**	
3a	will to implement learning into practice	*'For me it was an attitude-lifting programme, I am now more motivated to set higher standards for myself and for my organisation'.(F1)* *I cannot even explain, it's a feeling, but all this process has a power. It completely changed the way I see things. (E2)*
3b	re-assurance of one-s competence in the field	*'It is very motivating to see evidence, that what i already knew and what I did [before the programme] is supporting the Youthpass approach in youth work. I see it as a very valuable result for myself.'(F20)*
4	**Experience**	
4a	active involvement	*'I would have loved to dedicate more time to my practice task and in parallel to have the mentoring sessions that were offered. I feel I missed that chance to get the maximum out of the programme'. (F22)* *'The one thing I would change to add value would be that I'd be more detailed and more focused in my practice project. [...] I feel I didn't take the most from the learning opportunity'. (F5)*

Performance improvement, both on personal and organisation level (subcategories 1a and 1b) was strongly represented. Informants provided a lot of specific examples, how they have improved their professional behaviour and how the organisation has optimised the performance and the results.

The second highlighted element of value construct is interaction. It is noteworthy that looking back at the service and evaluating it the participants highlighted only collecting knowledge on the experience of other practitioners (2a) and contact making (2c).

At the same time the aspect of sharing (contributing) knowledge (2b), which was described extremely high in value in previous service stages was no longer mentioned.

The value of motivation was also highlighted at this stage. Both the increase of will to implement the leanings (or in other works to change the professional behaviour) (3a) and the re-assurance of the correctness of knowledge and approach (3b), were described as the valuable outcomes by the informants.

The fourth element of value that informants referred to in this stage of the service was their contribution and involvement in the process (4a). There was a lot of appreciation expressed regarding involving the participants in the programme development process, encouragement to try out new skills in a safe environment and reflect afterwards. What is even more noteworthy – informants highlighted, that they feel, that the value of a service could have been higher for them in case they would have had time to contribute more time and effort into trying out the new skills to receive the expert's feedback and suggestions for improvement.

The examples in Table 5 illustrate how informants express the shared responsibility for the value of the programme. Even though in general they are satisfied with the service value, they still see that the value could have been larger in case the contribution from their side would have been more significant.

To summarise the results of the qualitative data analysis from all four service stages, we can say, that even though the categories and the keywords and the level of specifics of description varied noticeably throughout the whole research process, we see a definite pattern in the value co-creation process.

The general pattern of the dynamics of value-shaping service elements is as follows. When the customer first approaches the service provider he is mostly utilitarian value orientated, in other words, he seeks mostly practical and useful outcomes, such as performance improvement and potential partners. When the interaction begins – the hedonistic value constitutes come to play, which are more related to the process enjoyment. During the process delivery hedonistic approach to service, evaluation starts to dominate. The dynamics of the pattern is presented in Table 6.

It is noteworthy, that the traditionally considered key value component of KIBS, that has been mostly highlighted in the KIBS value studies so far – performance improvement– is not in the focus at service execution stage at all. In the post-service evaluation, the customer again becomes more practical and takes the utilitarian value constitutes into account. But at the same time, he also takes into account several experience-related factors, which also have a significant impact on value perception even after the service has been completed.

Table 6. The dynamics of value construct from customer's perspective in KIBS

Nr	Category	Identification of needs	Optimal service selection	Execution of the offering	Implemention and exploitation
1	**Performance improvement**				
1a	improving personal professional performance	x	x		x
1b	improving performance of the organisation	x	x		x
2	**Interaction with other practitioners**				
2a	collecting knowledge on experience of other practitioners	x	x	x	x
2b	*sharing information on personal experience*	*x*	*x*	*x*	
2c	contact making for further cooperation	x	x	x	x
3	**Motivation**				
3a	*will to implement learning into practice*		*x*	*x*	*x*
3b	*re-assurance of one's competence in the field*			*x*	*x*
4	**Experience**				
4a	*active involvement*		*x*	*x*	*x*
4b	*training space comfort (working environment)*			*x*	
4c	*comfort of supporting facilities*			*x*	
5	**Content relevance**			x	
6	**Facilitator**				
6a	professional skills of the facilitator			x	
6b	*personality of the facilitator*			*x*	

** - subcategories presented in italics are identified as hedonistic*

The description of how the construct of value and the dynamics described above correlate with existing literature and the suggested conclusions from this study are presented in the discussion part of the current article.

DISCUSSION

As described above, the results of our study confirm that KIBS client's perception of the value of the service is based on elements that vary in time throughout the service process. Table 2 provides an overview of the dynamics of value construct from customer's perspective. What is particularly interesting, is that those constitutes of value are not always in sound with the presumed utilitarian value of service (which value of KIBS is mostly associated with in literature).

Even the categories that at the first glance are more related to the utilitarian value, for example, the relevance of the information presented in the training (category 5), after the deeper data analysis appear to have more hedonistic dimension than it could be expected. We draw this conclusion as the informants mentioned a lot how ‘interesting’, ‘exiting’ and ‘relevant’ the content of the programme is, yet at the same time there are no mentions regarding how it could be applied in the practice or how it would be useful in performance improvement further on. Same goes for other subcategories presented in Table 6 in italics: the evidence from the data analysis shows clearly, that those subcategories are much more related to the enjoyment of the process than to actual usefulness of the programme from the practical point of view.

Our findings show that the utilitarian approach to value that is the primary approach in the existing literature on KIBS (Aarikka-Stenroos & Jaakkola, 2012; Lessard, 2014) is not entirely compatible. The proportion of subjective, experience-based constitutes of value in the proposed model is indeed significant. We can even argue, that even though there we not enough evidence in current data set that subcategories 2a and 6a can also be categorised as hedonistic, those three categories also are potentially more leaning towards enjoyment or comfort *feeling*, than towards *practical value*. For example, there is evidence in the data that collecting knowledge on the experience of other practitioners (2a) is often related to re-assurance of one’s competence in the field (3b) and, therefore, is more connected to ‘*feeling doing the right thing’* or ‘*not being alone with this question*’.

Similar logic applies to the professional skills of the facilitator (6a) that has been marked by several informants as a critical component of value during the service delivery process. As customers often lack the competence to evaluate on the facilitator’s professionalism, they base their judgement on the structure of the programme (‘too long days’ or ‘suitable intensity’ or ‘good variety of methods’). That, in turn, is again more an element of subjective perception than of an evidence-based evaluation.

Based on this we could say, that only performance improvement (1, inc. 1a and 1b) and contact making for further co-operation (2c) express value-in-use (Grönroos, 2011). The other categories are leaning towards value-in-experience (Kukk & Leppiman, forthcoming). It shows how big role does experience play in the value shaping process in KIBS.

The second interesting finding of the research, which we also find critical in understanding the value-shaping process in KIBS, is the amount of responsibility that customer himself feels. Active involvement (subcategory 4a) is essential for the client in three out of four stages of the service. When analysing customer’s post-service reflections on the value we see clear evidence that he feels that the service would be more valuable if he would have contributed more effort to it.

Based on this statement, and also looking at the pattern presented in Table 6, we can assume, that active involvement (in other words contribution to the service process from the customer’s side) is closely related to motivation (category 3). Inspiring and motivating elements of the service could potentially increase the client's level of involvement in the process and, as a result, increase the perceived service value significantly. This finding confirms the importance of value co-creation in KIBS, that has earlier been described in marketing literature (Aarikka-Stenroos & Jaakkola, 2010; Leppiman 2010; Aarikka-Stenroos & Jaakkola, 2012; Heinola, 2012).

We also find, that the pattern of the dynamics of value construct in KIBS described above provides insight on why KIBS practitioners often face the situation where they fail to create the desired high value for the customer. The KIBS process is typically arranged in a way that service provider has close cooperation with the client during the first two stages of the service (Kukk et al., 2014). The purpose of such co-operation is to find out the particular needs and expectations of the customer and to create the tailor-made offering that would meet those needs and expectations precisely.

The results of our research show, that if the service is planned according to the expectations that the client states during the first two stages of the service, the result will not satisfy him when he evaluates the service during service execution and implementation of the results (stages 3 and 4). The data shows that customer evaluates the service based on a broader scope of (subjective) elements that he does not foresee at the beginning of the service process.

Those three key findings made based on current research provide significant insight on understanding value shaping process in KIBS and potentially as well in other types of services.

CONCLUSION

The value of a business service is a highly topical issue both for scholars and practitioners. Due to intangible nature of the offering, it is rather complicated to put a finger on what exactly shapes the result of customer's evaluation of the service. At the same time, it is a crucial question, as the answer to it would potentially provide the key to competitive advantage and sustainability of KIBS providers.

KIBS, such as training and consultation services, where the essence of the service can be described as purchasing the missing competence to solve an operational problem of the organisation, have one common feature: a significant informational imbalance between the service provider and service buyer. This imbalance concerns many blocks of information: information about client's situation and problems to be solved, professional competence, etc. But most importantly customer and provider don't have the same view of what makes the service valuable.

In the service-dominant logic of the economy, customer's perspective on value becomes the most important. Understanding this point of view is the key to the competitiveness of service provider. To perform with maximum efficiency provider needs to adapt to customer's needs and expectations and deliver accordingly. It seems (and previous research confirms this) that service provider does not always manage to meet the expectations of the client regarding the value.

Our study sheds the light on how does customer evaluate KIBS. After performing a 9-month long study of customer's perspective on KIBS value, we have made three general conclusions.

First of all, it is evident that construct of customer value is changing throughout the service process. At the beginning of the process, the client is very result-orientated and leans towards value-in-use as the central logic of value formation process. As the process of service delivery evolves much more experiential constitutes of value become important to the customer. To be more precise is not only about how *useful* the service is but also about how *pleasant* it feels to be receiving it. Even though after the service is completed, customer returns to evaluating the rational outcomes of service, the experience still continues to play a significant role in value perception.

Second, the customer feels that he also holds the responsibility for the service value. Value co-creation process is quite inevitable in KIBS, where the whole service offering is a result of the close cooperation between the service provider and customer. According to the results of our study, the customer does not see his contribution as a binding element of the service and expect all the value coming from the service provider. To the contrary: he feels that he has a significant role in value creation and is in the position to increase or decrease the value by his actions.

The third conclusion of the study is that the typical approach, where KIBS providers rely on the insights of customer's expectations gathered at the very beginning of service process, does not lead to value maximisation. The reason behind this is again the dynamics of value construct throughout the service. As service provider gathers the expectations in the first stage of the service, he manages to get an overview only of less than half of the elements that the client is going to base his evaluation of the service later on.

Those findings provide a significant amount of new information both for scholars and practitioners. The study contributes to the body of knowledge on service value, delivering new data on the KIBS value construct from the customer's point of view. It also highlights the importance of *experience* in shaping the value of a business service.

We suggest that further qualitative research could be performed to confirm the applicability of the suggested value construct in other types of KIBS. In addition to that, we propose a quantitative analysis to test the model suggested in the current article.

As for the practitioners – present study provides them with specific tips on organising the value co-creation process in KIBS to maximise the value. All three conclusions drawn from this research have practical applications for service providers in training and consultancy sector.

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The early growth and fall frost damage of poplar clones in Latvia

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Abstract. The early growth and frost damage of *Populus* spp. was studied in two sites. The height of 23 five-year-old poplar clones was measured in the central part of Latvia; and the early-fall frost damage of 19 one-year-old and two-year-old poplar clones were assessed in the eastern part of Latvia. The relation between the height growth and frost damage of 16 clones, which were common for both sites, was assessed. The phenologically dormant stage was denoted for three clones, among which two are collected across Latvia (the origin un-known; introduced in 1960s). All the other clones had trees with damaged leaves and two clones had stem damage. The height of the clones ranged from 273.3 ± 60.2 to 711.0 ± 32.0 cm. The 3 most productive clones (LV3, LV1 and LV4) significantly ($P < 0.01$) exceeded others, by 34 and 65% for height and biomass, respectively. The mean height of these clones was 649.0 ± 21.5 cm and stem biomass varied from 33.7 ± 4.2 to 55.0 ± 6.4 $t_{fresh} \cdot ha^{-1}$ (planting density 6,500 $trees \cdot ha^{-1}$). The clone had significant ($P < 0.01$) effect on the phenological stage, leaf and stem frost damage, as well as on the height and stem biomass. No relation ($P > 0.05$) between the frost damage of leaves and both tree height and stem biomass was found. The results suggest that fast-growing frost-tolerant clones might be selected.

Key words: height growth, height increment, biomass, frost damage, frost tolerance, short rotation coppice.

INTRODUCTION

A high productivity of the intensively grown *Populus spp*. has been reported (Heilman & Xie, 1993; DeBell et al., 1996; Scarascia-Mugnozza et al., 1997; Rae et al., 2004). It is strongly determined by genetics, and the growth and yield of the *Populus* clones substantially differs. A high number of *Populus* clones is introduced in the northern Europe (Karačić et al., 2003; Christersson, 2006; Karačić & Weih, 2006), mainly for the establishment of the plantations with the optimum (intended) rotation period of 5–10 to 20–30 years for biomass and solid wood production, respectively (Hynynen et al., 2004; Rytter & Stener, 2005; Tullus et al., 2012). For the last 15 years, substantial amount of *Populus* plantations has been established on abandoned agricultural land (Lazdiņš et al., 2010; Jansons et al., 2014) as well as in forest (Rytter et al., 2015). Nevertheless, poplars are suitable for biomass production also as the agricultural crop (Daugaviete et al., 2015; Smilga et al., 2015; Zeps et al., 2015).

High productivity of *Populus* hybrids is related to the prolonged vegetation period, in comparison to the parental species (Yu et al., 2001). Many of these hybrids can be grown beyond the natural range of their parents (Sykes et al., 1996). The growth cessation is affected by a complex of environmental factors, among which the increased photoperiod might delay the bud set if the clone is moved northward from the region of the genotype origin (Li et al., 2002; Ingvarsson et al., 2006; Kalcsits et al., 2009). Trees which are not acclimatised to the growing site could be damaged by cold injuries (Sykes et al., 1996). In the northern Europe, the severe frost damage of the introduced poplar clones has been reported (Ferm et al., 1989; Christersson, 1996; Ilstedt, 1996; Telenius, 1999; Karačić et al., 2003; Christersson, 2006; Pliura et al., 2014), linked with the decreased vitality and mortality of trees (Xiang et al., 1991; Diamandis & Koukos, 1992; Pliura et al., 2014). Frost damage has negative effect on the stem quality, e.g. formation of multiple leaders, deformed stem straightness, stem cracks (Verwijst et al., 1996; Christersson, 2006), which is important shortage for solid wood production. However, Schreiber (2012) have suggested that the potential benefits (biomass production) of northward transferred *P. tremuloides* outweigh the potential frost-related risks in western Canada. He has observed almost twice increased biomass for ten-year-old *P. tremuloides* clones which were transferred even 7° latitude to the north with no decrease of the survival rate (Schreiber et al., 2013). These clones showed delay of the leaf shedding and their frost hardiness was lower than that of the local origin clones; still it was sufficient to not experience the early-fall frost damage. Similarly, some, but not severe, adaptation problems for northward transferred poplar clones has been reported in Lithuania (Pliura et al., 2014).

The aim of the study was to assess the productivity and early-frost damage of the *Populus* clones in Latvia. We hypothesed that (1) the recently introduced clones are more productive, as a result of continuous breeding; but (2) the clones introduced in the 1960s (cuttings from mature trees collected across Latvia) are more tolerant to the frost damage due to the appropriate frost-tolerance of their parent trees.

MATERIALS AND METHODS

The study sites are located in the central and eastern part of Latvia, near Skrīveri (56°39′ N, 25°7′ E) and Kalsnava (56°41′ N, 25°58′ E), respectively. In Skrīveri, height of 23 *Populus* clones (Table 1; planting density c.a. 6,500 trees ha^{-1}) was measured after the second, third and fifth growing season. The clones (at least 30 cuttings from each) are planted in mono-clonal row-plots on flat area with similar growing conditions (former agricultural land) in spring 2001. The distance between the rows 2.2 m, between the trees within the row 0.7 m. Clones AF2, AF6, AF7 and AF8 are planted in 3 replications, all the other clones in 1–2 replications, distributed evenly and randomly over the site. After the first growing season, all clones with the exception of AF2, AF6, AF7 and AF8 were browsed by cervids to the ground level. These clones have additional measurements of height after the first and fourth growing season. Planting material (cuttings) from Skrīveri was used to establish clonal collection in Kalsnava in 2014 and 2015. In Kalsnava, the frost damage of 19 one-year-old and two-year-old *Populus* clones was assessed. The clones were planted in narrow spacing mono-clonal rows in nursery bed with no replications within small area. The terrain was flat, no frost-shelter were provided from any side of the site (open-field).

Table 1. The number of trees and origin of clones studied in Skrīveri (N_H and N_{ABG}) and Kalsnava (N_{FD-1} and N_{FD-2})

Clone	N_H	N_{FD-1}	N_{FD-2}	N_{ABG}	Origin of planting material
LV1	22	–	–	8	mix of 12 commercial poplar clones from Sweden (registration number KB-003, Swedish Forestry Agency); *Tacahamaca* section
LV3	22	10	2	10	
LV4	22	18	37	9	
LV5	17	29	2	6	
LV7	18	22	1	12	
LV9	17	27	2	9	
LV10	21	16	2	13	
LV11	18	21	27	11	
LV12	16	12	102	7	
LV14	21	–	43	13	
LVX	19	25	1	10	
AF2	72	27	–	–	Alasia New Clones, produced by ALASIA Franco Company, Italy; AF2 (*P. canadensis*), AF6 (*P. generosa* × *P. nigra*), AF7 (*P. generosa* × *P. canadensis*) and AF8 (*P. generosa* × *P. trichocarpa*)
AF6	55	28	–	–	
AF7	100	27	–	–	
AF8	122	29	–	–	
Max11	–	126	–	–	clone series from Germany; hybrids of *P. maximowiczii* and *P. trichocarpa*
Max24	–	191	–	–	
OP42	–	27	–	–	*P. maximowiczii* × *P. trichocarpa*
P0114	40	26	1	26	*Populus* × *woobstii* (R.I. Schröd. ex Regel) Dode; progenies (cuttings) of poplar trees collected across Latvia (Jansons et al., 2014)
POP1	14	–	–	2	progenies (cuttings) of poplar trees collected across Latvia; presumably *Tacahamaca* and *Aigeiros* sections, introduced (origin unknown) in 1960s (Saliņš, 1971)
POP2	20	–	–	10	
POP3	14	–	–	8	
POP4	15	14	–	14	
POP5	15	–	–	5	
POP6	13	–	–	10	
POP7	6	–	–	–	

N_H – number of trees measured for height after the fifth growing season;
N_{FD-1} – number of one-year-old trees, which have assessment of frost damage;
N_{FD-2} – number of two-year-old trees, which have assessment of frost damage;
N_{ABG} – number of trees used to develop the above-ground biomass equation.

The relation between height and frost damage of the 16 clones (common for both study sites) was assessed. In both sites, clones might be divided into groups, according to the origin of the used planting material. The clones of Swedish, Italian, German origin, as well as the clone OP42 are introduced recently, during the last 10 years. Clones collected across Latvia are progenies (cuttings) of the poplars that survived after introduction, most likely, in 1960s. Among them, clone P0114 has been tested and is registered as the forest reproductive material (Community Plant Variety Office, 2014). All the available information of the origin of planting material (region, species) is given in Table 1.

The frost event occurred in the beginning of October, 2015 (Fig. 1). From September 7th to October 6th, the mean of diurnal minimum and maximum temperatures were +8.0 and +17.8 °C, respectively. The temperature first dropped below zero at night to October 7th. From October 7th to 15th, the mean diurnal temperature ranged from –3.3 to +10.2 °C. The minimum temperature was –5.2 °C, recorded in October 12th.

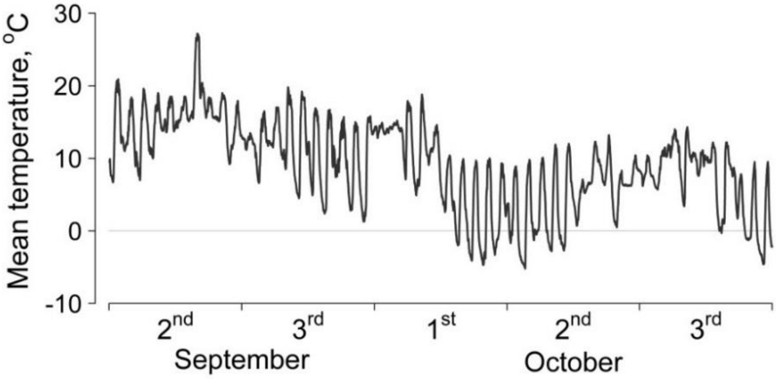


Figure 1. Temperature fluctuation (Δt = 15 min) for the period from the 2nd decade of September to the 3rd decade of October.

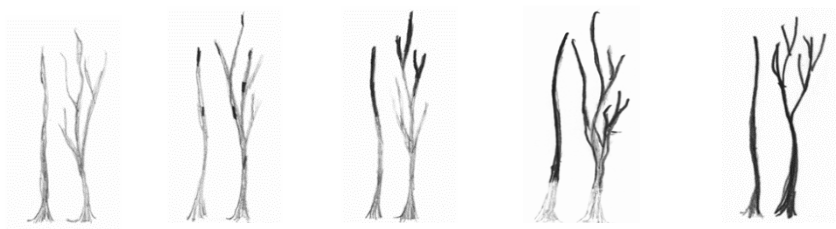
Damaged part	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
Canopy					
	intact leaves	several damaged leaves	damaged most leaves of current-year leading shoot	damaged most leaves of the whole tree	already fallen leaves
Stem and/or branches					
	intact stem	several stem injuries	damaged current-year leading shoot	damage of more than ⅓ of height	damage of whole stem

Figure 2. The schematic visualization of leaf and stem damage grades.

In October 15th, the visual frost damage was assessed (Fig. 2). The bud set was used to determine if trees were still in phenologically active stage or dormant. The damage of the leaves was evaluated at five grade scale. Grade 1_L ('intact leaves') corresponds to the visually intact leaves, Grade 2_L ('mild damage') to the several frost damaged leaves, Grade 3_L ('moderate damage') to the damage of most leaves in the current-year leading shoot and Grade 4_L ('severe damage') to the damage of most leaves of the whole tree. The Grade 5_L corresponds to the trees in the phenologically dormant stage, i.e. leaves were already fallen before the freezing-event and buds were set. Similarly, the damage of stem was evaluated according to five grades. The Grade 1_{ST} ('intact stem') corresponds to the visually intact stem, Grade 2_{ST} ('mild damage') to the several stem injuries, Grade 3_{ST} ('moderate damage') to the damaged current-year leading shoot, Grade 4_{ST} ('severe damage') to stem damage of more than ⅓ of height and Grade 5_{ST} to the damage of whole stem.

The effect of tree age on the frost damage was assessed at the individual tree level for 10 clones. Clone LV4, LV11 and LV12 had sufficient number of one-year-old and two-year-old trees, thus the distribution of number of trees among the grades of leaf and stem damage were assessed for only these clones.

The fresh above-ground biomass in the leafless stage was calculated by Equation 1. This equation is developed based on the biomass measurement of randomly selected ramets (number by clone is shown in Table 1) in Skrīveri after the fourth growing season (height range from 159 to 546 cm).

$$ABG_{fresh} = 10^{-6} \cdot H^{2.7759}, \quad (1)$$

where: ABG_{fresh} – fresh above-ground biomass in leafless state, kg; H – tree height, cm.

To model potential productivity of different clones at the stand level (6,500 trees ha^{-1}), three assumptions of the tree recovery were made: (1) the undamaged trees (Grade 1_L and 1_{ST}) and trees with the several frost damaged leaves (Grade 2_L) have no biomass reduction; (2) trees with the damage of most leaves in the last-year leading shoot (Grade 3_L) or with the several stem injuries (Grade 2_{ST}) have biomass reduction by 20%; (3) trees with the more severe damage (Grade 4_L and 5_L of leaf damage and/or Grade 3_{ST}–5_{ST} of stem damage) experience mortality. These assumptions are not tested, therefore the results are used only to illustrate the potential effect of the frost injuries.

The Shapiro-Wilk test was used to assess the normality of the data. The one-way analysis of variance was used to assess the differences of the height among the clones. The Kruskal-Wallis test was used to assess the differences of the biomass among the clones. The generalized linear model multivariate was used to assess (1) the effect of the clone and age on the phenological stage and level of leaf and stem damage and (2) the effect of the mean grade of leaf and stem damage on the tree height and biomass. The Chi-squared test was used to assess the distribution of the number of damaged trees of clones LV4, LV11 and LV12 among the grades of leaf damage and within the one-year-old and two-year-old trees. All tests were performed at $\alpha = 0.05$. All calculations were done in R 3.0.2. (R Core Team 2013).

RESULTS AND DISCUSSION

In total, 65.4% of trees were in the active phenological stage. All trees in the phenologically dormant stage were found for clones P0114, POP4 and LV10 (Table 2). All trees still growing were denoted for 10 clones, while 6 clones had trees in both phenological stages. The significant ($P < 0.01$) differences of phenological stage that were found between clones are in accordance with the moderate to strong genetic control of the bud set of *Populus spp*. (Hall et al., 2007; Rohde et al., 2011), and the variation of bud set timing may show high (up to ca. 100 days) differences between clones of different origin (Howe et al., 2000; Christersson, 2006; Friedman et al., 2008). The perennial plants in temperate and boreal zone are adapted to the seasonal cycle of the growth and winter dormancy (Howe et al., 2003; Rohde & Bhalerao, 2007). In our study, surviving clones from the earlier introduction (locally collected) demonstrated better fit to environment.The timing of the bud set is an important adaptive trait (Hänninen et al., 1990). At first, growth cessation is induced by decrease of day-length and temperature, than cold acclimation, endodormancy occurs and, finally, plants reach the maximal cold hardiness. Genotypes transferred northward delay the bud set mainly due to the longer daylight, while the genotypes transferred from the northern areas (or high elevations) tend to set bud earlier in the fall, than trees from the local populations (Weber & Stettler, 1985; Skrøppa & Magnussen, 1993).

Table 2. The number of trees according to phenological stage and leaf and stem damage grades

Clone	Phenological stage		Leaf damage Grades					Stem damage Grades					Total
	Dormant	Active	1_L	2_L	3_L	4_L	5_L	1_{ST}	2_{ST}	3_{ST}	4_{ST}	5_{ST}	
AF2	–	27	–	10	17	–	–	27	–	–	–	–	27
AF6	–	28	3	12	13	–	–	28	–	–	–	–	28
AF7	–	27	–	3	24	–	–	27	–	–	–	–	27
AF8	–	29	–	10	19	–	–	29	–	–	–	–	29
P0114	27	–	–	–	–	–	27	27	–	–	–	–	27
POP4	14	–	–	–	–	–	14	14	–	–	–	–	14
LV10	18	–	–	–	–	–	18	18	–	–	–	–	18
LV11	–	48	21	13	14	–	–	48	–	–	–	–	48
LV12	13	101	33	34	4	30	13	114	–	–	–	–	114
LV14	–	43	–	–	43	–	–	23	20	–	–	–	43
LV3	1	11	–	1	–	10	1	10	1	–	1	–	12
LV4	–	55	42	11	1	1	–	55	–	–	–	–	55
LV5	30	1	–	–	1	–	30	31	–	–	–	–	31
LV7	–	23	–	–	–	23	–	23	–	–	–	–	23
LV9	–	29	11	17	–	1	–	29	–	–	–	–	29
LVx	5	21	–	–	–	21	5	26	–	–	–	–	26
Max11	59	67	–	–	–	67	59	126	–	–	–	–	126
Max24	143	48	–	–	5	43	143	142	49	–	–	–	191
OP42	–	27	–	–	1	26	–	27	–	–	–	–	27

Out of the assessed 585 trees, 81% had damaged leaves at various grades (Table 2). Among the actively growing trees, four clones (LV3, LV7, LVX and OP42) had a high proportion (> 80%) of trees with the severely damaged (Grade 4_L) leaves. Clone LV4 showed the highest frost resistance – 76% of trees had intact leaves (Grade 1_L). Similarly, Howe et al. (2000) have reported significant differences and a wide range of the frost damage among clones: in the scale of 10, the least-square means were from –0.8 to 9.5. The frost damage of stem was less common (Table 2). Among the dormant trees, clone LV3 had one tree with the mild stem damage (Grade 2_{ST}). The high susceptibility of stem frost damage was denoted for clones Max24 and LV14, which had 87% and 100% of still growing trees mildly (Grade 2_{ST}) damaged, respectively. The severe (Grade 4_{ST}) stem damage was denoted for one tree (clone LV3). These results confirm that trees that set buds later in the fall are more susceptible to the frost damage (Junttila & Kaurin, 1990; Howe et al., 2000).

The tree age had significant ($P < 0.01$) effect on the level of damaged leaves, but not on the stem damage ($P > 0.05$) at individual tree level. Significant ($P < 0.01$) differences were found also among the clones of the same age. All trees from clones LV4 and LV11 were in the active phenological stage, regardless of the age (Table 2). Also all two-year-old trees and most (87%) of the one-year-old trees from clone LV12 were active. For these three clones, no stem damage was denoted but the damage of leaves differed significantly ($P < 0.01$) between trees of different age. Within clones LV4 and LV11, all two-year-old trees were intact (Grade 1_L) while one-year-old trees were damaged (Grade 2_L and 3_L). In contrast, within clone LV12, most of the two-year-old trees were damaged severely (Grade 4_L) but one-year-old trees had milder damage (Grades 3_L and 4_L). Younger and, consequently, shorter trees might be more damaged by frost. First, a number of physiological changes, including these which are regulating bud activity, are related with maturation (Brunner et al., 2003; Rozi et al., 2010). For instance, the spring phenology of five temperate tree species was found to be ontogenetically determined rather than result from microclimate (Vitasse, 2013). The ontogenetic effect has also been indicated by increased susceptibility to frost damage of one-year-old *Populus* × *rasumowskyana* shoots that were emerged after the coppicing in the south-western Finland (Ferm et al., 1989). Younger trees tend to emerge leaves earlier than adults (Vitasse et al., 2014), therefore have higher probability to suffer from early spring frosts. However, similar freezing resistance has been observed for leaves at the same developmental stage for seedlings and saplings (< 0.3 m and 2–4 m height, respectively) in comparison to adult trees (25–30 m height) for several temperate broadleaved species during the leaf-flushing (Vitasse et al., 2014). Also the cold hardiness was found to increase with age, and show significant differences between the adult individuals and trees in the juvenile stage for a number of deciduous species (Lim et al., 2014; Hofmann et al., 2014). Second, smaller trees are more exposed to frost. Relatively larger part of smaller trees is located near the ground, where, in open sites, the air temperature is the lowest (Snyder & Melo-Abreu, 2005). For instance, in the southern Sweden in clear-cut area during three growing seasons the observed mean difference between the minimum temperatures in 0.4 and 1.7 m height was 1.6 °C, reaching maximum difference of 3.8 °C (Langvall & Ottosson-Löfvenius, 2002). Consequently, shorter stands have higher probability of frost damage than taller stands. Moreover, the commercial plantations are commonly established on agricultural lands, often situated in open fields. This could lead to uneven distribution of damaged trees within the plantation – heavier damage nears the edge of plantation and less damaged trees in the centre of it or in the border with mature forest where mutual shield is provided (Verwijst et al., 1996).

After the bud set, i.e. phenologically dormant trees, are more tolerant to the frost damage (Junttila & Kaurin, 1990; Frewen et al., 2000; Howe et al., 2000), but too early bud set interferes with the growth and these trees tend to be shorter (Li et al., 1993; Howe et al., 2000).Thus, the trade-off between utilizing the full growing season and the proper frost-tolerance might occur. However, the frost injury depends on the frost event occurrence and severity. For instance, no frost damage of the clones AF2, AF6, AF7 and AF8 were observed during the first three years in Skrīveri (Lazdiņa et al., 2014). But in the study year, 97% of these trees had mild and moderate (Grade 2_L and 3_L, respectively) damage of leaves (Table 2).

The height growth showed temporal differences among the clones (Fig. 3). After the second growing season, the best results were demonstrated by clones AF6, LV3 and LV12: 159.5 ± 10.5, 154.3 ± 14.2 and 143.9 ± 8.5 cm, respectively. The significant ($P < 0.01$) differences between the clones were found, mostly caused by the superiority of clone AF6 and slow growth of clones POP1, POP2 and POP6. It should be noted that most of the other clones had similar or higher height as clones AF2, AF8 and AF7, regardless of the browsing at the end of the previous growing season. This indicates sprouting ability and vigorous growth due to the established root system (Christersson, 1986), and this advantage foster the yield of the second rotation to exceed yield of the first rotation (Dillen et al., 2013). The height differences between clones increased with age. After the second growing season 80 significantly different pairs between clones were found, after the third season 124, while after the fifth growing season this number increased to 169. After the fifth growing season, the height of clones ranged from 273.3 ± 60.2 to 711.0 ± 32.0 cm, and most of the clones LV exceeded those collected in Latvia, as well as AF2, AF7 and AF8. Each of the three highest clones (LV3, LV1 and LV4) was significantly higher than most of the other clones (Fig. 3). The height of these clones was 649.0 ± 21.5, exceeding ($P < 0.01$) others by 34%. The same three clones had the highest biomass and exceeded others by 65%. The fresh above-ground biomass of clones LV3, LV1 and LV4 was 8.47 ± 0.99, 6.40 ± 0.88 and 5.19 ± 0.64 kg (Fig. 4). The corresponding biomass (planting density 6,500 trees ha^{-1}) of these clones was 55.0 ± 6.4, 41.6 ± 5.7 and 33.7 ± 4.2 t_{fresh} ha^{-1}, respectively. In comparison, the mean above-ground biomass of the other clones was 14.8 ± 0.7 t_{fresh} ha^{-1}. The mean biomass increment of the three most productive clones was 8.7 ± 0.7 t_{fresh} ha^{-1} $year^{-1}$.

The relatively high genetic control of bud set indicates the relatively low microenvironmental effect (Howe et al., 2000). Hence, the relation of growth and frost-tolerance of the same clones in different sites was analysed. Similar (both $P > 0.05$) height and above-ground biomass of clones was found, regardless of the mean grade of leaf damage. In contrast, significant ($P = 0.049$ and $P = 0.026$, respectively) positive relation between both height and biomass with grade of the stem damage was found. This was caused by clones LV14 and LV3 – relatively high and productive clones that had 46.5 and 16.6% of trees with stem damage (Table 2), respectively. The trade-off between growth and bud set is reported by some authors that have noted the tendency of the clones that set bud early to be shorter than others (Li & Adams 1993) and the other way around – trees that set buds later to be higher and have larger diameter (Pliura et al., 2014). Our results are consistent with this belief, regarding the negative effect of stem damage on tree height and biomass. In contrast, no support to the trade-off was showed by similar level of leaf damage. It should be kept in mind,that the relations between clonal means are demonstrated and further studies should be done to assess these relations at the individual tree level.

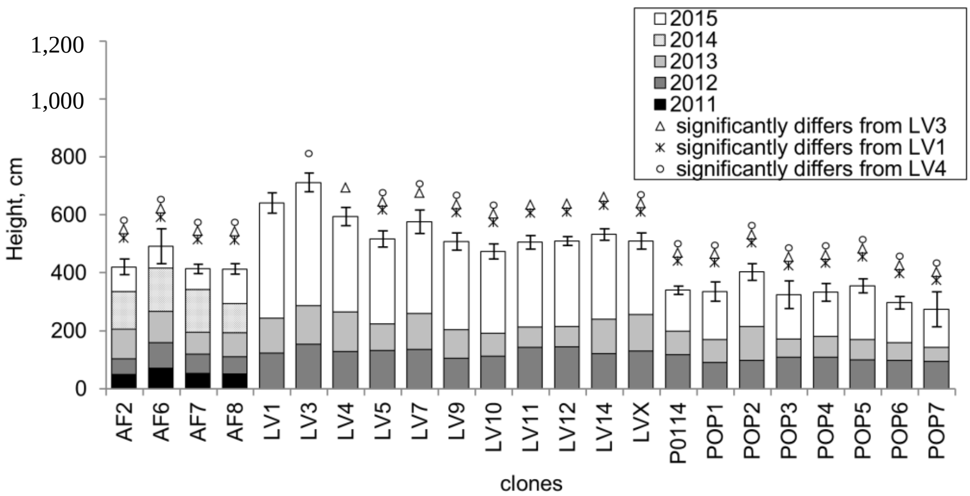


Figure 3. Height of clones after the first to fifth growing season and the confidence interval of height after the fifth growing season. The significant differences of the height after the fifth growing season between the three best (LV3, LV1 and LV4) and the other clones are denoted by symbols.

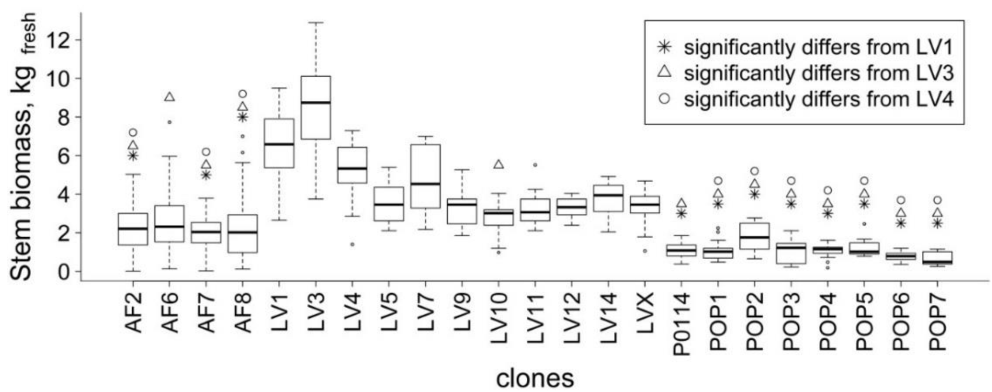


Figure 4. Fresh above-ground biomass of clones in the leafless stage. The significant differences of biomass between the three best (LV3, LV1 and LV4) and the other clones are denoted by symbols. Line shows median, box represents 1st and 3rd quartile, whiskers mark range (not exceeding 150% of interquartile distance) and circles denote outliers of the datasets.

The cold-resistance up to –70º C of the *Populus* species have been reported (Friedman et al., 2008). However, the mortality caused by the cold-injuries is possible if trees are not completely hardened and the sudden drop of temperature occurs (Friedman et al., 2008). Strong negative correlation between the fall frost damage and winter survival has been noted for poplars (Howe et al., 2000), as well as the changes of allometry (lower shoot weight) after the spring frost damage for one of two assessed

Salix hybrids during the first year after the coppicing (Verwijst et al., 1996). The heaviest damaged stand parts had biomass reduction in comparison to undamaged parts for both assessed clones by 47 and 60% (Verwijst et al., 1996). Similarly, Ilstedt (1996) has reported the dieback of ca. 20–60 cm of leading shoots after the fall frost at the age of 2–4 years for most of the poplar hybrid clones that where transferred as far as 10° latitude from the origin of the parental species. The dieback of up to one meter long leading shoot of some 2–3 years old poplar hybrid clones during the winter has mainly resulted with tree death, while other clones had experienced 10–20 cm long shoot dieback and successfully recovered (Christersson, 2006). Dieback of up to three meters long leading shoots of 11-year-old trees (height more than 20 m) were recorded due to the severe winter in 2001–2002 (Christersson, 2006). At the age of 13 years, 15% of the clones were dead due to the frost damage (Christersson, 2006). Nevertheless, frost damage may have indirect negative effect – decreased tree vitality, increased susceptibility to diseases and reduced wood quality. Therefore, we assumed that damaged trees might have biomass reduction, depending on the grade of damage. According to our assumptions (see Materials and Methods), the highest above-ground biomass reduction due to the frost damage caused mortality was expected for clones LVX, LV3 and LV7 (Fig. 5). The potential mortality of these clones resulted in biomass reduction by 80.8, 93.3 and 100%, respectively. Moreover, the clone LV3 would have the absolutely highest above-ground biomass if no frost damage would occur. The loss of biomass of the other clones varied from 0.6 to 29.3%. No biomass reduction was expected for clone P0114, POP4 and LV10. Yet, appropriate frost-tolerance of locally collected clones does not result in higher yield, in comparison to less frost-tolerant but more productive recently introduced clones at the particular frost-event. Further tests in different conditions and age need to be carried out for more comprehensive conclusions.

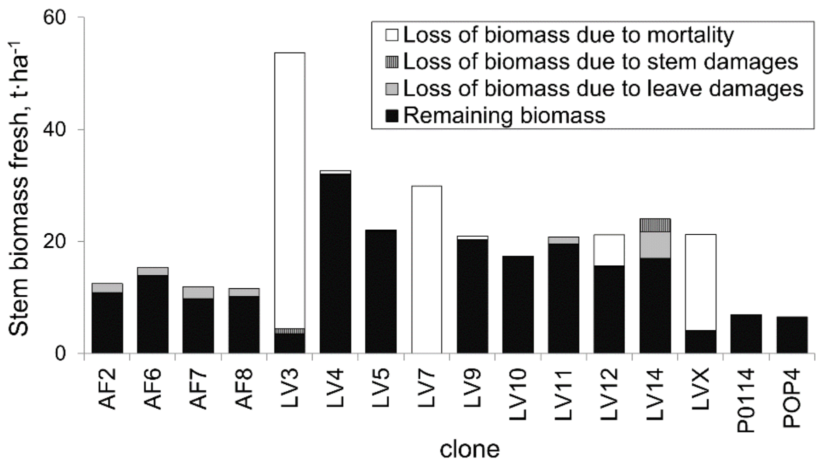


Figure 5. Potential (modelled) loss of the fresh above-ground biomass in the leafless stage (planting density 6,500 trees ha^{-1}).

Authors are aware that the assumptions placed in the model might not hold. Poplars have good regeneration ability after damage, as demonstrated by results (height growth) after the first-year browsing damage (Fig. 3), and also concluded by other studies (Mulak et al., 2006; Hamberg et al., 2011; Myking et al., 2011). For instance, 'soon recovery' after fall frost damage has been reported for northward transferred cuttings at the age of 2–4 years in the southern central Sweden (Ilstedt, 1996). Moreover, the frost damage could occur only in the frost years; while, in the absence of fall frost, trees might gain due to the prolonged growing season.

CONCLUSIONS

Frost injuries might result in noticeable biomass reduction and mortality of the most productive clones. Hence, the assessment of productivity, frost-tolerance and their interaction ensures valuable information for further clone tests. Clone had significant (all $P < 0.01$) effect on the phenological stage, leaf and stem frost damage, height and biomass. Our hypothesis was confirmed. Clones (cuttings) which are introduced in the 1969s were less frost-damaged than these which are introduced recently. However, the latter were superior in height and the above-ground biomass production (in the leafless stage). The significant ($P < 0.05$) trend of more stem damage for more productive clones was found. In contrast, the frost damage of leaves had no effect on both tree height and biomass (both $P > 0.05$). Therefore, the results suggest that fast-growing and frost-tolerant clones at the particular age could be selected.

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Fertilizer use efficiency impact on GHG emissions in the Latvian crop sector

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Abstract. Within increasing production activity Latvian agricultural sector has become one of the main sources of greenhouse gas emissions (GHG) in Latvia. In 2013, agricultural sector contributed 21.0% of the total GHG emissions originated in Latvia (2310.1 Gg CO_2eq). Analysis of agricultural GHG emissions by sources shows that direct N_2O emissions from agricultural soils through the usage of synthetic fertilizers are one of the most significant GHG source in Latvia. The usage of synthetic fertilizers is one of the most common widespread agricultural practices in Latvian cropping systems and according to statistical data usage of synthetic fertilizers is constantly increasing, for example, in 2013 it increased by 6.9% if compared with 2012. Taking into account that over-fertilization can lead to negative economic and environmental consequences, such as high production costs, depletion of energy resources, and increased GHG emissions, this research aims to estimate how effective usage of synthetic fertilizers are in Latvian crop farms. In order to achieve the set aim an N fertilizer usage were estimated in four crop farms by giving insight into N balance and N use efficiency (NUE) rate in these farms. Research results suggest that improved N efficiency can be selected as GHG mitigation measure as it reduces N surpluses and the use and production of mineral fertiliser while maintaining yield levels. It was also concluded that improved N efficiency reduces direct N_2O emissions from fertilized soils and indirect N_2O emissions that occur by the release of NH_3.

Key words: GHG, emissions, nitrogen use efficiency, Latvia.

INTRODUCTION

The agricultural sector has historically been the main provider of economic activity in Latvian rural areas. In 2015 32% of total Latvian population have been living in rural areas and for the major part of it agriculture provides employment opportunities – in 2015 agricultural sector provided workplace for 5.2% of the total employees in the country. Agricultural output data shows that Latvian agricultural sector year by year becomes more competitive and stronger player in the global markets. However, within increasing production activity Latvian agricultural sector has become one of the main sources of greenhouse gas emissions (GHG) in Latvia. In 2013, agricultural sector contributed 21.0% of the total GHG emissions originated in Latvia (2310.1 Gg CO_2 eq).

Analysis of agricultural GHG emissions by sources shows that direct N_2O emissions from the agricultural soils through the usage of synthetic fertilizers are the most significant GHG source in Latvia.

The Latvian agriculture has achieved marked progress with regard to cereal production over the past decade. Such an increase is the result, at least in part, of increased application of N fertilizers. The usage of synthetic fertilizers is one of the most common widespread agricultural practices in Latvian cropping systems and according to statistical data usage of synthetic fertilizers is constantly increasing, for example, in 2013 it increased by 6.9% if compared with 2012. Cereals: wheat (winter and summer), rye, barley, oats and triticale consume approximately 80% of the total N used as fertilizer. However, only 30–50% of this applied N is recovered by crop plants (Cassman et al., 2002). For example, NO_3 – N is easily lost from agricultural areas by leaching (Puckett et al., 1999), and high levels of NO_3 – N losses can reduce nitrogen use efficiency (NUE). While N losses cannot be avoided completely, there is certainly a scope to minimize losses with precision N management techniques and technologies. Current situation in Latvia showing fertilized cropland area, amount and rate of used N fertilizers and N_2O emissions are summarized in the Table 1.

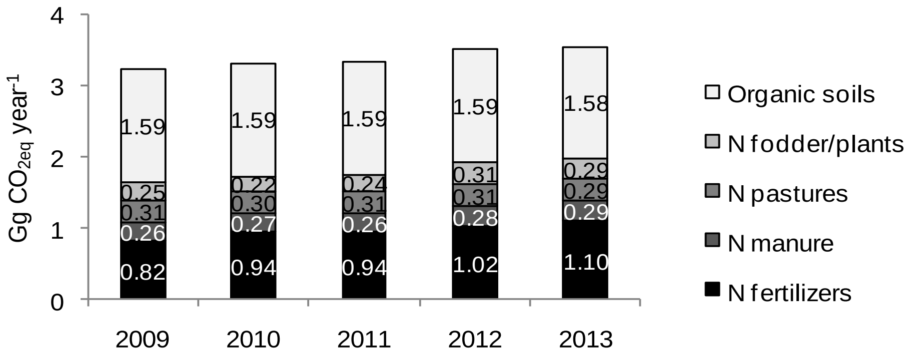
Table 1. Fertilized cropland area, amount and rate of used N fertilizers and N_2O emissions in Latvia, 2014

Type of crop	Area, thous ha	N, thous t	N application rate, kg ha^{-1}	N_2O emissions kg ha^{-1}
Cereals	511.70	57.90	113.15	1.78
Potatoes	13.80	0.80	57.97	0.91
Industrial crops	87.70	10.50	119.73	1.88
Vegetables	5.90	0.30	50.85	0.80
Fodder crops	69.40	3.10	44.67	0.70
Total	688.50	72.60	X	X

Source: authors' calculation after data from Central Statistical Bureau of Latvia

In Latvia fertilized cropland area in 2014 has reached 688.50 thous ha, which if compared with 2009 has increased by 23%. Within cropland area increases although N application rate has increased by 16% reaching 113.15 kg ha^{-1} in 2014. N fertilizer use has contributed to the total growth of N_2O emissions from Latvian agricultural soils (Fig. 1).

In 2013 managed organic soils formed the major part of total N_2O emissions (44.7%) following by emission from application of N fertilizers (30.9%). The N fertilizer use emissions over the last five years have increased by 25% reaching 1.1 Gg CO_{2eq} y^{-1}. Such situation analysis let us presume that in order to reduce negative impact on the environment in Latvia special attention should be paid on effective use of N fertilizers which can be expressed in such term as nitrogen use efficiency (NUE). The NUE for cereal production can be defined from the interplay of the following three different approaches: *economic* - to reduce N fertilizer application costs; *agronomic* – to maintain and increase crop yields without worsening soil qualitative indicators; *environmental and ecological* - to reduce the losses of N fertilizers and the N_2O emissions into the environment produced by the N fertilizers.



Source: authors' calculations after Latvia's National Inventory report, 2015

Figure 1. Main sources of N_2O emissions (Gg CO_{2eq} y^{-1}) in Latvia, 2009–2013.

Taking into account such considerations this research aims to estimate how effective usages of synthetic fertilizers are in Latvian crop farms. In order to achieve the set aim an N fertilizer usage were estimated in four crop farms by giving insight into N balance and N use efficiency (NUE) rate and its correlation with GHG emissions in these farms. It should be noted that in this study the NUE was used as an agro-environmental indicator (Johnston & Poulton, 2009), which is a well-known approach and commonly used in the agro-policy context (Brentrup & Palliere, 2010). From this perspective NUE can be calculated as the ratio between the amount of N removed by the crop and the amount of N fertilizer applied (Kārkliņš & Ruža, 2013).

MATERIALS AND METHODS

This study is part of a broader research aiming to assess the agricultural sector GHG emissions reduction potential and it represents initial findings about current situation in case studies of 4 crop farms in Latvia. To achieve the set aim and tasks of the research, the authors have used the publications and studies of foreign scientists, statistical data from the Central Statistical Bureau of Latvia. The research authors have widely applied generally accepted research methods in economics, i.e. monographic descriptive method as well as analysis and synthesis methods to study the problem elements.

However, primary data source in this research were case studies carried out in 4 agricultural farms in Latvia in 2014. The main aim of these case studies was to collect specific data, like land use, cropland management and fertilization practices, necessary for estimating GHG emissions from farming practices. These farms were selected on the basis of cluster analysis made in previous research (Naglis-Liepa et al., 2015) that shows that Latvian agricultural farms can be divided in four different clusters. In these case studies were selected farms representing large-scale intensive crop production farms, which is quite small in terms of number of farms, but impressive in terms of output.

Description of farms

In order to meet the set tasks of the study 4 crop farms in Latvia were surveyed. These farms can be characterized as very large and intensive grain production farms where utilized agricultural area comprises from 443 till 1,313 ha. These farms focus mainly on wheat (summer and winter), barley, as well as rape (mainly winter rape) production. However, yields of different crop cultures, if compared between farms, differs quite significantly (Table 2), which could be important factor when estimating N use efficiency at farm scale.

Table 2. Characteristic indicators of surveyed crop farms in Latvia, 2014

Indicator	Farm A	Farm B	Farm C	Farm D
Total UAA area, ha	530	443	801	1,313
Area of crop cultures, ha				
Winter wheat, ha	226	333	79	259
Summer wheat, ha	119	-	340	346
Summer barley, ha	95	145	185	226
Field beans, ha	28	-	38	30
Winter rape, ha	118	14	33	143
Summer rape, ha	-	-	99	-
Rye, ha	-	-	-	139
Potatoes, ha	-	-	-	131
Yield of crop cultures, t ha^{-1}				
Winter wheat, t ha^{-1}	6.5	5.8	5.0	3.1
Summer wheat, t ha^{-1}	4.5	-	7.1	5.0
Summer barley, t ha^{-1}	3.0	5.9	6.4	4.2
Field beans, t ha^{-1}	3.0	-	6.5	3.1
Winter rape, t ha^{-1}	3.0	2.9	1.8	1.0
Summer rape, t ha^{-1}	-	-	2.7	-
Rye, t ha^{-1}	-	-	-	6.1
Potatoes, t ha^{-1}	-	-	-	40.0

Source: authors' summarization after survey results.

Calculation of nitrogen balance and NUE rate

In this research fertilizer use efficiency were assessed using two different agro-environmental indicators – nitrogen balance and nitrogen use efficiency (NUE) index.

The N balance is already an established OECD indicator (OECD, 2008). It shows the difference between N inputs (fertilizer, manure etc.) and N outputs (arable, permanent and fodder crops) and in this research was expressed in kg N per hectare. Nitrogen balance has been widely acknowledged (Ribaudo et al., 2011) as key for improved nitrogen use efficiency and reduced risk of nitrogen losses on the farm. Nitrogen balance informs farmers about their degree of nitrogen utilisation and help to identify the risk of nitrogen leaching and other losses from the field and the whole farm. The work with nitrogen balance provides important information for improved fertiliser planning and improved farm finances.

A positive or surplus balance means that less nitrogen have been taken out of the field with the harvest than have been added e.g. in the form of fertilisers. Some of the nitrogen that left in the field will contribute to the build-up of soil organic and inorganic matter, but they may also contribute to an increased risk of nutrient leaching. A significant surplus is also economically unprofitable. In contrast, if the balance is negative or in deficit, more nutrients have been taken from the field than have been added. If the balance is negative for a long time, soil fertility will be weakened, which in turn will reduce possible yields. The ideal situation is for the nutrient uptake of plants and the supply by fertilisation to be in balance and the value of the field balance to be close to zero.

In the context of this research nitrogen balance were calculated using Eq. 1:

$$N_{balance} = \frac{N_i - N_o}{A} \tag{1}$$

where: N_i – total nitrogen input (kg); N_o – total nitrogen output (kg); A – utilized agricultural area (ha).

Total nitrogen output, i.e. nitrogen removed with crops, N_o was calculated using Eq. 2 (Kārkliņš & Ruža, 2013):

$$N_o = O_p + (O_b \times RA) \times F \tag{2}$$

where: O_p – N recovered in product (kg); O_b – N recovered in by-product (kg), RA – product and by-product ratio; F – production yields (kg ha^{-1}).

Total nitrogen input N_i was calculated using Eq. 3:

$$N_i = I_s + I_m + I_f + I_{fix} \tag{3}$$

where: I_s – N content in seeds (kg); I_m – N content in manure (kg); I_f – N content in fertilizer (kg); I_{fix} – N fixation with legumes (kg).

With a nutrient balance, it is easy to review the flows of nutrients to and from the farm. Thus nitrogen balance has been identified as a principal agro-environmental indicator that provides information on the potential loss of N to the air and to surface or groundwater. For example, in Nordic conditions and in the UK, a decrease in N balance of 10 kg N ha^{-1} year^{-1} implied a decrease in measured N runoff of 1.5–5.7 kg N ha^{-1} year^{-1} (Salo & Turtola, 2006).

The second parameter that where calculate was N use efficiency which is a critically important concept in the evaluation of crop production systems. It can be greatly impacted by fertilizer management as well as by soil, plant and water management. The objective of N use is to increase the overall performance of cropping systems by providing economically optimum nourishment to the crop while minimizing N losses from the field. NUE addresses some, but not all aspects of that performance. Therefore system optimization goals necessarily include overall productivity as well as NUE. The index NUE gives the ratio of output N to input N indicating how well the given N-management strategy performs in recovering the applied N. The national and regional

NUE values may reflect the particular mix of farming systems within those areas. NUE is calculated using Eq. 4 (Drechsel et al., 2015).

$$NUE = \frac{N_o}{N_i} \tag{4}$$

where: N_o – total nitrogen output, i.e. nitrogen removed with crops (kg); N_i – N fertilizer applied to crops (kg).

A complication of NUE estimates is the consideration of crop rotations. Where wheat and legumes are rotated on the same field annually, for example NUE would have to be calculated for a two-year rotation cycle in order to account for the N inputs from legumes in one year that could remain as inputs to the wheat crop the follow year. Where longer and more complex crop rotations are employed NUE estimates would need to consider the whole crop cycle and not just crops in isolation. When NUE = 1, the amount of nutrient removed equals the input of N. When NUE < 1, more N is being applied than is being removed, and the N not removed could either be stored in the soil and/or flow through to the environment causing ecosystem degradation. When NUE > 1, more N is being removed than is being supplied, which indicates that the soil is being mined of nutrients, eventually depleting soil fertility (Norton et al., 2015). NUE index values for winter wheat are summarized in Table 3.

Table 3. NUE of different mineral fertilizer application rates in a long-term field trial with winter wheat

N_i (kg N ha^{-1})	N_o (kg N ha^{-1})	NUE	Interpretation
0	26	-	Soil over-fertilization
48	56	1.16	Soil over-fertilization
96	92	0.96	Risk of soil over-fertilization
144	126	0.88	Balanced in- and outputs
192	151	0.79	Balanced in- and outputs
244	166	0.69	Risk of high N losses

Source: Brentrup, 2004.

Countries with intensive agriculture such as US, Germany, UK and Japan generally show increasing NUE as a result of stagnant or even decreasing N use and increasing crop yields (Drechsel et al., 2015).

Calculation of N_2O emissions

Nitrous oxide (N_2O) emissions for surveyed crop farms were calculated following the IPCC (2006) guidelines at Tier 1 level. According to the IPCC guidelines for calculation of N_2O emissions from agriclultural soils equation (5) were used:

$$N_2O_{SNDirect} - N = \left[N_2O - N_{Ninput}\right] = \mathrm{F_{SN}} \cdot EF \tag{5}$$

where: $N_2O_{SNDirect}$–N – direct emissions from mineral fetilizers used in crop farming (kg N_2O–N year^{-1}); F_{SN} – mineral fetilizers used in crop farming (kg N year^{-1}); EF – emission factor for direct N_2O emissions from mineral fertilizers (kg N_2O–N kg^{-1}).

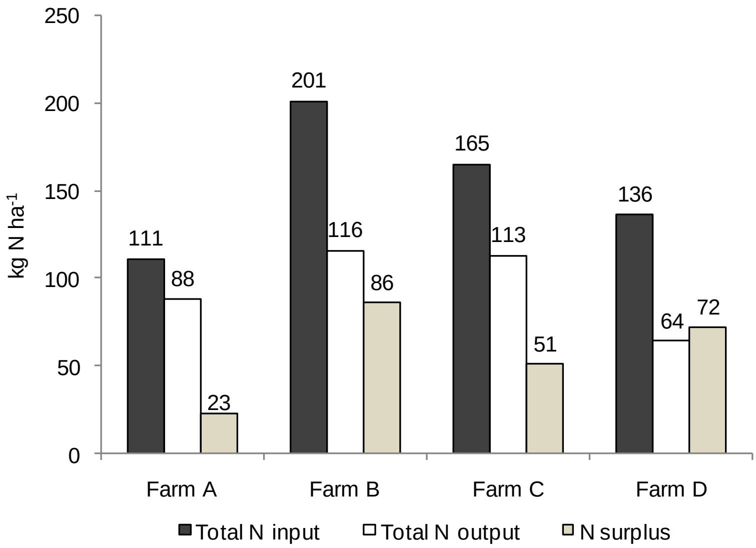
Calculated N_2O–N emissions from used fertilizers were converted in N_2O emissions after equation (6):

$$N_2O = N_2\text{O - N} \cdot \frac{44}{28} \qquad (6)$$

RESULTS AND DISCUSSION

Nitrogen balance

Taking into account that direct and indirect N_2O emissions were among main GHG emissions sources in the all surveyed farms and that primary reason for N_2O release from cultivated soils are N inputs by mineral fertilizers, analysis of N balance were performed. The total N input from synthetic fertilizer, organic fertilizer and crop residues at the surveyed farms varied between 111 and 201 kg per ha per year (Fig. 2).



Source: authors' calculations

Figure 2. Nitrogen annual flow in the surveyed Latvian crop farms (kg N ha^{-1}), 2014.

The highest N surpluses were found in Farms B, C and D, respectively 86, 51 and 72 kg N ha^{-1}, indicating that in these farms N losses to the environment through N_2O emissions could occur as each kilogram of N fertilizer results in 0.016 kg N_2O emissions. It means that more attention should be paid on the improvement of N management. Results summarized in Figure 2 also shows that in Farm A there can be observed almost balanced usage of N fertilisers as N surplus is 23 kg N ha^{-1} thus showing that in this farm nutrient-efficient farming by minimization of nutrient losses to the environment while ensuring the necessary nutrient supply to crops can be observed.

From such obtained results it can be concluded that fertilisation planning is essential to obtain the best balance of economic and environmental benefits in each farm as lack of certain plant nutrients, in the case of this research it is nitrogen, can reduce plant growth and lower yield, but surpluses can be costly both from an environmental and an economic perspective. In order to provide effective farming practice crop fertilization plans should be developed for all farms that use fertilizers in crop cultivation. Currently in Latvia crop fertilization plans are mandatory for those farms that are located in nitrate vulnerable zones and uses 20 ha or more of agricultural land, but for horticulture vegetable growing farms – 3 ha or more of agricultural land, and since 2015 fertilisation planning is obligatory for those farmers who uses professional plant protection products.

N use efficiency rate and GHG emissions

The next indicator that was assessed in surveyed farms was NUE index. According to other similar research results (Hawkesford, 2014) decrease in NUE index does not always guarantee lower N pollution, but it is an essential step for reducing N loss to the environment while maintaining high agricultural productivity. Using NUE as an indicator it will likely reduce N losses to the environment, which will be followed in time by improved indicators of environmental quality, albeit with lags in the system. Indicative results about situation in Latvian large-scale and intensive crop farms regarding NUE index and N_2O emissions from the use of N are summarized in the Table 4.

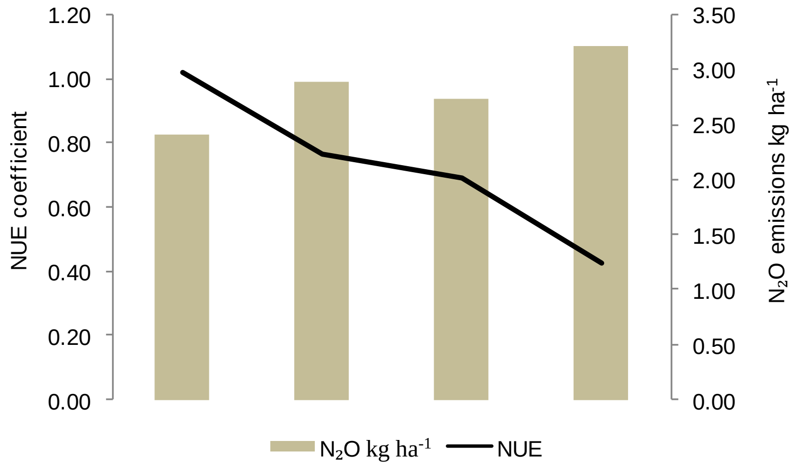
Table 4. NUE index and N_2O emissions from the use of N fertilizers in the surveyed Latvian crop farms, 2014

Crop	Farm A		Farm B		Farm C		Farm D	
	N_2O kg ha^{-1}	NUE	N_2O kg ha^{-1}	NUE	N_2O kg ha^{-1}	NUE	N_2O kg ha^{-1}	NUE
Winter wheat	2.40	1.02	2.88	0.76	2.73	0.69	3.21	0.43
Summer wheat	1.49	1.32	-	-	2.94	1.06	3.28	0.67
Summer barley	1.24	0.93	2.65	0.87	2.25	1.10	1.43	1.12
Field beans	0.50	4.89	-	-	2.00	2.66	1.35	1.86
Winter rape	2.07	0.84	3.07	0.54	2.75	0.38	3.11	0.19
Summer rape	-	-	-	-	2.61	0.80	-	-

Source: authors' calculations

Results summarized in Table 4 shows the differences of NUE index for most commonly grown crop cultures in Latvia between different farms. These results show indicative trend developments with regard to N fertilizer use, production of arable and permanent crops and the resulting NUEs. Overall there can be observed alarming indicators showing that in all surveyed farms there is risk of soil over-fertilization. And here special attention should payed on field beans, where NUE index is the most highest among all surveyed farms.

In this research NUE has been viewed not as a final indicator of success, but rather as an important and essential indicator of progress in the agricultural sector in order to control possible N_2O emissions from the use of N. For this purpose authors' have displayed relation between NUE coefficient and N_2O emissions (Fig. 3) as well as calculated correlation coefficient (r). This analysis was performed only for one crop culture, i.e. winter wheat, which is the most common crop among surveyed farms and is the main crop farming output product in Latvia.



Source: authors' calculations

Figure 3. N_2O emissions (kg ha^{-1}) and NUE coefficient associated with winter wheat production in the surveyed Latvian crop farms, 2014.

Fig. 3 shows that correlation between NUE coefficient and N_2O emissions is negative ($r = -0.95536$). A negative correlation coefficient means that increase in NUE coefficient value is associated with a decrease in N_2O emissions and vice versa. These results go in line with findings of other authors (Cui et al., 2014) thus marking new paradigm for productivity and environmental sustainability.

However, according to Robertson & Vitousek (2009) in intensive cropping systems, the more efficient cycling of N depends on environmental management interactions that influence the balance and rate of microbial processes (e.g. nitrification and denitrification) and transport among plant, soil and environments (e.g. air and water). Thus impact of different environmental management interactions on N balance and N use efficiency should be taken into account in the further research.

CONCLUSIONS

In Latvian cropping systems usage of synthetic fertilizers has been constantly increasing, for example, in 2013 it has increased by 6.9% if compared with 2012, where 80% of the total N fertilizer has been used for cereals' production. However, according to literature only about 50% of this applied N fertilizer has been recovered by crop plants and high levels of NO_3 – N losses can reduce nitrogen use efficiency (NUE). Such indications shows that in Latvia special attention should be paid on effective use of N fertilizers in order to reduce negative impact on the environment.

Research results reflecting nitrogen annual flow in surveyed farms that represents typical large-scale intensive crop production farms in Latvia, indicates that N surpluses ranging from 23 till 86 kg N ha^{-1} can be found in surveyed farms, indicating that in these farms N losses to the environment through N_2O emissions could occur as each kilogram of N fertilizer results in 0.016 kg N_2O emissions. However, these are only indicative results and further research should be proceed.

Assessment of NUE index for most commonly grown crop cultures in Latvia between different farms showed alarming indicative trend developments where in all surveyed farms there can be observed risk of soil over-fertilization. And here special attention should be payed on field beans, where NUE index is the most highest among all surveyed farms. However, these NUE results need an interpretation scheme because very high as well as low NUE values represent unsustainable situations.

In the surveyed Latvian crop farms there can be observed negative correlation between NUE coefficient and N_2O emissions ($r = -0.95536$) which means that increase in NUE coefficient value is associated with a decrease in N_2O emissions and vice versa. These results go in line with findings of other authors thus marking new paradigm for productivity and environmental sustainability.

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Mechanical durability and water absorption of pellets made from different tree species - a case study

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Abstract. Seven different tree species (coniferous and broad leaved) were selected for small scale pelletizing tests: birch (*Betula sp.)*, aspen (*Populus tremula L.*), grey alder (*Alnus incana L.*), poplar (*Populus sp.*), European larch (*Larix decidua* Miil*.)*, pine (*Pinus sylvestris*) and lodgepole pine (*Pinus contorta*). Tree species were mixed in different combinations and proportions. Wood mixture from one tree specie (several tree species were tested as base material during study) was used as base material with volume share in the mix at least 70% and mixtures from other tree species were used as additives. In total 49 different tree mixes were tested in pellet production where mechanical durability and water absorption was later measured for each sample. Mechanical durability where grey alder was mixed with pine was 98.8% (fulfils ENplus quality class). Poplar also showed high results and in some mixes meet the criteria for mechanical durability with best result 99% in mixes with European larch and lodgepole pine (proportions 80:10:10). From 9 different poplar mixes 7 of them showed mechanical durability higher than 97.5%. In tests where no additives was added (100% poplar), poplar pellets mechanical durability was 98.8%. Other mixes with birch, aspen and grey alder when they were taken as base material for pellet production (base material wood volume share in the mixture at least 70%, where remaining 30% consists of other tree specie mixtures) didn't meet the mechanical durability limit for ENplus quality classes and it was lower than 97.5%. Also in samples where birch and grey alder were used without adding other tree species durability was under 97.5%. European larch was the only one from coniferous trees was tested as base material and the best results in mechanical durability showed in mixes with lodgepole pine (proportion 70:30). From 9 different European larch mixes 7 of them showed mechanical durability higher than 97.5%, which is suitable for ENplus certification. Water absorption in pellets with different tree species composition does not change significantly and ranges from 0.70 to 0.73 ml g^{-1} when in commercially available litter material it is 0.75–0.8 ml g^{-1}. Water absorption tests leads to a conclusion that if pellets mechanical durability is not sufficient to sell it as combustion material in could be sold as litter material for animals.

Key words: pellets, coniferous pellets, deciduous pellets, poplar pellets.

INTRODUCTION

Europe Union (EU–28) is the main wood pellet market, in 2013 the market share was 49% of the global production and 80.3% of the global wood pellet consumption (Calderon et al., 2014). Expected wood pellets consumption in European countries according to European Biomass Association in 2020 will be 50Tg (Pirragila et al., 2010).

In the last two decades European demand for wood pellets has increased steadily, mostly stimulated by public policies and governmental supports (Karkania et al., 2012, Olsson et al., 2011, Sikkema et al., 2011, Mola–Yudego et al., 2014). Wood pellets are important fuel in heat and power production with a high potential to grow in the future. Industrial pellets for co–firing and combined heat and power production are the main product in pellet market. However, demand for high quality wood pellets from medium to small scale users in residential heating sector is increasing (Kristofel et al., 2016), where they can be purchased in small quantities and be more affordable on a limited budget. (Thomson & Liddell, 2015). Small and medium pellet consumers usually purchase pellets from domestic traders with national or regional supply chains (Hiegl and Janssen, 2009). Typical medium scale users are public, commercial and apartment buildings (e.g. administrative buildings, schools, family houses). Small scale users are private households using pellets in pellet boilers and pellet stoves (Kristofel et al., 2016).

Pellets quality issues are important for all users. Many European countries have developed pellets quality standards. Pellet quality depends on chemical, mechanical and physical properties of biomass (Kaliyan & Vance, 2009; Obernberger & Thek 2004). Some parameters are related to raw material (Arshadi et al., 2008) and some to quality management of the manufacturing process (Lehtikangas, 2001). One of the main quality indicators is mechanical durability. High content of fine particles in the fuel, which is dependent on mechanical durability, can cause problems in transportation and can favour ash melting (Garcia–Maraver et al., 2011).

According to recent studies, biomass growth in future could increase due to climate changes and mean temperature rise (Jansons et al., 2013a; Jansons et al., 2013b, Jansons et al., 2014a) as well as increased tree production on former agriculture lands (Daugaviete et al., 2015).

Small scale pellet production could be useful for private forest owners who had small, but stable annual wood resource flow from forest or it could be small business niche where pellets are produced for own use or sold in domestic market. Raw material could be taken also from pre-commercial thinning, which so far has not been done in large scale. Totally Latvian pre-commercial thinning is possible in 161 kha (Lazdins et al., 2013) and some of these resources could be used in pellet production. That could open market for new players in forest energy market.

Pellets with high mechanical durability could be sold as energy material, but pellets with low mechanical durability can be used as litter material for animals. This study tested pellets mechanical durability to different tree raw material mixes, to gain insight, which tree species could be more useful in small scale pellet production.

MATERIALS AND METHODS

The aim of this study was to compare different tree mixtures from common tree species in small scale pellet production and test pellets mechanical durability and water absorption. Assuming that pellets with lower mechanical durability could be used as litter material for animals.

In this study seven different tree species (coniferous and broad leaved) were selected for small scale pelletizing tests: birch (*Betula sp.)*, aspen (*Populus tremula L.*), grey alder (*Alnus incana L.*), poplar (*Populus sp.*), Europena larch (*Larix decidua* Miil.*)*, pine (*Pinus sylvestris*) and lodgepole pine (*Pinus contorta*). Tree species were mixed in different combinations and proportions to test pellets durability and water absorption, together 49 different mixtures were tested. Pelleting material mixtures were mixed manually and the proportions were mixed according to wood volumes. In all mixtures one of tree species were taken as the base material, where the share in mixture was no less than 70%. Exceptions were in mixtures, where birch and aspen were mixed equally together and the common share was no less than 70%. Selected tree trunks with bark were chipped at first and grounded before pelleting. Bark share in mixture was not particularly measured and calculated. Peletizer capacity was 200–250 kg pellets per hour. This mill has flat, horizontally configured die with 250 mm diameter, 34 mm thickness and die rotating speed 100 rpm. Average particle size before peletizing was approximately 3.0 to 5.0 mm and pellet diameter 6 mm. Determination of mechanical durability of pellets were done according to LVS EN 15210–1:2010 standard 'Solid biofuels – Determination of mechanical durability of pellets and briquettes – Part 1: Pellets'. Pelletizing for every tree mix was done in 2 repetitions, mechanical durability was measured for every repetition and average mechanical durability of these two repetitions is shown in this paper. This study was done like pilot project, where production conditions were close as possible to real and simple small scale pellet production system. Therefore there was no possibility to measure energy input and this factor was not measured.

For water absorption certain amount of pellets were weighted and placed on a sieve in one round, then the pellets were watered with 10 ml of water for 15 seconds, waited until the surplus water drained and then weighed again. Weight difference between dry pellets and pellets after watering is the water absorption, expressed in ml g^{-1}.

RESULTS AND DISCUSSION

The ENplus certification scheme defines three pellet quality classes and they are based on the classes of ISO 17225–2 and are named ENplus A1, ENplus A2 and ENplus B. To fit in these classes several parameters must be met. One off the parameter is mechanical durability (wt.%) which for ENplusA1 class should be ≥ 98.0 and for ENplus A2 and ENplus B ≥ 97.5 (ENplus quality certification...2015).

In the paper deciduous and coniferous trees were tested for pellet production. In one case deciduous tree was taken as the base material for pellet production and coniferous trees were added as supplements. In other case base material was coniferous tree and deciduous trees were added as supplements.

In the beginning three single species (poplar, birch and lodgepole pine) were tested in pellet producing, where no other species were added. Best results in pellets mechanical durability showed poplar durability as 98.8%, which would met the ENplus certification requirements in mechanical durability. Lodgepole pine (96.8%) and birch (92.3%) pellets showed lowed durability and will not meet the ENplus certification requirements in mechanical durability.

Deciduous trees in 2014 covered 54.8% of all forest lands in Latvia (Latvian forest sector...2015). Most of the deciduous stands are forests that emerged naturally on former agricultural land and consist mainly of so-called pioneer species including birch (*Betula* spp.), grey alder (*Alnus incana* (L.) Moench) and aspen (*Populus treemula* L.). (Liepins et al., 2015). According to area common species are birch (28%), grey alder (10%) and aspen (8%) (Latvian forest sector...2015). Low quality and small dimension timber could be used in pellet production. In this study all three main deciduous tree species were tested as main material for pellet production and mixed with coniferous trees. Birch was mixed with larch and pine, grey alder mixed with pine and lodgepole pine, aspen was mixed with pine and larch and mixture of birch and aspen (50:50) was mixed with pine and larch. In all cases deciduous trees were the base material and their share was at least 70% of the mixture.

Two mixes with grey alder were tested where it was mixed with pine (proportion 75:25) and lodgepole pine (proportion 70:30). Mechanical durability where grey alder was mixed with pine was 98.8% (fulfils ENplus quality class) and with lodgepole pine 95.5%. In this particular case grey alder mix with pine showed better durability results than mix lodgepole pine.

Pellets where only birch wood was used showed low mechanical durability – 92.3%. To improve durability other coniferous tree species were added to birch and tested. Mixtures were made mixing birch wood (where total birch share was 85–70%) with pine and larch (with total share in mixture 15–30%). (see Fig 1)

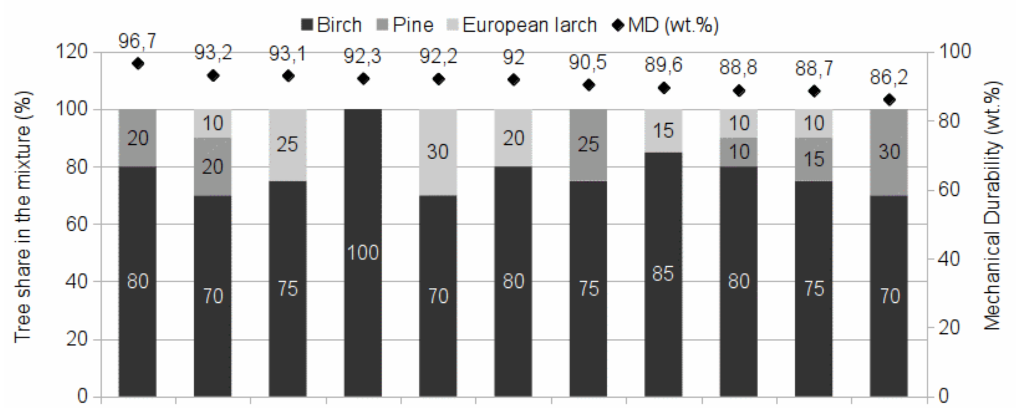

Figure 1. Pellets mechanical durability where birch is the base component.

Durability for pellets where birch was mixed with pine and larch ranged between 96.7% and 86.2% which is not enough to meet any of the ENplus quality classes. These pellets could be used as lower quality burning material or used as litter material for animals. Tests showed that mixing birch with coniferous trees will not improve pellets durability, at least in this case where birch proportion is at least 70% and pellets are made in small scale machine. Significant difference between added coniferous species was not detected.

Aspen was mixed with pine and larch in different proportions where aspen share was at least 70%. All mixes shoved low mechanical durability where the highest number was 94.6% and the lowest 88.1%. All mixtures are under ENplus durability standards. Pellets with added pine shoved better results than mixtures with added larch (see Fig. 2).

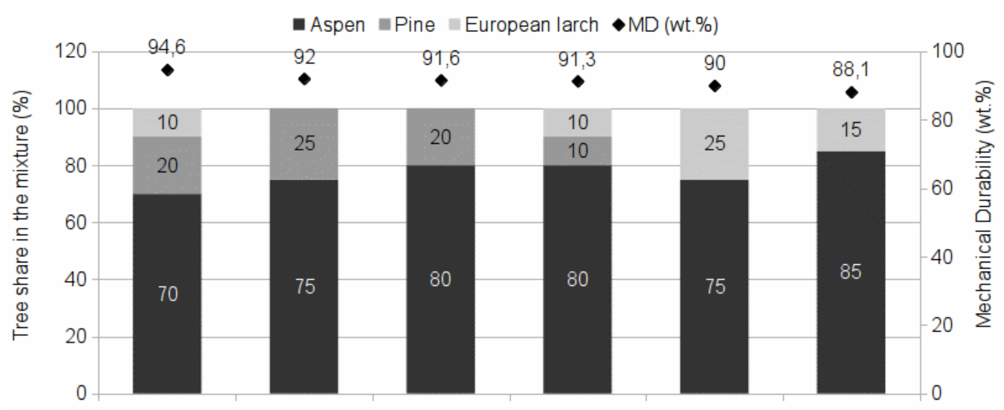

Figure 2. Pellets mechanical durability where aspen is the base component.

Birch and aspen in equal parts were mixed with pine and larch, where deciduous tree share was at least 70%. All mixes showed low mechanical durability where the highest number was 95.4% and the lowest 88.5%. All mixtures are under ENplus durability standards (see Fig. 3). Birch and pine mixture as base material didn't show noticeably better results in mechanical durability than single specie used as base material.

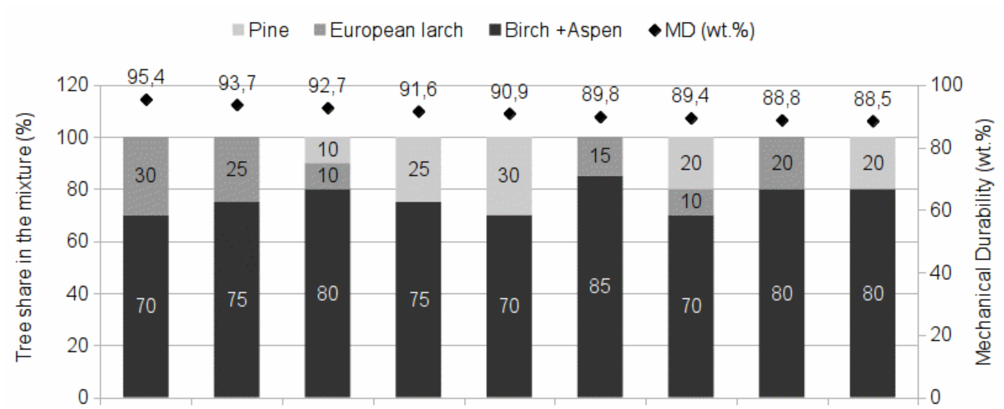

Figure 3. Pellets mechanical durability where birch and aspen mixture is the base component.

Best pellet mechanical durability from deciduous trees was with poplar. Poplar was mixed with larch and lodgepole pine, where poplar share was at least 70%. Best durability was 99% where poplar was mixed with larch and lodgepole pine (proportions 80:10:10). Totally from 9 different mixes 7 of them showed pellets mechanical durability higher than 97.5% which is enough to fulfil the ENplus durability standards. From all deciduous tree species that were tested for pellet productions, poplar shoved the best results in mechanical durability (see Fig. 4).

Previous studies shows that poplar hybrid (*Populus balsamifera x P. laurifolia*) planted density 5,000–7,000 trees ha^{-1} at the age 54–65 mean annual volume increment is 7.5–21 m^3 ha^{-1} y^{-1} and total above-ground dry biomass increment reached

4.2–9.8 t ha^{-1} y^{-1}. This suggests that poplar could be a viable alternative for biomass production in Latvia (Jansons et al., 2014b).

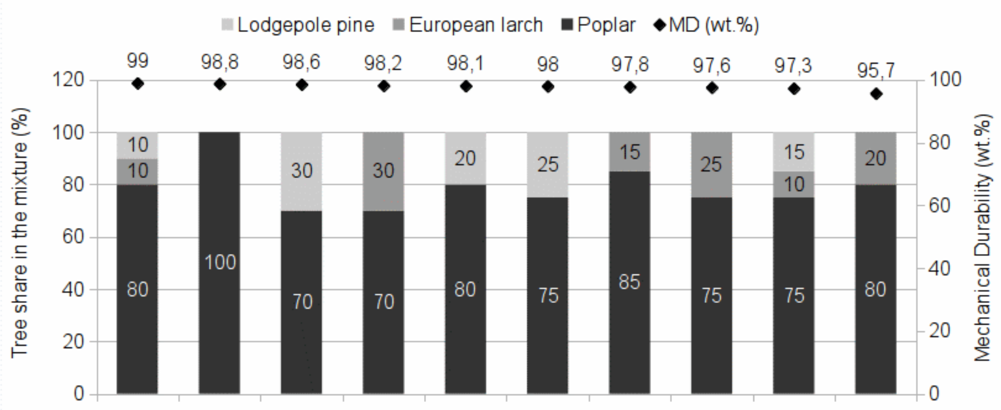

Figure 4. Pellets mechanical durability where poplar is the base component.

Coniferous trees in 2014 covered 45.2% of all forest lands in Latvia with main species - pine (29%) and spruce (17%). (Latvian forest sector...2015). Main species were not taken as base material in study, pine was used only as added material. In this study basic material was from coniferous trees taken European larch, which is introduced species with total area of 1139 ha (Dreimanis, 1995). European larch was mixed with other coniferous trees -pine and lodgepole pine and deciduous trees–birch and grey alder and larch share in all cases was at least 70% of the mixture. Better results showed from mixtures with lodgepole pine and little worse in mixtures with grey alder and pine. Totally from 9 different mixes 7 of them showed pellets with mechanical durability higher than 98% what is enough to fulfil the ENplus durability standards. Pellets only from lodgepole pine were made and mechanical durability was 96.8% which is not enough for ENplus standard (see Fig. 5).

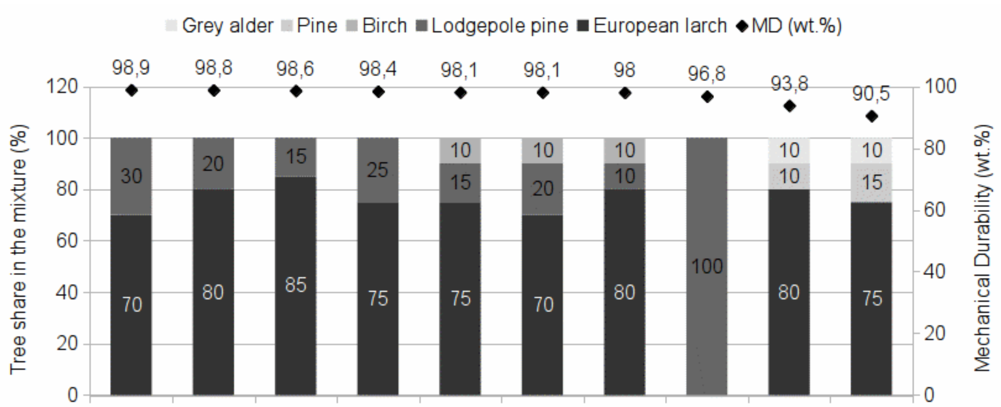

Figure 5. Pellets mechanical durability where European larch is the base component.

In cases where pellets quality is not sufficient as combustion material, instead of remaking them, they could be used as litter material for animals. All pellet samples that were used for durability tests also were tested for water absorption. The results of experiments show that the water absorption in pellets with different tree species wood composition does not change significantly and ranges from 0.70 to 0.73 ml g^{-1}. Pellets that are sold in market as animal litter pellets also were tested for water absorption according to the same methodology. Tests were done to three different manufacturers of wood pellets which were manufactured as litter material. Water absorption for pellets sold in retail shops as litter material was 0.75–0.8 ml g^{-1}. Results showed that commercially available pellets water absorption is not significantly higher than in this study manufactured pellet, which lead to an option that pellets that could not meet the durability criteria could be sold as litter material for animals.

CONCLUSIONS

During this study 49 different tree wood mixes were pelletized in a small scale pelletizer where mechanical durability and water absorption for produced pellets was later tested. Quite big difference was observed between different deciduous tree species that were tested. Mechanical durability where grey alder was mixed with pine was 98.8% (fulfils ENplus quality class). Poplar also showed good durability results and in some mixes meet the criteria for mechanical durability with best result 99% in mixes with European larch and lodgepole pine (proportions 80:10:10). From 9 different poplar mixes 7 of them shoved mechanical durability higher than 97.5%. Other mixes with birch, aspen and grey alder when they were taken as base material for pellet production (wood volume share in the mixture at least 70%) didn't meet the mechanical durability limit for ENplus quality classes and it was lower than 97.5%. Also in samples where birch and grey alder were used without adding other tree species durability was under 97.5%. Poplar also showed high pellets durability results–98.8% when no additives was added to poplar in pelletizing process. After first trials it was concluded that not all deciduous tree species could be used in pellet production, at least with regard to concerns of mechanical durability and when they are pelletized on small scale pelletizer. On the other hand tree species like poplar and grey alder in some mixes showed promising results in pellets mechanical durability tests and advanced researches on these species could be desirable.

Coniferous trees in this study mostly were used as additives to deciduous tree mixes and added wood volume did not exceed 30%. European larch only from coniferous trees was tested as base material, with share proportion in the wood mixes at least 70%. Best results in mechanical durability European larch showed in mixes with lodgepole pine (proportion 70:30). From 9 different European larch mixes that were tested, 7 of them showed durability higher than 97.5%, what is sufficient for ENplus certification. In test where lodgepole pine with no additives was used in pellets showed unsatisfactory results in mechanical durability. European larch shoved promising results as base material in pellet productions and advanced researches could be desirable.

In small scale pelletizing most of the activities are done manually which may have impact of quality issues. Mechanical durability could be improved by adjusting pelletizer and work methods to specific tree specie or mixture. In this tests several tree species were tested in short time period and in relatively small volumes. According to previous experience different tree species could have different regulations on the pellet machine and it could be done more precisely when larger amount of one tree specie or the same tree mixture is pelletized.

According to literature studies, no single factor in pellet production, including tree species or different tree specie fraction mixing can't be assumed as dominant factor. Many different factors could influence the pellet mechanical durability and in most of the cases it's the interaction of all these factors. However, tree species or tree specie mix is one of the factors that could influence the pellets mechanical durability and should be taken into account before starting small scale pellet production.

Water absorption in pellets with different tree species composition does not change significantly and ranges from 0.70 to 0.73 ml g^{-1}. For pellets sold in market as litter material water absorption was 0.75–0.8 ml g^{-1}. Preliminary tests leads to conclusions that if pellets mechanical durability is not satisfactory to sell it as combustion material in could be sold as litter material for animals.

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Analysis of organic agricultural waste usage for fertilizer production

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Abstract. Waste management, especially biodegradable (organic) waste, is highly relevant in agriculture. Increasing the intensity of agricultural production inevitably increases pollution of soil, water and air due to chemical, biological and other effects because of untidy agricultural waste. Currently there is a search for new and more rational ways to use waste for new forms of energy, making fertilizer, building materials and other products. One of the processes of biodegradable waste management is pelleting; i.e., the processing of recyclable materials into organic ecological products.
The SWOT analysis-expert, literature survey methods were used for the analysis of animal and plant origin organic agricultural waste's suitability for production of fertilizer. The analysis has shown that the granulation of animal waste allows making better use of nutrients, significantly reduces the amount of fertilizer needed to be deposited into the soil and reduces the cost of storing, transportation and spreading into the soil. SWOT analysis motivated the need for further research of manure waste and its pelletizing.

Key words: Composted manure, agricultural plant wastes, pelletizing, SWOT, fertilizer.

INTRODUCTION

Agricultural practices, environment and human health are intrinsically linked. Therefore, environmental quality is crucially important to agricultural production, and management of agricultural waste has potential to harm human health and environment. Accordingly, farmers have a duty to ensure that they do not treat, keep or dispose of agricultural waste in a manner likely to cause pollution of the environment or harm to human health. A non-appropriate treatment or disposal of organic wastes can become risky for environment and humans, for instance it can support the spread of diseases and may pollute soil and groundwater (Roeper et al., 2005).

According to statistics in 2014 Lithuanian agriculture is responsible for about 3.8 million tons of manure and 1.68 million tons of slurry and about 3.7 million tons of straw and other waste (Oficial, 2016). Total amount of organic agriculture wastes is about 4 million tons in Lithuania. Manure compose about 1.5 million tons of waste. Cattle manure forms about 1200 thousand tons dry substance, pig manure about 250 thousand tons dry substance, hen, chicken manure 50–75 thousand tons dry substance, straw about 2 million tons, the different plant origin waste about 500 thousand tons (Brazas et al., 2012). It is composted only a very small part of it. Only a very small proportion (about 3%) of liquid manure (slurry and manure mixture) is currently being treated in anaerobic – producing biogas. Litter per year on average consumed about 1.0 to 1.25 million tons of straw. Currently, most of the resulting manure is liquid or semi-liquid manure – manure, slurry mixture – which is considered manure storage or slurry tanks and almost all, is inserted into the soil or spread out untreated. Crop production farms forms about 5 million tons of wastes in Lithuania. Excess biomass consists of 1.56 million tons while assessing available waste recovery possibilities (Mazeika et al., 2011). Small amounts of crop residues, food processing wastes, municipal bio solids and wastes from some industries are also applied to land.

According to EU requirements manure is considered to be waste by the livestock owner has to account for and eliminate using as crop fertilizer and not polluting the environment. Untreated manure is not humus substances, organic bedding materials are not available for plants condition. Soil spread fresh manure can cause even a short denitrification processes or contaminate soil pathogenic micro flora, weed seeds, and so on (Bleizgys, 2015). Compost made from livestock manure is an effective material for improving the physical and chemical condition of soil (Hara, 2001).

The newest trends in research and production are the recycling of agricultural waste (bio-waste), the search of alternative energy resources as well as the rational use of raw materials (by-products) and waste products. One way of the organic waste management are using these waste as secondary raw material for recycling to organic products by pelleting. Granular manure is a universal complex organic fertilizer containing all the macro and micro elements. Pelleted manure nutrient content for soil micro flora is optimal, it quickly dissolves in water and is easily absorbed by plants. Granular manure can be called concentrated fertilizer, because the recycling process reduces the volume of material more than 10 times, due to water removal (Polovcev & Cherkasov, 1992). It is economically expedient to create and use a granular organic fertilizer (cattle, poultry manure and organic compost) with relevant physical-mechanical properties which influence product warehousing (storage), transport, straggling spreading in the soil and localized insertion. It is really hard to store high amounts of manure, and there is almost no way to spread it over the soil evenly. The process of fertilizing the soil using organic fertilizers is seasonal, while production of manure continues throughout the year. The solution can be recycling of cattle, cow and bird manure compost by pelletizing it. The goal of pelletizing is to produce an easily manageable product for land crop fertilization, that conserves all the properties of the original material (nutrient content), and with better storage and handling properties as compared to a dusty product (compost). In such agricultural waste management the first point is to establish technology for producing high-quality compost. The second is to establish a method of fertilizing crops which takes into account the needs of the environment. Molding composted livestock wastes into pellets can solve both problems, and seems to be a promising technology. The most important task is to reduce the pellets manufacturing cost (Hara, 2001).

Therefore, to motivate organic waste recycling strategy was reviewed quantitative and qualitative analysis methods and chosen SWOT method. The SWOT analysis is one of the most popular tools in use for defining a strategic action. The analysis begins with four factors identification list, in order to improve understanding of the typical SWOT analysis structured four-cell table (matrix). Purpose of SWOT analysis is to collect information by analyzing the environment, divide this information to internal and external factors. The entities analyzed with in multi-purpose and multidisciplinary areas are too complicated to be strictly quantitatively described. For the evaluation of system‘s behavior the mechanism of SWOT analysis, which enables to cope with problems static, is frequently employed. In order to fill in SWOT analysis tables, the descriptions of all fuzzy situations should be normalized, which means that characteristics of features should become quantitatively measured and compared (Jasinevicius & Petrauskas, 2008).

Subject of the research – analysis of organic animal and plant origin agricultural wastes suitability for production of fertilizer using SWOT analysis.

MATERIALS AND METHODS

To characterize the organic agricultural waste’s suitability for production of fertilizer the SWOT analysis was used. We wanted to find out which agricultural wastes are better to recycle – animal or plant residues origin wastes. There was chosen two waste types. According to Waste Classification (EPA, 2015) those wastes are classified as: 02 01 06 code – animal faeces, urine and manure (including spoiled straw), effluent, collected separately and treated off-site and 02 01 03 code – plant-tissue waste.

Because manure and plant compost is not convenient to spread on the soil, to transport and storage, it was proposed organic waste pelletizing. There was prepared four lists of factors for experts (3 persons) and for analytics (5 persons). The most important factors affecting Lithuanian agricultural organic waste management were identified by using literature research methods. Experts and analytics had task to weight quantitatively each selected factor probability function value μ (till value 1) and impact on influence value c (till value 1) depending on the organic waste pelletizing. Selected experts were competent in agricultural waste management and recycling spheres.

Evaluating the SWOT analysis the each of the four elements is evaluated separately and the detailed analysis of the situation is carried out too. First of all was used simply method to calculate sums of Opportunities, Threats, Strengths and Weaknesses by formulas:

$$OP_\Sigma = \sum_{o=1}^{O} \mu_o \cdot c_o \; ; \; TH_\Sigma = \sum_{t=1}^{T} \mu_t \cdot c_t \; ; \; ST_\Sigma = \sum_{o=1}^{O} \left(\sum_{s=1}^{S} ST_{os} \right) \cdot c_o \; ;$$
$$WK_\Sigma = \sum_{t=1}^{T} \left(\sum_{w=1}^{W} WK_{tw} \right) \cdot c_t \qquad (1)$$

where: OP_Σ – sum of Opportunities; TH_Σ – sum of Threats; ST_Σ – sum of Strengths; WK_Σ – sum of Weaknesses; μ_o – probability function value of Opportunities, c_o – impact influence value on Opportunities; c_t – probability function value of Threats; μ_t – impact influence value on Threats.

For Opportunities and Threats total amount assessment was used formulas:

$$OP_\Sigma = \sum_{o=1}^{O} \left\{ c_o \left(\mu_o + \sum_{s=1}^{S} ST_{os} + \sum_{w=1}^{W} WK_{ow} \right) \right\} \qquad (2)$$

$$TH_{\Sigma} = \sum_{t=1}^{T} \left\{ c_t \left(\mu_t + \sum_{s=1}^{S} ST_{ts} + \sum_{w=1}^{W} WK_{tw} \right) \right\} \quad (3)$$

RESULTS AND DISCUSSION

According to literature survey there was made Opportunities, Strengths, Threats and Weaknesses factors lists for plant and manure wastes, because those two groups are mostly divided. From lists was chosen the most important factors and marked with codes, for example Opportunities – OP1, OP2, OP3, Strengths – ST1, ST2, ST3, Threats – TH1, … , Weaknesses – WK1, … . There was made two SWOT lists, one for plant origin waste, second one for manure wastes (Tables 1, 2).

Table 1. SWOT analysis for plant waste in crop production agricultural raw material granulation

Marking	**Opportunities**	Marking	**Strengths**
OP1	Provision of waste biomass raw materials and rational utilization of plant biomass in order to preserve the fundamental components of ecosystems.	ST1	Purposeful use of waste biomass creates new work places, strengthen energy independence.
OP2	Supply of ecological fertilizers, agricultural waste products and by-products, sustainable use, the EU and other various funds for waste management.	ST2	The growing demand of organic fertilizers and other products.
OP3	High waste biomass processing (crushing, grinding, granulation) equipment acquisition opportunities especially for small and medium-sized farms.	ST3	Balanced accumulation of organic matter in the soil – an important measure to ensure the quality of the soil and a significant opportunity to reduce CO_2 emission.
		ST4	Improvement of environmental conditions.
Marking	**Threats**	Marking	**Weaknesses**
TH1	Processed biomass purchase and sales instabilities, predicted economic change (unstable market).	WK1	In Lithuania there is no biodegradable long-term waste management strategy. Organic farming is less competitive.
TH2	Chemical, biological and physical environment (including work environment) pollution.	WK2	Manure management technological equipment is not produced in Lithuania, and their installation expensive. Lithuanian production of industrial waste processing plant equipment is expensive and difficult to use in, there is need for skilled professionals and high investment.
		WK3	Low farmers education, information and understanding of environmental requirements level.

Table 2. SWOT analysis for manure waste in agricultural activities raw material granulation

Marking	**Opportunities**	Marking	**Strengths**
OP1	The economic benefits of a source of raw materials and ecological fertilizers.	ST1	The growing demand of organic fertilizers.
OP2	Manure separation and granulation equipment purchase in world market (especially for small and medium farms).	ST2	Reduced investment in manure storage and transportation systems engineering.
OP3	Smaller environmental risk.	ST3	Significant reduction in manure emissions.
		ST4	Better qualitative indicators of organic fertilizer (NPK ratio).
Marking	**Threats**	Marking	**Weaknesses**
TH1	Not innovative technologies and equipment in Lithuania. Industrial manure managing equipment is expensive.	WK1	In Lithuania there is no biodegradable long-term waste management strategy.
TH2	Chemical, biological, physical (including work environment) pollution.	WK2	Organic farming is less competitive.
		WK3	Low farmers education, information and understanding of environmental requirements level.

According to formulas (1) was calculated Opportunities, Threats, Strengths and Weaknesses sums (Table 3). The difference for manure waste was positive for Strengths (0.67), for plants wastes also positive rate (0.22). Simply Strengths, Weaknesses, Opportunities, Threats assessment results shown that manure wastes are better for agricultural fertilizer production.

Table 3. Simply Strengths, Weaknesses, Opportunities, Threats assessment results

	Plant origin wastes	Manure wastes
OP_{Σ}	0.57	0.96
TH_{Σ}	0.39	0.39
ST_{Σ}	1.38	0.74
WK_{Σ}	1.34	0.64

To obtain more exact and reliable result SWOT analysis summary tables were made. Experts analyze a magnitude of additional factors, and change the weight of influence on strengths and weaknesses on the basis of Opportunities and Threats total results (Tables 4, 5). For total amount calculation was used formulas (1 and 2).

Table 4. SWOT analysis summary for plant origin agricultural wastes

		μ	c	Strengths				Weaknesses			$\sum$
				ST1	ST2	ST3	ST4	WK1	WK2	WK3	
Opportunities	OP1	0.82	0.45	0.68	0.32	0.25	0.4	-0.76	-0.83	-0.48	0.2
	OP2	0.25	0.34	0.15	0.46	0.33	0.24	-0.2	-0.27	-0.15	0.15
	OP3	0.6	0.2	0.28	0.41	0.11	0.14	-0.5	0.28	-0.32	0.078
									Total amount:		0,428
Threats	TH1	0.55	0.46	-0.39	-0.25	-0.19	-0.1	0.3	0.5	0.23	0.188
	TH2	0.35	0.4	-0.2	-0.36	-0.39	-0.2	0.15	0.25	0.36	0.096
									Total amount:		0.284

Table 5. SWOT analysis summary for manure agricultural wastes

		μ	c	Strengths				Weaknesses			$\sum$
				ST1	ST2	ST3	ST4	WK1	WK2	WK3	
Opportunities	OP1	0.55	0.45	0.4	-	-	-	-0.5	-	-	0.2
	OP2	0.65	0.54	-	0.25	0.27	0.37	-	-0.45	-0.5	0.24
	OP3	0.86	0.42	0.57	-	0.65	0.35	-0.5	-0.5	-0.4	0.47
									Total amount:		0.91
Threats	TH1	0.55	0.46	-0.4	-0.25	-0.2	-0.6	0.5	-	0.43	0.184
	TH2	0.35	0.4	-0.3	-	0.65	-0.4	-	0.45	-	0.04
									Total amount:		0.22

SWOT analysis shows that manure wastes suitability for fertilizer production is better (discrepancy of *Strengths* among *Threats* for manure wastes 0.69), compared with plant origin wastes (discrepancy 0.14). SWOT analysis motivated the need for further research of manure waste and its pelletizing. As it mentioned in introduction a granular organic fertilizer with relevant physical-mechanical properties which influence product warehousing (storage), transport, straggling spreading in the soil will be very important for our future research. It is therefore expected to pelletize various mixtures of manure wastes in laboratory conditions and investigate optimal parameters of organic pellets physical-mechanical properties.

CONCLUSIONS

The analysis indicated that organic wastes are utilized in agriculture mainly for improving the soil physical and chemical properties and for nutrient sources for growing crops. The major source of organic waste used in agriculture is animal manure.

Agriculture forms about 4 million tons per year of organic wastes in Lithuania. Excess biomass consists of about 1.5 million tons while assessing available waste recovery possibilities.

To characterize the organic agricultural waste's suitability for production of fertilizer the SWOT analysis was used to determine which agricultural wastes are better to recycle – animal or plant origin. The SWOT analysis shows that manure wastes suitability for fertilizer production is better (discrepancy of Strengths among Threats for manure wastes is 0.69, compared with plant origin wastes discrepancy is 0.14).

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Ethics audit as a marketing instrument and its potential for organic farming

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Abstract. Demand for organic foods is growing quickly but remains to be a relatively small segment of the food market. In order to increase the market share there is important role in an effective and smart marketing communication. According to many researches consumers are mostly interested in additional ethical attributes in organic food producing. Organic food farmers' ability to earn profit from experience marketing according ethical values in organic food production is rather weak. At the same time organic farming faces many significant ethical risks from unregulated area of organic food-production. Consumer trust in environmentally friendly or organic products is often being undermined by business scandals, unsubstantiated 'organic' claims and assessment practices. The current paper aims to improve ethics audit framework as a marketing instrument for organic farming companies in order to increase the trust between producers and consumers. This paper draws upon previous researches and adds new approach based on the needs of organic farming.

Key words: ethical values, organic producing, marketing communication, risk assessment.

INTRODUCTION

Organic farming and consumerism are both growing trends worldwide and have continued to expand during the last few years. Moral responsibility is an important buying motivation among various consumer groups (Shaw & Shiu, 2003; Carrigan et al., 2004). Ethical values and behaviour have played an essential role in the self-conception of organic agriculture from the very beginning (Browne et al., 2000; Lautermann et al., 2005). It is well known that there are several regulations governing organic farming. In addition to the regulations of the European Union (EC Reg. 2092/91), the Estonian Organic Farming Act provides for requirements not regulated by EU law, and the extent of supervision exercised over individuals operating in the area of organic farming, and liability in cases of the violation of the requirements established by such legislation. These are mainly a set of standards relating to the physical-technical terms of organic production and certification. Ethical values and corporate social responsibility, which go far beyond the production rules or beyond the systematic approach to organic agriculture, are mentioned neither in the EU Regulation nor in other local government regulations.

Many scientists (Maloni & Brown, 2006; Zander & Hamm, 2010) argue that increasingly more consumers are discontent with the consequences of globalisation on organic food provision: anonymous, uniform and replaceable organic food products. Consequently, a new demand for products produced under ethical standards going beyond the current organic standards seems to be emerging. A large number of studies indicate that consumers tend to be rather sceptical towards green product claims and organic food (Schlegelmilch et al., 1996; Bech-Larsen & Grunert, 2001; Aarset et al., 2004; Vermeir & Verbeke, 2006; D'Souza et al., 2007; Bray et al., 2011; Janssen & Hamm, 2011; Janssen & Hamm, 2012). Consumers do not only want the products to seem to be organic; they also want to know that these products are produced according to ethical values. At the same time, the producer and the farmers may earn a profit from well-communicated ethical values and social norms in organic food production. There are many consumers of organic food demanding evidence that additional ethical values are really included in the production, processing and retailing. Therefore, it seems an urgent task to gain experience about what communication strategies can be successful in implementing additional ethical values in the market for organic products (Leppiman, 2010a; Leppiman, 2010b; Zander & Hamm, 2010). Authors can assume that there are grey areas between regulation and consumer demand for ethical values according organic food consumption. Authors believe that abovementioned gap may include hidden risks for the producers and may decrease consumers trust. To avoid such threats using an ethics audit as a marketing instrument could be invaluable. Here it is necessary to say in advance that an ethics audit is not an additional regulatory tool, but it follows an advisory approach for farmers so they can avoid hidden ethical risks and promote better relationships between producers and costumers. Aforementioned is supported by studies of Başgöze and Tektaş (2012) who stated that trustworthy certification and control, and effective communication are the most important keys to further enhancement of consumer trust towards organic food consumption. With the help of an ethics audit, managers can evaluate how well a company has fulfilled its economic, legal and ethical obligations, discover or prevent ethical risks and plan CSR activities strategically to satisfy stakeholder interests (Carmichael et al., 1998; Kaptein, 1998; Rosthorn, 2000; Morimoto et al., 2004; Bennet et al., 2006). The results of research carried out by Pivato et al. (2008) referred that trust is a key mediator capable of measuring and explaining the success or the failure of the organic food producing policies adopted by a company. The price of organic food products is usually higher than that of comparable non-organic alternatives. In such cases, the act of purchase is strongly dependent on the belief that the organic food is healthier and valuable. The business model of organic farms is more value-oriented then conventional farming. This is the reason, why organic food is more trust and value sensitive.

The ethics audit has been thoroughly researched by Muel Kaptein (1998) and later improved by authors (Rihma, 2012; Rihma et al., 2014).The aim of the authors here is to improve the ethics audit framework for the assessment of organic farming, especially in areas which are not covered by other official regulations. The research tasks of this paper are to explain what ethics audit is and how it will work in order to increase trust and transparency amongst the stakeholders. The paper also aims to explain how ethics audit model can be adjusted to organic farming companies. To fulfil these tasks, authors of this paper provide an overview of ethics auditing and explain how an ethics audit could work for organic farmers as a marketing instrument. Finally, a framework for an improved ethics audit model for organic farming will be presented. The main methodological basis for the current paper is qualitative research. This paper draws upon previous researches and emerging ethical issues to develop an ethics audit model for organic farmers.

MATERIALS AND METHODS

Business can be understood as a system of how to create value for stakeholders. The ethics audit clarifies the actual values, to which the company operates, provides a baseline by which to measure future improvement and how to meet any societal expectations which are not currently being met, but also identifies specific problem areas within the company and general areas of vulnerability, particularly related to a lack of openness (Carmichael et al., 1998).

An ethics audit, as Kaptein (1998) has said is like an ethics thermometer to measure the 'health condition of organizational ethics'. Kaptein asserts that ethics audit improves the ethical functioning of the organization and is conducted periodically and verifies the accuracy of the ethics report. He defined the ethics audit as a systematic approach, which provides a description, analysis and evaluation of the relevant aspects of the ethics of a corporation. He highlights six important aspects of auditing to which attention has to be paid: an audit's arrangement characteristics, indicators of behaviour, processing of measurement results, solving dilemmas, individual characteristics and evaluations of the situation (ibid). According to the fact that previous ethics audits lack a risk assessment and analysis component the author improved ethics audit model do not merely improve the ethics climate, but risk assessment charts the likelihood and significance of the risks in addition (Rihma, 2012; Rihma, 2014). It is essential to keep in mind that after detecting ethical risks, it is necessary to evaluate and analyse the risks. Ethical risk assessment and analyses help managers to quickly recognize potential adverse events, be more proactive and forward-looking, and establish appropriate risk responses. In following Fig. 1 describes an improved model and the process of the ethics audit.

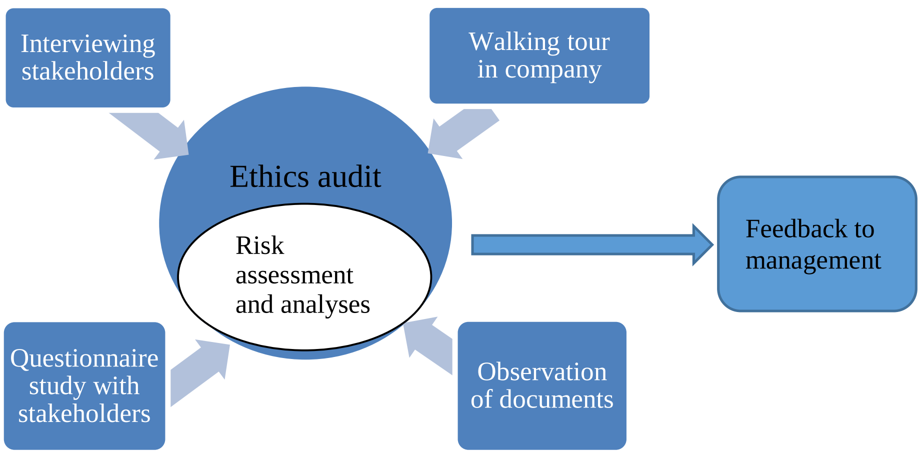

Figure 1. Model of the process of the ethics audit (Rihma, 2012; Rihma, 2014).

There are four main data sources for collecting information: observing documents, a questionnaire and interviews with selected stakeholders and a walking tour in the company. All data will be categorised, analysed and assessed through risk mapping. Finally, feedback with risk analyses and a suggested action plan is given to the company's management.

Auditing process is carried out by the external auditing committee. The auditing committee should be composed of at least three independent and independent experts. Hess (1999), Zerk (2006), Crane & Matten, (2007,) emphasize that independent and external monitoring of CSR-related disclosures by companies is essential for the credibility of CSR initiatives and for increasing consumers trust. Auditing committee has to avoid conflicts of interests with stakeholders.

The auditing process consists regularly from six stages:

First stage involves quantitative analyses through questionnaire to selected stakeholders groups (e.g. employees, shareholders, clients, suppliers, the community etc.) identified for the research depends on the company's interest and focus.

Second stage is a walking tour in the company workspace during working hours (office, factory, plant, leisure area etc.) to obtain information about the physical evidence that supports or contradicts the results of other stages of the audit.

Third stage involves a focus-group interview with selected stakeholders.

Fourth stage elaborates conferring and solving ethical dilemmas. Story-telling and dilemmas specify attitudes which shape or reflect behaviours in terms of honesty, individual and corporate ethics, satisfaction, expectations and tolerance for lack of trust, or quality.

Fifth stage involves analysing and observing of documents (contracts, annual reports, internal documents, codes of conduct or values statements, regulations, rules etc.).

Sixth stage after collecting and analysing data, risk assessment and analyse will be done. Also feedback for the company's management will be compiled (Rihma, 2012).

Every risk that appeared will be placed on scale of 1–5 based on the likelihood of its occurrence. On the second scale of 1–10 according to its significance for the company will be marked. Since significance is considered more important than likelihood, it is scored highly. Subsequently, all potential risks are categorized and divided between four quadrants depending on level of significance and likelihood of occurrence (Rihma, 2014; Rihma et al., 2014).

An auditing report as feedback is a factual document, which takes the most important findings as the basis for an action plan. The feedback contains the company's description of the audit methodology and the interpretation of the data, while best practices and hidden ethical and IT related risks are pointed out. In the final report every risk will be supported with at least one example drawn from the facts identified in the auditing process. The feedback document is structured according to stakeholder groups: employees, managers, customers/consumers and shareholders.

The main methodological basis for the ethics audit is based on triangulation. Triangulation means that there are connections between different research methods and multiple theories (embedded theories) during auditing. Also multiple methods will be used in auditing process, including quantitative and qualitative approach (Denzin, 1988; Leppiman, 2010a). In auditing process for example, questionnaires, interviews, observations and monitoring are used. One advantage of this method is that the particular weakness of one method can be compensated for by the particular strength of another (Denzin, 2006).

RESULTS AND DISCUSSION

Framework for ethics audit for an organic farming improved based on ethics audit model described above. Many fields of organic farming are regulated by the Organic Farming Act or other regulations but there are also some grey areas. For example, organic farming does not regulate in detail the requirements of the food processing (with some exceptional, for example: the prohibition of the use of ionizing radiation) or cleaning and disinfection. Another unregulated area is connected with the fact that one producer may also produce both organic and conventional foods. As illustrated by abovementioned, how can consumers be sure that the bought products, are indeed, organic and produced according to best practices? As it is said in the introductory part of the current article, most of the standards or regulations do not state values. Federation of Organic Agriculture Movements (IFOAM) has approved normative principles to identify organic agriculture:

- the principle of health,
- the ecological principle,
- the principle of fairness,
- the principle of care.

Trust is also very important aspect within the decision of purchasing organic food. Many researchers found out that the strongest influence on purchasing organic food were ethical concerns, followed by food safety and health (Michaelidou & Hassan, 2008; Tarkianen & Sundqvist, 2009). Ethics audit in an organic farm or food producer oftentimes indicate of possible risks associated to unethical instances, which in return may decrease the trust between consumers and producers. An ethics audit can help managers to quickly recognize potential adverse events, be more proactive and forward-looking, and establish proper risk responses. By using the ethics audit in organic farming, one can get an insight to the company and enable to develop tools to protect the business and consumers from hidden risks and ethical issues, which may usually stay unnoticed and may affect the company unexceptionally. On the other hand best practices identified during the audit are valuable marketing assets which build trust and indicate of highest ethical values in the production process. 'Do something good and let others talk about it' is probably the most effective way of communicating ethical values (Zander & Hamm, 2008). Communication and open dialog with potential consumers are therefore critical for the success of adding ethical values to organic offerings. The survey among organic small and medium sized farming enterprises in five European countries (Austria, Italy, German, Switzerland and United Kingdom) regarding additional ethical activities showed that a large range of different ethical arguments are realised but not always well communicated (Padel & Gössinger, 2008). According to Basgöze and Tektas (2012) majority of organic food consumers find it difficult to understand whether the product is 'green' or not. This approach is supported also by Zander and Hamm, who said that 'the messages pinpointing the additional ethical benefits are also spread by third persons or organisations with a high credibility and reliability, such as consumer organisations or environmental organisations'.

The auditing model in the current framework involves elements form grey areas of organic farming such as: supply chain, process of the production, cleaning and disinfection, protecting and preventing diseases, working conditions, relationship with local community, communication and PR.

Tabel 1. Fields of auditing, stakeholders, target groups and methods of auditing

Field of auditing	Core stakeholders	Data/ sources	Methods of auditing
Corporate Governance			
Efficiency and profitability	Owners	Annual report, declared values, mission	Observation of documents
Health and sustainability of the environment.	Society, employees, consumers	International standards, compliance to regulations, values	Interviews, observation of documents
Working conditions	Employees	Cases of discrimination, inequality, remuneration, undeclared salary contracts, declared values	Questionnaires, interviews, Walking tour in company
Personal policies	Employees	Recruitment and dismissal procedures, Training plan, bonuses	Questionnaires, interviews, observation of documents
Marketing policies and consumer dimension			
Producing process: cleanliness	Consumers, employees	Policies and procedures of producing, compliance to regulations	Questionnaires, interviews, observation of documents, Walking tour in company
Producing process: Conventional* and organic food	Consumers, employees	Policies and procedures of producing, compliance to regulation	Questionnaires, interviews, observation of documents, Walking tour in company
Producing process: Disinfection, safety	Consumers, employees	Policies and procedures of producing	Questionnaires, interviews, observation of documents, Walking tour in company
Producing process: Protecting and preventing diseases	Employees, consumers, Local community	Plan for self-control, compliance to regulation	Questionnaires, interviews, observation of documents
Consumers perceptions, trust	Consumers	Complaints handling procedure	Questionnaires, focus-group interviews
Relationship with society, local community	Local community, consumers	Involvement in social activities, sponsorship. Fair trade policies	Interviews, observation of documents

*In case when one producer also produces both organic and conventional foods.

Principles to what draw attention in auditing process are worked out according to literature review (Maloni & Brown, 2006; Michaelidou & Hassan, 2008; Zander & Hamm, 2008; Tarkianen & Sundqvist, 2009; Leppiman & Same, 2011) and experiences of ethical auditing carried out by the authors previously. Table 1 gives a general overview about the field of auditing, stakeholders and target groups of auditing and data sources, which auditors can use during the auditing process to collect information.

Indicators on assessing the specific field of ethics should be meaningful, significant, measurable and unpretentious. Indicators must tell to the auditors whether the company is making progress toward achieving ethical production and expectation of stakeholders. Compliance with relevant regulation is essential for auditing organic farming. However, the grey areas between regulation and real production process should not left without attention. For example, compliance with regard to auditing conventional food producer is not as important as auditing organic producer. According to Crane and Matten (2007) each organization needs a tailor-made approach towards stakeholder expectations and interests. When carrying out ethics audit, it is essential to take into account their nature, size, activities and location as well as capacities and other competitive in order to further improve their environmental and social performance in an innovative manner. Characteristics of auditing and surveys content should always be in correlation with the aim of auditing.

There are several reasons to implement auditing process and possibilities to take advantage of it.

Positive results of ethics audit will contribute to the disclosure of the marketing and communication process, helping to segregate themselves from other farmers. Ethics auditing is about supervising and advising, therefore the results cannot be released to the public, if owners or top managers do not agree with that.

From the other side, ethics audit is definitely a new tool for establishing trust and relevant communication for stakeholders within the Estonian business context. The Estonian business community needs more public information about the benefits of implementing an ethics audit. The ethics audit can improve farmer's ability to build up a transparent marketing communication between consumers and producer. In this way, businesses can guarantee that their activities are visible to the consumer. More energy should be invested in communication efforts by building up close relationships to important non-governmental organisations and stakeholder groups which fit into the main ethical messages.

CONCLUSIONS

Many consumers of organic food are demanding evidence that additional ethical values are really included into production. Both literature review and the findings of other authors confirm that official regulations and acts of organic food producing do not draw attention to ethical values and social responsibility aspects. The aim of this paper was to introduce ethics audit model and improve this model for organic farming companies by adding specific field of relevant aspects of the organic food producing, which are not regulated by others regulations or which are essential to increase trust between consumers and producers. An ethics audit enables farmers' better to plan marketing communication.

From theoretical contribution is important to mention that new framework of the ethics audit model can be used as a systematic survey instrument and theory-based process for correlating real organic producing and consumers' expectations with the aim to increase consumers' trust and awareness of organic food advantages. The current paper also contributes in terms of planning marketing communication strategies through an ethics audit. An ethics auditing can contribute in increasing the trust and transparency of companies among stakeholder.

Compiling the paper leads authors to another connected issue for the future research – what are the core values of organic farming companies and how these values support the main business activities. For the future, a trademark such as Approved Estonian Taste should be coined for ethical, organic farming, too – it is well known practice that a trade mark will help consumers to orientate better in a diverse food-market.

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Use of automatic system for pig feed consumption control

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Abstract. The aim of this study was to analyse average daily gain and feed conversion ratio, and to estimate daily gain and feed conversion ratio during the pig fattening period. 100 pigs from the same herd were housed in pens of around 10–15 animals and fed ad libitum with one single-place electronic feeder. Average on-test weight and off-test weight were 34.8 kg and 119 kg, respectively. Average daily gain, average daily feed intake and feed conversion ratio were computed. During investigation the average daily gain was 0.788 kg, the daily feed intake was 2.25 kg and feed conversion ratio was 2.86 kg. The differences in investigated traits between male and female pigs were significant. Generally, male pigs had greater off-test weight (+7.3 kg, $p < 0.05$), average daily gain (+0.037 kg, $p < 0.1$) and feed conversion ratio (+0.13 kg) in the fattening period. Average daily gain and feed conversion ratio were also calculated based on 100 kg off-test weight. If pigs will be fattening till 100 kg, than daily feed conversion ratio decreased and is 2.25 kg, but average daily gain increased and is 0.840 kg. The average fattening duration when pig has 100 kg off-test weight was 154.8 days. Phenotypic correlations between production and feeding traits were calculated. Correlation between average daily gain and feed conversion ratio was moderate negative (r = -0.542), pigs with higher average daily gain had better feed conversion ratio.

Key words: growth traits, feed intake, FCR, pigs.

INTRODUCTION

Pig selection program in Latvia is focused on production traits such as test daily gain, lifetime daily gain, and backfat thickness, whereas in pig selection program of different countries is payed more attention to production costs and the efficiency of conversion of feed.

Two maternal breeds – Landrace and Yorkshire and two paternal breeds – Pietrain and Duroc – are used in the pig breeding programme in Latvia. In the breeding goals for the maternal breed is put more attention on maternal traits (Paura et al., 2014). Paternal breeds' selection is focused on production traits. Many of the pigs on commercial farms are crossbred pigs.

Profitability in commercial pork production is determined not only by daily gain and backfat thickness, but also by lean growth rates and levels of feed intake and feed conversion ratio (FCR). There are many factors that influence feed intake and FCR. FCR are associated with breed, sex effect, and feed and management system.

According to Canadian Swine Improvement Program investigation Duroc and Yorkshire pigs grew faster than Landrace, with a difference of about 15 g d^{-1}, but there was not significant differences in feed intake and feed efficiency among breeds (CCSI report, 2007). Differences in pigs grow performance and FCR were found between barrow and female pigs. The barrows' grow performance and daily feed intake were higher, and lower feed efficiency or FCR than in female pigs (Latorre et al., 2003; Quiniou et al., 2010). Coffey et al. (1995) concluded, that gilts consumed 10 to 12% less feed and were about 4% more efficient in converting feed to body weight gain.

The aim of this study was to analyse grow performance and FCR during the fattening period of crossbred pigs used for commercial pork production in Latvia and to compare grow performance and FCR of barrow (males pigs) and female pigs.

MATERIALS AND METHODS

Data for this study included 100 pigs from the same herd. The performance test is carried out with Landrace x Pietrain and Landrace x Jorkshir x Pietrain crossbreds. Individual piglet weight at weaning was recorded. Piglets were weaned at 28 days of age and 70–77 days of age were allocated to tests. 10 till 12 pigs from one or two litters were grouped in one group into batches. Groups were held in pens with a single-place electronic feeder and fed ad libitum with the same feed composition.

Weight and feed intake were measured one time per week on each pig during a test period. Individual feed intake, weight and FCR were recorded when a pig visited single-place electronic feeder (Pig performance station, Holland). The Pig performance station consists of two parts: a feed through with weighing unit for the feed and a separate weighing unit for the pig. The pig-weighing platform can be easily adjusted to the size of the pig and the system has enough capacity for 15 pigs to feed.

FCR represents the proportion of food that is converted into the meat. FCR was calculated for week periods and over a set period as daily feed intake and average daily gain ratio. Average daily gain and daily feed intake were calculated for week periods and a test period. Average daily gain was calculated as the total weight in week or test period divided by the number of days. Average daily feed intake was calculated as the total amount of recorded feed intake divided by the number of the days. Average daily gain and FCR were also calculated based on 100 kg off-test weight. In total 1500 individual visits were recorded. Test period was 98–112 days. In the end of the test period, when the pigs reached in average 120 kg, ultrasound backfat thickness was measured.

The investigation data were processed using a program *R*. For comparison of investigation traits between sexes the *t-test* was used.

RESULTS AND DISCUSSION

Phenotypic description of traits

Average on-test weight and off-test weight were 34.8 kg and 119 kg, respectively. During investigation the average daily gain was 0.788 kg, the daily feed intake was 2.25 kg and feed conversion ratio was 2.86 kg (Table 1).

The results show the crossbreed animals' daily feed intake for the testing period was in range from 1.62 to 2.93 kg d^{-1} with variation 14.88%. In Baumung et al. (2006) study was reported the average daily feed intake during the fattening period from 30 kg live weight up to 106 or 110 kg Landrace animals showed the highest feed intake per test day – 2.35 kg d^{-1}. The highest Landrace daily feed intake results followed by Large White (2.29 kg d^{-1}) and Pietrain (1.72 kg d^{-1}) and differences between breeds were detected.

Table 1. Summary statistics for grow performance and feed efficiency traits (n = 100)

Traits	*Min*	*Max*	$\bar{x}$	*S*	*S*, %
On-test weight, kg	20.5	54.5	34.84	8.02	23.03
Off-test weight, kg	88.5	144	119.00	10.13	8.52
Daily gain, kg d^{-1}	0.509	1.010	0.788	0.114	14.56
Feed intake, kg	170.3	306.4	237.08	31.60	13.33
Daily feed intake, kg d^{-1}	1.62	2.93	2.25	0.34	14.88
Feed conversion ratio	2.29	3.83	2.86	0.33	11.54
Back fat thickness, mm	7	23	14.2	3.5	24.82

Analysis of the traits by sex

The male and female pigs were grouped into one pen and during the fattening period there were differences by sex.

The differences in investigated traits between male and female pigs were significant. Male pigs had higher off-test weight (+7.3 kg, p<0.05), average daily gain (+0.037 kg d^{-1}, p<0.1) and backfat thickness (+2.5 mm, p<0.05) in the fattening period. Generally, male pigs had higher daily gain in the fattening period; they also ate more feed (2.32 kg d^{-1}) and tended to have poorer FCR than female pigs. The female pigs are characterized by lower traits variation than male pigs' traits (Table 2).

Table 2. Analysis of production and feed efficiency traits by sex

Traits	Male		Female		*p-value*
	$\bar{x}$	*S*	$\bar{x}$	*S*	
On-test weight, kg	35.23	8.30	34.83	7.49	0.838
Off-test weight, kg	122.04	9.43	116.26	8.72	0.011
Daily gain, g d^{-1}	0.809	0.111	0.764	0.106	0.098
Feed intake, kg	243.30	32.37	231.22	28.64	0.109
Daily feed intake, kg d^{-1}	2.32	0.34	2.19	0.30	0.108
Feed conversion ratio	2.92	0.34	2.79	0.31	0.106
Back fat thickness, mm	15.4	3.6	12.9	2.6	0.003

According to the investigation of O'Connell et al. (2006) the average daily gain, when weight ranges from 80 to 100 kg, was 0.882 kg d^{-1} for male and 0.750 kg d^{-1} for female pigs, which corresponds to the average FCR – 2.92 kg and 3.30 kg, respectively. In different study considered to have separate diets for females, which have lower requirements for protein and amino acids at heavier weights (O'Connell et al. 2005, 2006) and is appropriate to keep separate male and female pigs during fattening period. When sex segregation was not practiced (mixed-sex pens), FCR was around 3.8% poorer (Agostini et al. 2014).

Analysis of the traits during the fattening period

Pig fattening started when pigs were 70–77 days old and the length of the fattening period depended on the intensity of pigs' growth and it was 98–112 days. In the end of fattening period pigs were minimum 168 and maximum 182 days old.

Pigs' average daily weight gain and food consumption ratio during the fattening period given in Fig. 1.

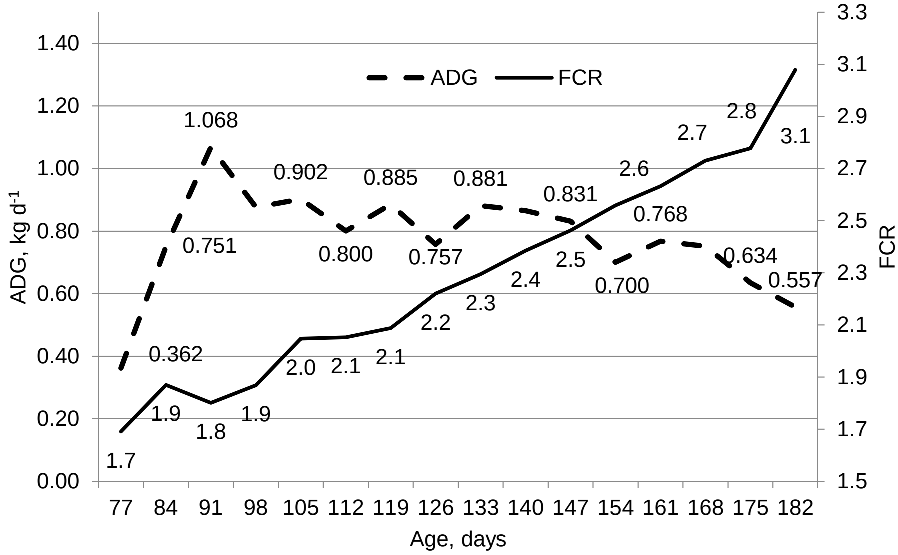

Figure 1. Average daily gain (ADG) and FCR during the fattening period.

In the first week of fattening, when pigs was 70–77 days old, the average daily weight gain was only 0.362 kg d^{-1} and was the lowest in the whole fattening period. It can be explained by the stress during adaptation period.

The higher average daily weight gain pigs showed in the 3rd fattening week and it was 1.068 kg d^{-1}. During the fattening period average daily weight gain was variable and in the end of fattening period when pigs was 175–182 days old it was significantly decreased till 0.557 kg d^{-1}.

The amount of feed consumed per day is highly influenced by age and live weight of animals (Baumung et al., 2006). High feed intakes in the finishing stage of fattening will improve the average daily gain – almost fat gain, which results in a higher feed conversion ratio and giving a higher feed cost per kg gain and less desirable carcass (Geurts & Hazzledine, 2011).

In our study the FCR increased during fattening period and in the last five weeks of the fattening period increased and reached 3.08. FCR increased with the age of the pig. This indicates that a slow fattening is not profitable, because the food consumption increased. Pigs were fattened till 120 kg of average live weight (Fig. 2). 154 days old pigs reached 102.2 kg the average live weight with average FCR 2.56.

Phenotypic correlation between average daily gain and feed conversion ratio was moderate negative (r =-0.542), pigs with higher average daily gain had better feed conversion ratio.

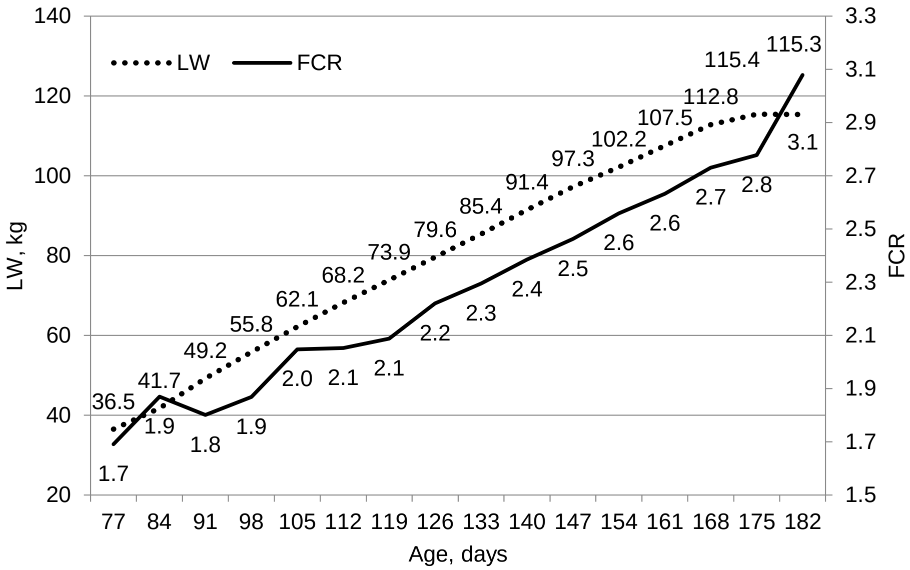

Figure 2. Average life weight (LW) and FCR during the fattening period.

Average daily gain and feed conversion ratio were also calculated based on 100 kg off-test weight. If pigs will be fattening till 100 kg, than daily feed conversion ratio decreased and is 2.25, but average daily gain increased and is 0.840 kg d^{-1}. The 100 kg off-test weight pigs reached when they were 154.8 days old.

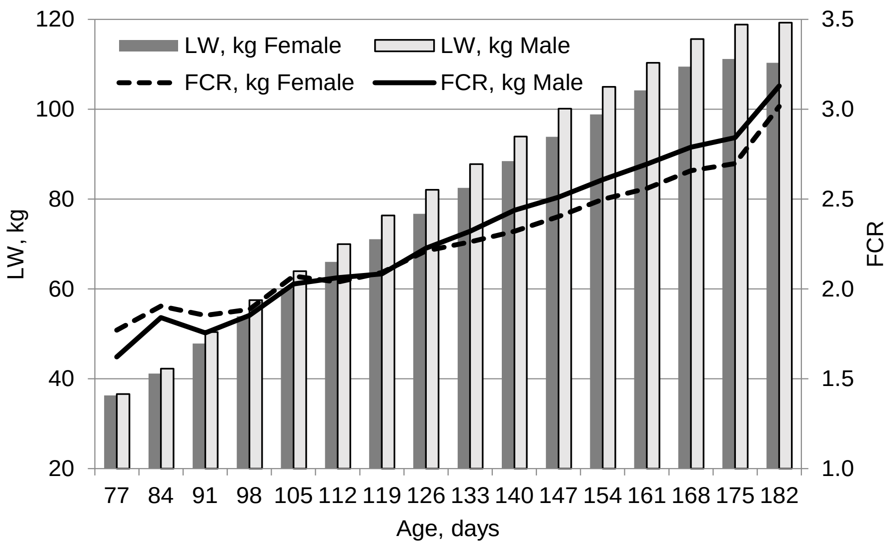

Figure 3. Average live weight (LW) and FCR during the fattening period by sex.

The average live weight and FCR in the first part of fattening period was not differing between female and male pigs (Fig. 3). A clear difference for average live weight and FCR between sexes ($p < 0.05$) was detected starting from the 70^{th} day of fattening period, when pigs were 147 days old. Male animals showed higher live weight and higher FCR.

According to investigations carried out by Moore et al. (2012), pigs from 20 to 50 kg live weight, entire males had a similar average daily gain, lower feed intake and better feed gain ratio, but from 50 to 100 kg live weight, entire males had a higher average daily gain, similar feed intake and improved feed gain ratio compared with females.

In the current study the live weight of male pigs in the end of fattening period was 8.9 kg greater ($p < 0.05$) and their feed conversion ratio was 0.11 poorer than female pigs.

CONCLUSIONS

The results of this study showed, that crossbred pigs from 35 to 120 kg live weight had the average daily gain 0.788 kg d^{-1}, the daily feed intake 2.25 kg and feed conversion ratio 2.86. Male pigs had higher daily gain in the whole fattening period; they also ate more feed and had higher FCR than female pigs. Male and female pigs had differences in FCR, because they were kept in mixed groups or the same differences would have been observed if pigs will be keeping separate. Male pigs showed higher live weight and the higher FCR starting from the 70^{th} day of fattening period, when pigs were 147 days old. It is concluded, if pigs will be fattening till 100 kg, than whole fattening period daily feed conversion ratio decreased from 2.86 to 2.25, but average daily gain increased from 0.788 kg d^{-1} to 0.840 kg d^{-1}.

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The influence of biobutanol on performance parameters of mobile generator

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Abstract. The expansion of biofuel also affects the area of using small internal combustion engines, which are widely used in municipal equipment such as minitractors, chainsaws, mowers and brush cutters. These small engines have their specific operation conditions, especially given by high operating speeds and high loads. Current legislation for fuel BA 95 prescribes the addition of ethanol. The percentage is however very small nearly not affecting the operation of combustion engines. The paper is focused on biobutanol since it is considered as more advanced type of alcohol based fuel than bioethanol. The measurement is focused on a small combustion engine of portable generator with maximum power of 2.5 kW. There is monitored influence of biobutanol on their performance parameters. As the mixing ratios are in the range of 100% fuel BA 95 (without ethanol) to 100% biobutanol.

Key words: combustion engine, bio-fuels, biobutanol, generator, engine parameters, fuel consumption.

INTRODUCTION

In order to reduce the amount of the greenhouse gases released into atmosphere, reduce the dependence on fossil fuels and their import to country, furthermore for support of local production the biofuels are used (Demirbas, 2009). The aim is to achieve a 10% share of energy from renewable sources in transport in 2020 according to EU directive 2009/28/EC. Currently, the ethanol is mostly used as a bio-substitution for gasoline in spark ignition engines. However, the ethanol has many disadvantages such as its affinity to the water, insufficient lubricity, aggression to the most of current sealing elements, low calorific value etc. (Čedík et al., 2014a; Čedík et al., 2014b). Butanol is the second generation biofuel and it is mostly used as admixture in diesel or biodiesel in compression ignition engines (Rakopoulos et al., 2010; Altun et al., 2011; Tüccar et al., 2014; Yilmaz et al., 2014). Production of butanol is similar as ethanol, it can be produced by fermentation or in petrochemical way (Ezeji et al., 2003). It is mainly used in spark ignition engines, requires the modification of the air-fuel mixing ratio, due to lower stoichiometric ratio of butanol, similar as when using ethanol. Butanol has several advantages over ethanol, such as a lower ignition temperature and higher calorific value. Butanol is more mixable with hydrocarbon fuels and the stoichiometric ratio is close to that of gasoline. This ratio allows the use of higher concentrations of butanol in gasoline without engine modification. Butanol is less corrosive due to lower affinity for water.

Properties of butanol are closer to fossil fuels. (Durre, 2007; Shapovalov & Ashkinazi, 2008; Qureshi & Ezeji, 2008; Andersen et al., 2010; Harvey & Meylemans, 2011; Swana et al., 2011; Serras-Pereira et al., 2013; Hönig et al., 2015a,b,c). Gasoline fuel blended with butanol was studied in the ratios from 3% vol. to 100% butanol (Rice et al., 1991; Alasfour, 1997; Yacoub et al., 1998; Gautam & Martin, 2000a; Dagaut & Togbé, 2008; Gautam & Martin, 2000b; Dagaut & Togbé, 2009; Wallne et al., 2009; Williams et al., 2009; Yang et al., 2009; Dernotte et al., 2010; Wigg et al., 2011; Gu et al., 2012; Feng et al., 2013; Elfasakhany, 2014). The results show that addition of butanol reduces exhaust emissions of CO, HC, CO_2, but NO_x emissions are increased depending on concentration and test conditions, as compared with gasoline. The increase in CO and HC and NO_x emissions is reduced at concentrations greater than 60% butanol. Due to lower calorific value than gasoline the specific fuel consumption is higher and the torque and power are lower compared with gasoline. Better combustion efficiency can be achieved due to better anti-detonation characteristics of butanol compared with gasoline and higher oxygen content. Some sources indicate the increased torque and reduced energy consumption at 35% concentration of butanol in gasoline (Feng et al., 2013). Other sources state that the engine power is maintained at proportion of 80% (by volume) gasoline and 20% butanol. (Yang et al., 2009). Most of the above studies were carried out on the engines with fuel injection. Sources indicate small ratios to (3, 7, 10%$_{vol.}$ Butanol) mixture of butanol in gasoline for testing engine carburettor (Elfasakhany, 2014).

Due to the fact that the market for small internal combustion engines is currently based on the delivering fuel through the carburettor, this paper is focused precisely on this issue. Fuel injection on small internal combustion engines is used only rarely at their recent construction.

The aim of this paper is to compare the performance parameters and fuel consumption of the mobile generator with rated power of 2.7 kW powered by small combustion engine while using fuels based on biobutanol and BA 95 petrol. The mixing ratios are selected in the range from 100% BA 95 (without ethanol) up to 100% biobutanol.

MATERIALS AND METHODS

Measurements were carried out on mobile generator ProMax 3500A with a rated power of 2.7 kW powered by small Briggs and Stratton engine type Vanguard 6,5 HP with a rated power of 4.8 kW. Assembly of small combustion engine and the alternator is suitable for the quick and easy driving of load of the engine. In this case value of the output current of the alternator is proportional to combustion engine load.

During loading of the combustion engine there is measured frequency, electrical current and voltage of the output of the generator (elektrometer ZPA ED310 equipped with an RS 485, the accuracy of 0.05%). Simultaneously with the measurement of electrical parameters is also measured fuel mass flow rate using Vibra AJ 6200 standard precision scale (measuring range from 0 to 6,200 grams and the accuracy 0.1 g). In order to monitor the operating parameters of the engine during measurements, the oil temperature sensor, fuel temperature sensor and intake air temperature sensor was mounted on the engine. All data are stored to the PC memory using RS482 to RS232 interface and for this purposes software application was developed.

The principle of measurement is based on the principle of operation of the internal combustion engine and electric generator. The internal combustion engine operates in the range about 3,000 rpm, corresponding to a frequency of 50 Hz of electric generator output. During loading of the internal combustion engine decreases its speed according to the control part of the engine characteristics. However, properly adjusted governor of the engine keep the engine speed steady regardless of engine load. At the moment when is external speed characteristics is achieved, so there is a significant change in engine speed and thus the output frequency of the electric generator.

Measurement is focused on monitoring of the impact of fuel mixture on the fuel consumption during controlled loading of the engine.

Based on engine operation while using pure BA 95 petrol (% BUT) there was selected several measurement points in steps approximately 25%, 50%, 70% and 95% of rated power. Measurement point at a full load (100%) is not selected because of possibility of reaching the external speed characteristic of the engine.

Transmission losses and the change in viscosity of the oil are not considered. The measurement is performed at an operating temperature, which is dependent on the load and the engine oil temperature was kept within the range of from 90 °C to 110 °C.

Used fuels are based on biobutanol and BA 95 petrol. Especially for this measurement there was fitted BA 95 petrol without any bio-components required by the law. In the Czech Republic ethanol is mainly used as this component. There were chosen several ratios of biobutanol and BA 95 petrol:

100% of petrol (0% BUT)
75% of petrol and 25% of biobutanol (25% BUT)
50% of petrol and 50% of biobutanol (50% BUT)
25% of petrol and 75% of biobutanol (75% BUT)
100% of biobutanol (100% BUT).

During the measurement there the air–fuel equivalence ratio was monitored. Consequently, the air-fuel ratio (AFR) was changed using the choke valve. AFR for pure petrol is commonly 14.7:1 and 12:1 for butanol.

RESULTS AND DISCUSSION

Table 1. shows average values of engine torque (calculated), power, speed, mass fuel consumption and specific fuel consumption and standard deviations for each operation mode of an engine.

Fig. 1. shows engine speed and power developed at the respective engine modes. It is obvious, that engine mode is set without significant inaccuracies. Only in the case of engine mode no. 20 there is evident, that 95% engine load results in significant decrease in speed. At this particular point there was transition between control area and external speed characteristics of the engine. Based on this point it can be expected that 95% load of the engine using 0% BUT fuel corresponds with 100% load of the engine running with 100% BUT fuel. Performance parameters of the engine declined about 5% when changing fuel from pure petrol to pure biobutanol.

Table1. Engine mode and measured engine parameters

		Engine parameters					Standard deviation		
Fuel	Engine mode	Torque (Nm)*	Power (kW)	Engine speed (rpm)	Fuel consumption (kg h^{-1})	Specific fuel consumption (g kWh^{-1})	Power (kW)	Engine speed (rpm)	Fuel consumption (kg h^{-1})
0% BUT	1	2.01	0.666	3,169	0.459	689.1	0.00139	2.78	0.0306
	2	3.96	1.302	3,141	0.712	547.4	0.00112	1.50	0.0813
	3	5.87	1.913	3,113	0.895	468.3	0.00185	3.17	0.0854
	4	8.04	2.554	3,046	1.088	426,3	0.00979	6.61	0.0703
25% BUT	5	2.01	0.666	3,169	0.560	841.2	0.00105	5.00	0.0448
	6	3.93	1.304	3,140	0.728	558.1	0.00287	3.18	0.0865
	7	5.89	1.921	3,113	0.934	486.5	0.00370	2.84	0.0575
	8	8.11	2.580	3,046	1.126	436.4	0.00830	4.23	0.0808
50% BUT	9	2.01	0.665	3,166	0.617	928.1	0.00153	10.26	0.0632
	10	3.96	1.298	3,131	0.724	557.4	0.00356	4.83	0.0992
	11	5.85	1.903	3,106	0.892	468.7	0.00130	4.50	0.0704
	12	8.05	2.560	3,038	1.113	434.7	0.00749	11.93	0.0719
75% BUT	13	2.03	0.672	3,157	0.679	1009.8	0.00211	5.66	0.0958
	15	5.88	1.912	3,106	0.900	470.8	0.00487	3.43	0.0494
	16	8.10	2.557	3,013	1.165	455.7	0.00843	4.80	0.0643
100% BUT	17	2.05	0.677	3,152	0.664	980.0	0.00185	4.80	0.0410
	18	4.03	1.321	3,127	0.832	630.1	0.00170	2.72	0.0429
	19	5.97	1.939	3,080	1.019	525.3	0.00406	3.37	0.0510
	20	8.46	2.589	2,902	1.236	477.6	0.00785	16.46	0.0537

* calculated value

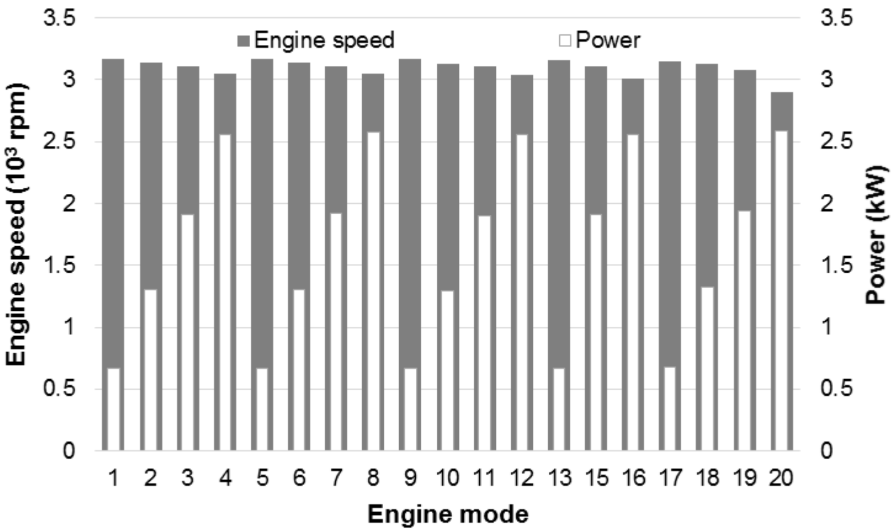

Figure 1. Engine modes selection chart.

The progress of fuel consumption in various operating modes of the engine is shown in Fig. 2. It is evident that a change in fuel consumption due to the changes in air-to-fuel ratio of the fuels' mixture occurred primarily in the engine performance modes corresponding to the lower loads. For loads of 25% was due to addition of biobutanol the increase in specific fuel consumption was 30%, while the fuel consumption did not change by more than 10% when running at a full load. The lowest specific fuel consumption of 426.3 g kWh^{-1} was achieved when using a fuel containing 0% butanol (0% BUT) for full load (about 95%) operation.

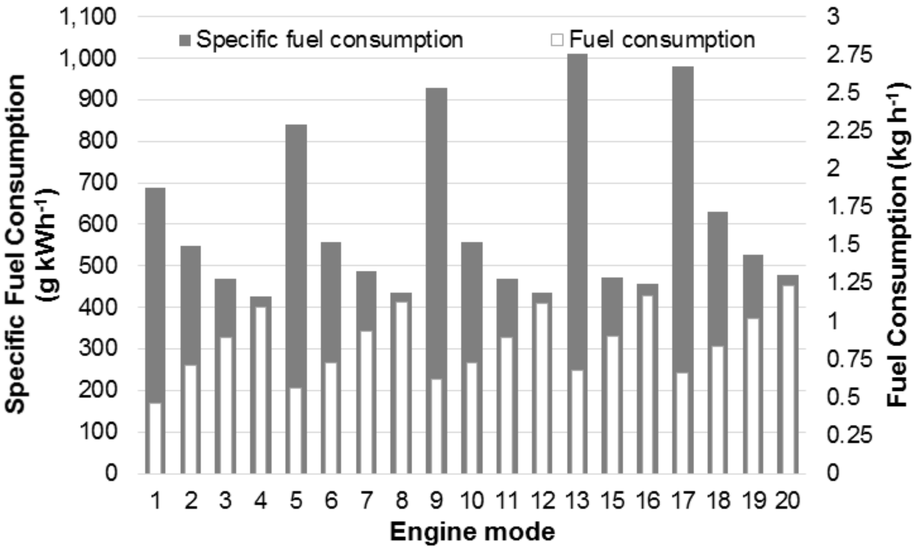

Figure 2. Changes in fuel consumption at specific engine modes.

CONCLUSIONS

When operating with a small internal combustion engine, it was noted that in short terms of combustion any ratio of biobutanol and petrol premixed can be suitable for generation of electrical energy. The higher percentage of biobutanol results in a worse start of cold engine. There were no major changes in other evaluated parameters (Table 1., Fig. 1., Fig. 2.):

- performance parameters (output power) of the engine were not decreased by more than 5%,
- mass fuel consumption and specific fuel consumption varies mainly at lower loads, where the difference is up to 30%,
- the difference in fuel consumption does not exceed 10% at higher loads (The lowest specific fuel consumption 426.3 g kWh^{-1} was achieved at full load (about 95% of rated power) with a fuel containing 0% butanol).

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New constructs for ethanol production via cyanobacteria

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Abstract. Alternatives to fossil fuels must be developed due to several already known reasons. Bioethanol can be an attractive energy concept. Bioethanol gasoline hybrid fuel can be used by most internal combustion engines. First and second generation bioethanol production is already available – here agricultural crops or residues are utilised. There are controversial discussions about these bioethanol production methods – the food versus fuel debate, cost and energy efficiency. Alternative advanced bioethanol production must be established with competitive production costs. Photosynthetic prokaryotes like cyanobacteria are attractive organisms for this purpose – these prokaryotes are fast growing organisms and utilize solar energy and CO_2. But these prokaryotes must be genetically manipulated for ethanol production. In this study transformation was performed using homologous recombination to introduce the pyruvate decarboxylase (*pdc*) and alcohol dehydrogenase B (*adhB*) genes of *Zymomonas mobilis* into the photosynthetic prokaryote *Synechococcus elongatus* PCC 7942 genome. These cyanobacteria grow in fresh water and seawater or even in wastewater. Both genes were expressed under the control of the strong constitutive promoter of psbA1 gene (encoding photosystem II protein D1). Various cloning strategies were done. Each construct was transformed successful in *Synechococcus elongatus* PCC 7942 and the potential bioethanol production was determined with HPLC. Only one construct produces bioethanol at detectable level. Diverse reactors and scale up steps were done to increase the bioethanol production. Anyhow further cloning strategies must be implemented to improve the production rate to achieve an effective bioethanol production from *Synechococcus elongatus* PCC 7942.

Key words: bioethanol, third generation, cyanobacteria, genetic manipulation.

INTRODUCTION

For transportation bioethanol is a good possibility to replace fossil fuels, up to 10 percent gasoline can be replaced by bioethanol in each gasoline-powered vehicle without any modification. Bioethanol is actually produced from food crops (first generation bioethanol) or lignocellulose (second generation bioethanol) but also other routes for bioethanol production must be established to meet the demands. One route is the usage of photo-autotrophic microorganisms. The bioethanol production via photo-autotrophic microorganisms demands short fermentation times, high volumetric productivity, simple handling, low risk of contaminations and low operating cost. Microorganisms like cyanobacteria are in focus of the research – due their potential for photoautotrophic conversion of CO_2 into a broad range of industrially valuable compounds like isobutanol, isopropanol and also bioethanol (Ducat et al., 2010).

The first paper about the bioethanol production via *Synechococcus elongatus* was published in the year 1999 (Deng & Coleman, 1999). Several companies and working groups work on this issue using diverse cloning strategies and various cyanobacteria strains (reviewed in Dexter et al., 2015). The latest patent from the company Algenol reported a maximum rate of 0.552 g L^{-1} bioethanol after one day from the strain ABICyano1 (patent 2014178958). Anyhow for efficient bioethanol production via cyanobacteria higher ethanol concentration must be achieved in shorter time.

In this work several vectors were designed to achieve *Synechococcus elongatus* PCC 7942 strain that converts CO_2 to bioethanol. The *Synechococcus elongatus* PCC 7942 strain is a fresh-water cyanobacterium, obligate autotroph with a genome of approximately 2.7 Mb and two endogenous plasmids (Kaneko et al., 1996). It was the first cyanobacterium demonstrated to be reliably transformable by exogenously added DNA (Shestakov & Khyen, 1970). First the gene cassette pyruvate decarboxylase (*pdc*) and alcohol dehydrogenase B (*adhB*) genes from *Z. mobilis* under the control of the strong constitutive promoter of psbA1 gene (encoding photosystem II protein D1) was used for the transformation of *Synechococcus elongatus* PCC 7942. The strong constitutive promoter of psbA1 gene was never used for ethanol production in *Synechococcus elongates*. In another study the psbAII promoter was used (Dexter & Fu, 2009) which differs according the publication of Mulo et al. (2009).

Furthermore diverse constructs from this cassette or adding of the *adhA* gene direct amplified from the genomic DNA of *Z. mobilis* were done to check a potential increase in the bioethanol production after successful transformation. Only the *Synechococcus elongatus* PCC 7942 transformed with the vector including the gene cassette exhibited ethanol production. The transformations of the other two vectors were successful but no bioethanol production was detectable. Further cloning must be done to achieve successful bioethanol production via cyanobacteria.

MATERIALS AND METHODS

Cloning vector and cloning stratagies

The vector pSyn_6 from the company Invitrogen (www.invitrogen.com) was used for each strategy. The vector contains among other important normal cloning sites two specific cloning sites – NS1 (neutral site 1) homologous recombination sites for the integration of the vector into the *Synechococcus elongatus* PCC 7942 genome and the strong constitutive promoter psbA1 gene (ending photosystem II protein D1) from *Synechococcus elongatus* PCC 7942 enabling the high level expression of the cloned gene. The construct pLOI295 was kindly provided by Lonnie O. Ingram (Department of Microbiology and Cell Science, University of Florida, Gainesville 32611). This construct contains the gene cassette encoding *adhB* and *pdc* gene from *Z. mobilis*. The construct P6C were produced using the construct pLOI295 as template via the PCR method. The other two constructs – were amplified via PCR from the construct pLOI295 or direct from the genomic *Z. mobilis* DNA as described in detail elsewhere (Pfannerer, 2014). Here each gene has its own promtor and terminator and was subcloned consecutively. The vector named P6PA included the gene *adhB* and *pdc* gene and the vector P6PAA contained an additionally gene, *adhA* see Fig. 1).

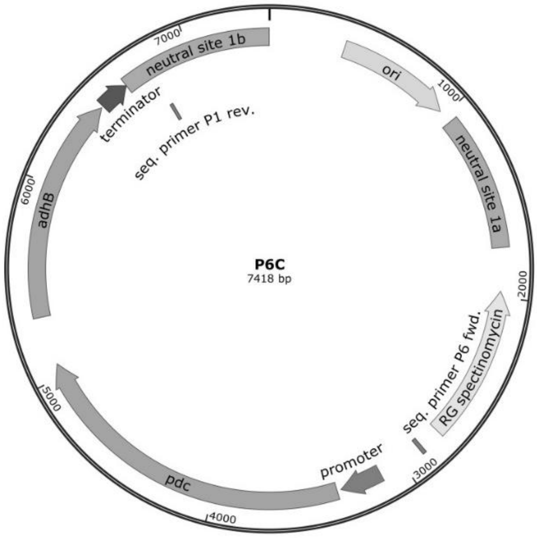

Figure 1. The map of the vector P6C – The vector with the name P6C included the original gene cassette encoding *adhB* and *pdc* gene.

PCR conditions and primers

The PCR was done with the forward and reverse primer (each 50 pM), 1 Unit Pfu Polymerase (company: Promega; www.promega.com) plus buffer, 200–500 ng template DNA, 10 mM dNTP Mix (company: Promega; www.promega.com), 3 µl DSMO (fill up to total volume of 50 µl with water). The sequences from forward and reverse primer from construct P6C were: 5´-GGA ATT CCA TAT GAG TTA TAC TGT CGG TAC C-3´and 5´-CCA ATG CAT TTA GAA AGC GCT CAG GAA GAG-3´. The PCR product was digested with NdeI and NsiI and ligated into NdeI and NsiI digested vector pSyn_6. Diverse subcloning steps were necessary for the construction of the other two constructs and are described in detail elsewhere (Pfannerer, 2014). Only the primers for the ampification of the *adhA* gene from the genomic DNA of *Z. mobilis* are mentioned: 5´-CAC CAT GAA AGC AGC CGT CAT AAC TAA A-3´and 5´-CTA GTG ATG GGT AAA ATC AAC AAC C-3´. Each construct was sequenced (company: VBC-Biotech; www. http://www.vbc-biotech.at/) to verify the correctness of the cloning. Transformation of *Synechococcus elongatus* was done according to the manufactory manual (www.thermofisher.com).

Ethanol measurements with HPLC

The potential ethanol production via cyanobacteria was measured with HPLC analyses. One milliliter of medium was transferred into a 1.7 mL centrifugation tube and centrifuged for 5 minutes at an rotational speed of 13,000 min^{-1} (centrifuge: Eppendorf 5417C with an angle rotor type FA 45-30-1). The clear supernatant was transferred into a 1.7 mL screw cap vial and stored at -18 °C until measurement. Ethanol concentrations were quantified by HPLC, using an Agilent Technologies 1200 Series equipped with a Varian Metacarb 87 H column (300 x 7.8 mm) at 65°C, H_2SO_4 (c = 5 mmol L^{-1}) eluent and an isocratic flow rate of 0.8 mL min^{-1} was used. The data acquisition was performed per refractive index detection and UV–detection at 210 nm.

For calibration the method of external standard was applied. Data analysis was performed per Agilent Chemstation 04.03 b.

Determination of the growth curve from *Synechococcus elongatus*

After transformation precultivation of *Synechococcus elongatus* positive clone were done in BG11 media after transformation at illuminance of 100 μE m^{-2} s^{-1}. The BG11 media persist of boric acid 0.00287%, manganese chloride tetrahydrate 0.00181%, zinc sulphate heptahydrate 0.00022%, sodium molybdate dehydrate 0.00039%, copper sulphate pentahydrate 0.00008%, sodium nitrate 0.15%, calcium chloride dehydrate 0.0027%, ferric ammonium citrate (green) 0.0021%, EDTA 0.0001%, potassium phosphate dibasic 0.0039%, magnesium sulfate heptahydrate 0.0075%, sodium carbonate monohydrate 0.002%, each concentration in [%w/v]. Optimal density was measured at 750 nm with photometer (spectral photometer Hach Lange Xion 500). At $OD_{750} = 1$ the precultivation sample was diluted in BG11 media to $OD_{750} = 0.01$. Samples were taken each 24 hours. Cell growth was recorded as increase in OD_{750} and the potential ethanol production via cyanobacteria was measured with HPLC analyses. As negative controls the BG11 media and wild type *Synechococcus elongatus* were used.

RESULTS AND DISCUSSION

Three different vectors were constructed via PCR from the template construct pLOI295 or amplified direct from the genomic DNA of *Z. mobilis* and named P6C, P6PA and P6PAA. The vector P6C contains the original cassette encoding *adhB* and *pdc* gene from *Z. mobilis* (see Fig. 1).

This cassette was separated in the vector P6PA using PCR and ligation and each gene had its own promoter and terminator (see Fig. 2). One additional gene, *adhA* from *Z. mobilis*, was introduced using PCR and ligation, the resultant vector was named P6PAA (see Fig. 2).

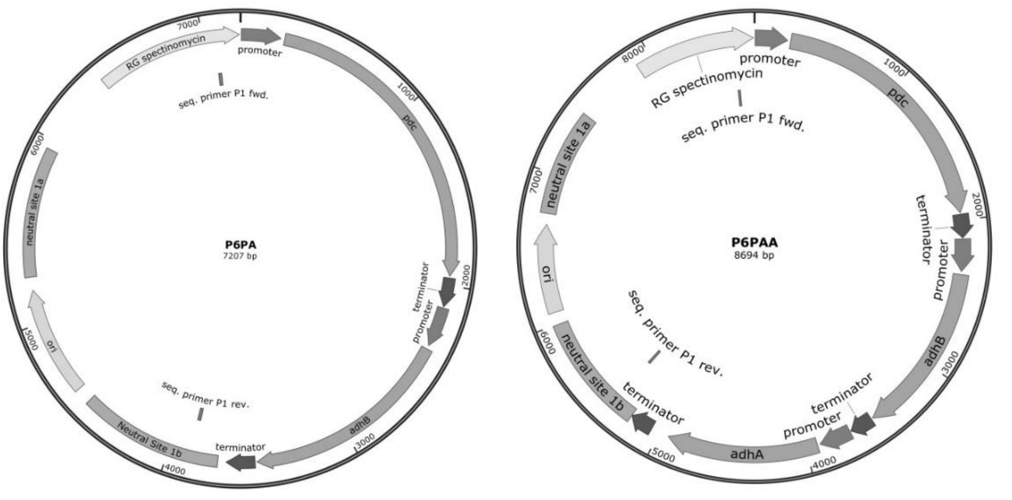

Figure 2. The map of the vectors 6PA and P6PAA – The P6PA contained the gene *adhB* and *pdc* gene consecutively, each with its own promoter and terminator. The vector P6PAA included an additionally gene, *adhA*.

Each vector was controlled via sequencing and transformed into *Synechococcus elongatus* cells. After several days many colonies were observably on the agar plate.

Exchange the Fig. 2 (plus text).

Ten colonies were picked, the successful transformation of the *Synechococcus elongatus* cells was controlled via PCR using the cloning primers and cultivated in 6 mL BG 11 media (in 6 wells plate) to check the growth. Well growing colonies were transferred to 500 mL shake flasks containing 100 mL media. Media and wild type *Synechococcus elongatus* cells were used as negative controls. Each 24 hours samples were taken and the potential bioethanol production were checked via HPLC method. Furthermore the optical dense was measured from each sample. Wild type *Synechococcus elongatus* cells grown faster than the transformed *Synechococcus elongatus* P6C cells (see Fig. 3).

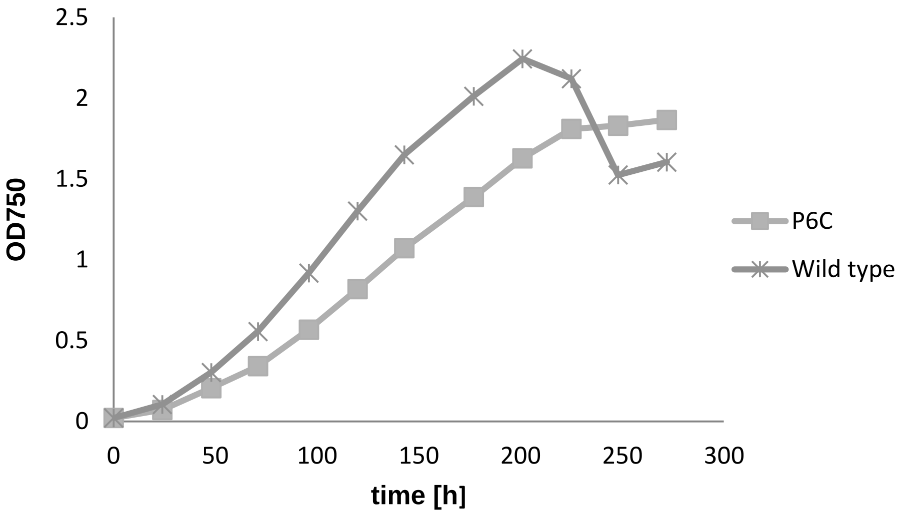

Figure 3. Growth curve of wild type and transformed *Synechococcus elongatus* P6C cells at OD 750 nm.

The sharp decrease within the growth curve after about 220 hours from wild type *Synechococcus elongatus* was generated maybe due to decline of trace elements like iron but must be clarified in detail. Bioethanol was only detected in media from *Synechococcus elongatus* P6C cells See Fig. 4). Also the other transformed *Synechococcus elongatus* shown the same growth curve like *Synechococcus elongatus* P6C cells (data not shown) but produced no bioethanol.

The bioethanol production from *Synechococcus elongatus* P6C cells increased up to a maximum of 0.05 g L^{-1} after about 250 hours (see Fig. 4). In comparison the strain ABICyano1 from the company Algenol reached a the maximum rate of 0.552 g L^{-1} bioethanol after one day (patent 20140178958). Also direct comparison with other data is not possible – our strategy was never use from other researcher.

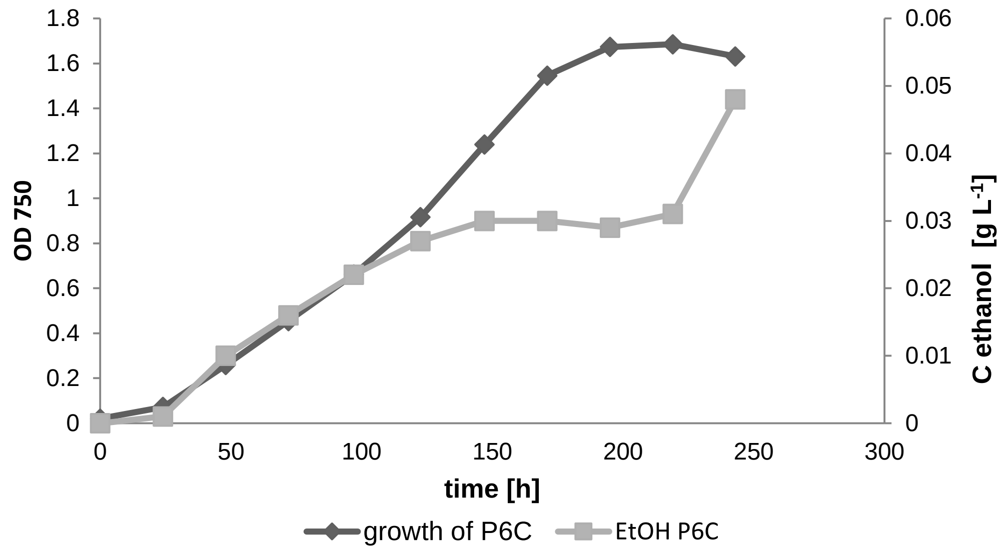

Figure 4. Growth curve of transformed *Synechococcus elongatus* P6C cells at OD 750 nm. Parallel potential bioethanol production of each sample was measured with HPLC.

Anyway here the experiments were done in a very simple way – no fixed closed system (only closed with cotton wool) in a shaker flask – no reactor with regulation of the light, CO_2, pH value and nutrients within the media like the system from the company Algenol. Therefore improvements concerning the *Synechococcus elongatus* cultivation are underway in our lab and further genetic improvements must be performed to increase the bioethanol production.

CONCLUSIONS

Diverse products like bioethanol can be manufactured from cyanobacteria after genetic manipulation, but also glucose/fructose or lactate (for further information see Ducat et al., 2010). But the productivity must be increased for industrial scale up – diverse different strategies were done concerning the genetic manipulation of cyanobacteria – other kind of vectors, other promoter and other strain of cyanobacteria and so on. Here we tested the strong constitutive promoter of psbA1 gene (ending photosystem II protein D1) and diverse combinations of the gene pyruvate decarboxylase (*pdc*), alcohol dehydrogenase B (*adhB*) or *adhA* from *Z. mobilis* or the gene cassette (original from Lonnie O. Ingram). Only the *Synechococcus elongatus* P6C cells transformed with the vector including the gene cassette produced bioethanol at high level after about 250 hours at suboptimal cultivation condition. Furthermore technical and genetic improvements must be done for industrial scale up.

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Reuse of spent mushroom substrate by modification and its qualitative parameters

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Abstract. In this study the agronomic viability of *Pleurotus ostreatus* (Jacq.) P. Kumm. is studied by reusing the spent substrates previously used in crops of the same mushrooms. After the physical and chemical characterization of the substrates, we have evaluated qualitative production parameters in one growing season. As base material, the experiment was arranged with wheat straw (WS) and spent *Pleurotus* substrate (SPS) to generate prepared substrates with the participation of the same, alone and mixed in different proportions with wheat bran (WB). Unsupplemented SPS, supplemented SPS with 600 g of WB, mixture of WS + unsupplemented SPS, and mixture of WS + supplemented SPS with 600 g of WB, are prepared substrates that have achieved acceptable crude protein content in fruit bodies at the expense losing texture, but not firmness. Also these substrates promote brightness, and yellow-blue (b*) and red-green (a*) chromaticity of the harvested mushrooms.

Key words: Agricultural wastes; Edible mushrooms; *Pleurotus ostreatus* (Jacq.) P. Kumm.; Breaking strength; Growing media.

INTRODUCTION

The potential production of edible fungi is promising in the world market, as the current production does not reach to cover its demand. Most producing countries are importers too, since the average consumption in these countries is very high. Nutritionally, these species have moderate amounts of high quality protein, contain all essential amino acids, are rich in lysine and leucine, vitamin C, B vitamins, minerals, and trace elements. Furthermore, lipid levels are low, the ratio of saturated to unsaturated fatty acids is low, contain relatively high amounts of carbohydrates, and most species have high amounts of nutritionally valuable fibers (Chang & Miles, 1997). Complementary to its nutritional properties, there are various health benefits known in the fields of Medicine and Therapeutics, such as antitumor, antibiotic, antifungal, and anti-inflammatory effects, they are hypocholesterolemic, and they promote a healthy immune system. Additionally, they have been widely used to treat cancer and HIV (Brizuela et al., 1998). Approximately, there are around 300 species of cultivated mushrooms, but only 30 have been domesticated and just 10 are commercially grown. The most important cultivated mushroom worldwide is *Agaricus bisporus* (Lange)

Imbach, followed by *Pleurotus ostreatus* (Jacq.) P. Kumm. and other species of the genus *Pleurotus*; *Lentinula edodes* (Berkeley) Pegler is third and other edible fungi are making headways into the market.

The reason for this growth is because of the characteristics of the genus *Pleurotus* species (Sanchez, 2010): they have excellent organoleptic quality. They are easy to grow on a wide variety of substrates within a wide temperature range, and they have a great potential in bioremediation processes. Moreover, little initial capital is required to establish warehouses for growing. The preparation of the substrate does not require a lengthy complex composting, nor an application of a casing at the end of mycelial growth (such as white mushrooms), or a water immersion or dipping phase (such as shiitake). Unlike white mushrooms (*Agaricus bisporus* (Lange) Imbach), these do not require a substrate with chemical selectivity because they can grow in nutrient media with a C/N ratio between 30 and 300 (Rodriguez Barreal, 1987; Garcia Rollán, 2007). However, they need to grow in a specific biological environment with accompanying flora to protect and promote growth (Muez & Pardo, 2002). Approximately, 13,500 t of this fungus are produced in Castilla - La Mancha (67% of the national total) (Pardo et al., 2009). The Mushroom Growing Sector in Spain generates about 5 10^5 Mg of spent compost, while the EU, as a whole, produces more than 3.5 10^6 Mg (Pardo et al., 2009; Picornell et al., 2010). This lignocellulosic material called mushroom spent substrate, can be used in various fields of Agriculture (animal feed (Zadrazil, 1980), amendments (Tajbakhsh et al., 2008), substrates of nurseries, nurseries, (Medina et al., 2009), Bioremediation (Faraco et al., 2009), Aquaculture, Vermiculture and Biofuel (Pathak et al., 2009). But these uses are not enough to output the high volumes generated year after year that are accumulated in collection centers located in production areas of Spain, which can be potential contaminants, not to mention, a waste of energy. *P. ostreatus* has specific enzymes capable of degrading cellulose, lignin, phenols, and polyphenols to 60% of the original content of the spent substrates. Currently, cereal straw (wheat in particular), with increasing constraints in availability and price, is almost the only material used at an industrial scale for the production of *P. ostreatus* in Spain. The feasibility of using alternative materials of high availability and low price is a line of research of great technological interest to keep up with improve productivity and reduce processing costs (Muez & Pardo, 2002; Pardo et al., 2007, 2009; Picornell et al., 2010).

According to various studies, the most commonly profitable and readily available spent substrate which generates high quality fruit bodies for *P. ostreatus* mushroom growing (although this fungus can be grown on virtually any lignocellulosic substrate (sawdust, cereal straw, etc.)) is the trunk of *Quercus humboldtii* Bonpland specie (oak) (Garcia Rollán, 2007; among many others). Commercially in most industrial exploits, 2–4 cm long (Sanchez, 2010) pieces of winter cereal straw (wheat, barley and rye) (Savalgi & Savalgi, 1994) is used in the substrate container for the production of *Pleurotus* genus and others, such as *Pleurotus eryngii* (DC.: Fr.) Quel., *Pleurotus sajor-caju* (Fr.) Singer, *Pleurotus pulmonarius* substrate (Fr.) Quel., etc. Khanna & Garcha (1982) refer to rice straw as the best substrate for the cultivation of *Pleurotus sajor-caju* (Fr.) Singer, while wheat straw (which is similar to rice straw) is the best substrate for the cultivation of *Pleurotus* spp. (Bonatti et al., 2004). Biodegradation of these cellulosic residues by *Pleurotus* spp. growing depends on the production of hemicellulases, cellulases, and ligninases enzymes (Kurt & Buyukalaca, 2010). These enzymes, and others, turn and degrade long and insoluble components of lignocellulosic materials into soluble components and of low molecular weight that are taken by intracellular enzymes from fungi for their nutrition. Additional, enzymes play an important role in the growth and development of fungi (Kuforiji & Fasidi, 2008). However, the lignocellulosic materials are generally low in protein content with insufficient values of nitrogen, phosphorus, and potassium (Vijay et al., 2007) mushroom cultivation. Organic supplements commonly used in the preparation of growing substrates are organic in nature (Wang et al., 2001). Among these substrates, wheat and rice bran are the most used (Wang et al., 2001; Peksen & Yakupoğlu, 2009; Kurt & Buyukalaca, 2010).

The aim of this work is the qualitative agronomic evaluation of the spent *Pleurotus* substrate (SPS), and its mixture with WS in different proportions, as lignocellulosic source in new growing cycles of *P. ostreatus*, unsupplemented and supplemented with different doses of WB.

MATERIALS AND METHODS

Analytical methodology for the characterization of materials

For the characterization of raw materials and processed substrates the following parameters were determined: moisture (MAPA, 1994), pH (Ansorena, 1994), total nitrogen (MAPA, 1994; Tecator, 1987), ash (MAPA, 1994), organic matter (Ansorena, 1994), C:N ratio, crude fiber (ANKOM, 2008), crude fat (ANKOM, 2009), nitrogen free extractives (González et al., 1987), cellulose, and neutral detergent-soluble (NDS) (ANKOM, 2005, 2006a, 2006b). Furthermore the exploration of mites (Krantz, 1986) and nematodes (Nombela & Bello, 1983) was performed.

Preparation of substrates and experimental design

Source materials used in the preparation of the substrates were spent *Pleurotus* substrates remaining after the growth of *P. ostreatus* (SPS), and the mixture of WS with unsupplemented and supplemented SPS with a dose of 600 g, 1,200 g, and 1,800 g of WB. For reference, two commercial substrates from different sources were used to WS, unsupplemented and supplemented with the same doses of WB. According to the corresponding experimental design, twelve different treatments were generated, beside the two substrates corresponding to the commercial reference. In all treatments calcium sulfate was added at 50 g kg^{-1} of base material. $CaCO_3$ was not added to the 4 base substrates consisting of WS solely, whereas the remaining treatments received various amounts of $CaCO_3$ depending on the amount of SPS used (20 g kg^{-1} of SPS). $CaCO_3$ or gypsum was not added to the commercial substrates (Table 1). The first step in the preparation of the tested substrates consisted of the chopping and pre-soaking of the WS and subsequently mixing them with the substrates to adjust their moisture content. Once ready, the substrates proceeded to a pasteurizing heat treatment (60–65 °C, 8 h), and a progressive decrease of at least 15 h to a 'seeding' temperature (25 °C). Finally supplementation and 'seeding' were carried out (dose, 30 g kg^{-1} of Gurelan mycelium H-107) before manual bagging in CIES pilot plant.

Table 1. Treatments tested (g bag^{-1}) in the Experiment

TREATMENT	WS	SPS	WB	GYPSUM	$CaCO_3$
T1	6,000	0	0	300	0
T2	5,400	0	600	300	0
T3	4,800	0	1,200	300	0
T4	4,200	0	1,800	300	0
T5	3,000	3,000	0	300	60
T6	2,700	2,700	600	300	54
T7	2,400	2,400	1,200	300	48
T8	2,100	2,100	1,800	300	42
T9	0	6,000	0	300	120
T10	0	5,400	600	300	108
T11	0	4,800	1,200	300	96
T12	0	4,200	1,800	300	84
T13	Commercially controlled based substrates (A) (6.5 kg bag^{-1})				
T14	Commercially controlled based substrates (B) (6.5 kg bag^{-1})				

WS, wheat straw; **SPS**, spent *Pleurotus ostreatus* (Jacq.) P. Kumm. substrate; **WB**, wheat bran; **T**, treatment; **T1**, WS 6,000 g; **T2**, WS 5,400 g + WB 600 g; **T3**, WS 4,800 g + WB 1,200 g; **T4**, WS 4,200 g + WB 1,800 g; **T5**, WS 3,000 g + SPS 3,000 g + $CaCO_3$ 60 g; **T6**, WS 2,700 g + SPS 2,700 g + WB 600 g + $CaCO_3$ 54 g; **T7**, WS 2,400 g + SPS 2,400 g + WB 1,200 g + $CaCO_3$ 48 g; **T8**, WS 2,100 g + SPS 2,100 g + WB 1,800 g + $CaCO_3$ 42 g; **T9**, SPS 6,000 g + $CaCO_3$ 120 g; **T10**, SPS 5,400 g + WB 600 g + $CaCO_3$ 108 g; **T11**, SPS 4,800 g + WB 1,200 g + $CaCO_3$ 96 g; **T12**, SPS 4,200 g + WB 1,800 g + $CaCO_3$ 84 g; **T13**, commercially controlled based substrates (Quintanar del Rey); **T14**, commercially controlled based substrates (Villamalea).

All substrates were packed into transparent polyethylene bags of 29 cm in diameter and a height ranging from 25 to 35 cm, depending on the type of substrate, sheltering 6.5 kg approximate of weight. Four holes 2.2 cm in diameter were uniformly drilled over the side surface of each of them.

Driving and monitoring of the crop cycle

The development of the crop cycle was in an experimental greenhouse located at the Center for Research, Experimentation and Mushroom Services (CIES), located in the town of Quintanar del Rey (Cuenca, Spain) under controlled conditions (room temperature, substrate temperature, relative humidity, and carbon dioxide concentration) within the recommended range for a variety of selected mycelium and in each stage of cultivation (CIES, 2007). This tunnel-shaped greenhouse is also equipped with lights of different wave lengths (among these are 12 fluorescent Sylvania lights), and various insect traps (20 cm x 14 cm) placed throughout the greenhouse to ensure a controlled environment. Incubation of the substrates lasted approximately 17 days with no outside ventilation or lighting. During the incubation period, the relative humidity inside the greenhouse ranged between 81% and 96%, while the substrate temperature ranged between 24 °C and 32 °C, and room temperature ranged between 21 °C and 28 °C. After this, we proceeded to the induction of fruiting by ventilation (to keep CO_2 levels regulated between 0.14% and 0.10%), reduction of room temperature (23 °C to 13 °C) and substrate temperature (25 °C to 16 ºC), and the reduction of humidity (96% to 93%) and **2*** lighting. Throughout each cycle, temperature, relative humidity and CO_2 concentration were automatically recorded by various instruments within the greenhouse. These values are close to the microclimatic conditions recommended by other researchers (Pardo et al., 2005b; Garcia Rollán, 2007; Pardo et al., 2007; Gregori et al., 2008; López-Rodríguez et al., 2008; Gea et al., 2009; Kurt & Buyukalaca, 2010).

Evaluation of qualitative parameters

For the evaluation of quality parameters mushrooms of uniform size maturity were used and selected on the most optimal day of the harvest period. The color of the surface of fruit bodies was measured by reflection using a Minolta brand colorimeter, model CR-300, previously calibrated with a calibration plate CR-A43 ($L^* = 96.12$, $a^* = -0.11$, $b^* = +2.66$) and illuminant D65. To evaluate the mechanical properties of mushrooms, in terms of firmness, an analyzer (TA-XT Plus of Stable Micro Systems) was used. To take this measure the fruit bodies were cut into small pieces (4 cm^2, approximately) and were introduced into the 5-bladed Kramer Shear Cell (KS5), arranged in two adjacent uniform layers and performed the test at a constant speed of 2 mm s^{-1}; thus breaking strength (Bs) was obtained, defined as the maximum force required to tear the fruit bodies (expressed in N). Protein content in the carpophores was calculated by multiplying the total nitrogen content by a conversion factor of 4.38 (Delmas, 1987). Total nitrogen content was determined by the Kjeldahl method (Tecator, 1989; MAPA, 1994). To determine the ash content of the fruiting bodies, we proceeded to direct calcination of the samples at 540 °C (MAPA, 1994).

Mushrooms were harvested daily at their optimal commercial development. The quantity of 'cones' and mushrooms harvested were determined by counting throughout the whole mushroom growth cycle; it was defined as a group of fruit bodies that simultaneously fruited from the same drilled hole in the substrate bag. To calculate the yield of mushrooms produced daily, each bag was weighed. The estimated net yield was performed by weighing the fruit bodies after removing the stipe and calculating the percentage of shrinkage resulting from this operation. Once fruiting occurred, the biological efficience (BE) was calculated and expressed as a percentage of the fresh weight of the harvest over the dry weight of the substrate used. The BE was established from the yield provided by each packet, taking into consideration the charge density of the substrate in the bags and their moisture content. The unit weight of mushrooms (gross and net) was determined from the yields obtained and the quantity of sporophores harvested.

4* Statistical analysis

The corresponding experimental design of this trial was a Balanced Plan Factorial Design 3 x 4 with 6 replicates (randomized block factorial with two factors).

To carry out the statistical analysis, two software packages were used: Statgraphics® Plus version 5.1 (Statistical Graphics Corp., 2001) and SPSS® (SPSS, 2004). Descriptive statistical techniques, principal component analysis, variance analysis and correlation and regression methods were used to evaluate the data.

Differences were considered significant for $p < 0.05$.

RESULTS AND DISCUSSION

Analytical characterization of base material used and substrates made

The research was conducted over an 80 day cycle, similar to Gea et al. (2009). Additionally, this cycle was longer than the cycle used in Pardo et al. (2007) with 69 days, but shorter than the total cultivation time of *P. ostreatus* in Sales-Campos et al. (2010) with 100 days. In each treatment in this experiment, the third flush did not show results of agronomic interest. The total gross yield was concentrated in the first two flushes.

Gregori et al. (2008), during the cultivation of *P. ostreatus* maintained CO_2 concentration at approximately 1,300 ppm and light cycles of 10 h (both very similar to those used in this experiment). Bermúdez et al. (2002) demonstrated that the BE and yield of *P. ostreatus* cultivated with cocoa waste are reduced between 68% and 63% respectively when the mushroom is exposed to light for less than 12 hours during its' fructification phase.

The chemical characteristics results of the different source materials, substrates made and commercially controlled based substrates tested are shown in Table 2. The processed substrates show great variability in most of analytical parameters tested (Table 2). Within the same group of processed the substrates (WS, WS + SPS and SPS) with increasing the dose of WB, the analytical parameters increase as well; however, these increases stop when the dose of WB reaches to 1,800 g in the physicochemical characteristics of substrates made.

Substrates prepared from WS and WB at doses of 1,200 g and 1,800 g (T3 and T4) have higher total nitrogen, protein and ash contents than commercial substrates (T13 and T14). The substrate made by T4 has the highest NDS content (23.04%), due to its high hemicellulose content (25.63%). The substrate made by T3 has the second highest NDS content (18.37%) because of its high lignin (6.94%), and ash content (24.11%). Compared with commercial substrates, these substrates (T3 and T4) reach higher hemicellulose values, lower lignin values, and similar cellulose and NDS values. As for the developed substrates formed with WS + SPS in the same proportions, but decreasing, and with WB and $CaCO_3$ as supplements in increasing amounts (T5 to T8), these substrates reach higher values of pH and a similar moisture level to commercial substrates (T13 and T14) (Table 2); ash content is higher than commercial substrates (T6, 28.25%; T14, 9.51%) with a lower content of organic matter (T7, 76.94%; T13, 92.94%). The third group of substrates made, is formed by a mixture of SPS (in decreasing amounts) + WB (in increasing amounts) + $CaCO_3$ (in decreasing amounts) (T9 to T12). This group exhibits a pH and moisture content very close to those corresponding to the commercial substrates. However, total nitrogen and protein content of the treatments with higher doses of WB (T11, 10.30%, 64.60%, respectively; T12, 12.70%, 79.20%, respectively) expressed higher values than the reference commercial substrates. This superiority is manifested also in ash content, in all different treatments of this group.

Crude fiber, cellulose and lignin content of all tested substrates were inferior in all cases showed by the commercial control (a situation related to the lower content of organic matter).

Table 2. Elaborate physicochemical characterization of source materials and substrates used

		pH (aq. 1:5, p v^{-1})	Moisture (g kg^{-1})	Total nitrogen (g kg^{-1}, d.m.)	Protein (g kg^{-1}, d.m.)	Ash (g kg^{-1}, d.m.)	Organic Matter (g kg^{-1}, d.m.)	C/N ratio	Crude fiber (g kg^{-1}, d.m.)	Crude fat (g kg^{-1}, d.m.)	NFE (g kg^{-1}, d.m.)	Cellulose (g kg^{-1}, d.m.)	NDS (g kg^{-1}, d.m.)
BASE MATERIALS	**WS**	5.85	685	3.5	21.9	76.0	924.0	153.1	391.4	6.9	503.8	407.8	156.8
	SPS	5.50	689	4.8	30.0	89.0	911.0	110.1	190.2	6.6	684.2	453.1	166.0
	WB	6.64	112	23.9	149.4	61.8	938.2	22.8	137.3	30.0	621.5	134.1	353.8
SUBSTRATES MADE	**T1**	7.70	713	3.6	22.5	199.3	800.8	129.0	355.8	5.8	416.6	324.5	156.3
	T2	8.09	733	7.3	45.3	226.3	773.8	61.9	334.2	10.4	383.8	295.0	165.6
	T3	8.36	743	11.6	72.6	241.1	758.9	37.9	306.6	13.8	365.9	262.8	183.7
	T4	7.11	714	16.4	102.4	218.9	781.1	27.7	261.4	16.5	400.9	225.4	230.4
	T5	7.37	711	4.7	29.6	247.3	752.7	92.2	322.0	5.5	395.6	299.1	186.1
	T6	8.16	725	8.0	49.7	282.5	717.5	52.3	301.4	10.2	356.3	289.4	166.1
	T7	8.28	739	11.2	70.2	230.6	769.4	39.7	287.3	13.6	398.3	270.1	200.1
	T8	8.03	713	13.7	85.7	268.7	731.4	30.9	264.9	16.2	364.6	227.6	210.5
	T9	7.19	704	4.0	25.0	281.6	718.4	104.2	320.0	5.3	368.2	309.0	147.8
	T10	7.81	718	7.8	48.6	234.5	765.6	57.0	322.6	9.9	384.4	317.9	167.9
	T11	8.26	709	10.3	64.6	267.6	732.4	41.1	294.5	13.3	359.9	268.5	179.3
	T12	8.17	715	12.7	79.2	252.1	747.9	34.2	276.7	16.0	376.1	248.8	209.1
	T13	8.08	735	8.2	51.1	70.6	929.4	65.9	448.4	14.1	415.7	389.1	181.3
	T14	7.94	711	8.0	49.9	95.1	904.9	65.7	404.7	12.9	437.4	383.1	169.7
	Average	7.90	720.21	9.1	56.9	222.6	777.4	59.9	321.5	11.7	387.4	293.6	182.4
	CV (%)	5.17	1.73	41.2	41.3	28.7	8.2	50.0	16.3	33.7	6.3	16.9	12.7

WS, wheat straw; **SPS**, spent *Pleurotus ostreatus* (Jacq.) P. Kumm. substrate; **WB**, wheat bran; **T**, treatment; **T1**, WS 6,000 g; **T2**, WS 5,400 g + WB 600 g; **T3**, WS 4,800 g + WB 1,200 g; **T4**, WS 4,200 g + WB 1,800 g; **T5**, WS 3,000 g + SPS 3,000 g + $CaCO_3$ 60 g; **T6**, WS 2,700 g + SPS 2,700 g + WB 600 g + $CaCO_3$ 54 g; **T7**, WS 2,400 g + SPS 2,400 g + WB 1,200 g + $CaCO_3$ 48 g; **T8**, WS 2,100 g + SPS 2,100 g + WB 1,800 g + $CaCO_3$ 42 g; **T9**, SPS 6,000 g + $CaCO_3$ 120 g; **T10**, SPS 5,400 g + WB 600 g + $CaCO_3$ 108 g; **T11**, SPS 4,800 g + WB 1,200 g + $CaCO_3$ 96 g; **T12**, SPS 4,200 g + WB 1,800 g + $CaCO_3$ 84 g; **T13**, commercially controlled based substrates (Quintanar del Rey); **T14**, commercially controlled based substrates (Villamalea). **CV**, coefficient of variation; **NFE**, nitrogen free extractives; **NDS**, neutral detergent-soluble. Results expressed in **g kg^{-1} dry matter**, except pH, moisture (fresh matter) and C/N ratio.

Production qualitative parameters. Descriptive statistics and ANOVA

In Table 3 descriptive statistics of crude protein and ash contents, as well as brightness values (L*), yellow-blue (b*) and red-green (a*) chromaticity color, Bs, and C_E in the harvested mushrooms are shown. Of the fourteen different treatments that have been generated with different combinations, including commercially controlled based substrates, in T8 (WS 2,100 g + SPS 2,100 g + WB 1,800 g + $CaCO_3$ 42 g) did not develop the mycelium due to difficulties in germination resulting in no production of mushrooms. Most likely, this accident was caused by an improper manual aggregation of high doses of WB, which led to a reduction in the pore spaces in the prepared substrate. This reduction caused a rise in temperature to the point of inoculation and agglomeration which reduced gas exchange with increased levels of CO_2 and the inhibition of mycelial growth. Due to these reasons, the substrate of T8 was not considered in the statistical analysis of this Experiment. When the substrates were supplemented with doses of 600 g of WB (T2, T6 and T10), a higher crude protein content was obtained in mushrooms than in the respective unsupplemented substrates (T1, T5 and T9) and in the commercial substrates (T13 and T14). Only the dose of 1,800 g of WB has shown the lowest contents of crude protein. Wheat straw + SPS and SPS do not improve the crude protein content relative to WS (there are not significant differences). Organic supplements such as soybean meal, alfalfa, flour, and cotton seed powder not only increase yields, but also, the protein content of mushrooms (Zadrazil, 1980).

Some researchers give values of crude protein content of fruit bodies of *P. ostreatus* varying between 17.80% and 34.10% (Benavides & Herrera, 2009; Rodríguez Barreal, 1987; Wang et al., 2001). Protein content in the carpophores of *P. ostreatus* with substrates based on alder tree sawdust supplemented with leaves of two different species of *Ginkgo biloba* L. according to Siwulski et al. (2009), depended on the number of sheets added of *G. biloba* L. to the growing substrate but not on the botanical species (between 17.30% and 21.10%). Higher values in *P. ostreatus* were obtained by Pardo et al. (2005a) in terms of protein content depending on the substrate type, treatment, and mycelium used: between 14.04% (straw, benomyl dip and pasteurization, Gurelan mycelium) and 17.75% (straw + vine shoot 1: 1 (v/v)), pasteurization and thermophilic conditions, Gurelan mycelium); substrate used: between 15.14% (straw) and 17.30% (straw + kenaf); treatment used: between 16.54% (pasteurization and thermophilic conditions) and 16.52% (benomyl dip and pasteurization); and mycelium used: between 16.74% (Amycel mycelium) and 16.33% (Gurelan mycelium). Lower values than those presented in this Experiment were obtained by Pardo et al. (2005b). In another further investigation they reached crude protein content in mushrooms of 22.40% (grape stalk + 'alperujo') from 11.80% (grape stalk + straw). When analyzing the studied substrates treatments, pasteurization and thermophilic conditions improved significantly (20.80%) compared to benomyl dip and pasteurization (19.20%). Although statistically insignificant, there were different values depending on the format of packaging: 20.60% in bags of 15 kg and 19.20% in bags of 5 kg. Pardo et al. (2007) obtained higher values of *P. ostreatus* depending on the different types of substrate and treatment used: between 19.07% (straw, pasteurization and thermophilic conditions) and 23.98% (straw + kenaf 1: 1 (v/v), benomyl dip and pasteurization); type of substrate used: between 20.61% (straw + 'alperujo' 1: 1 (v/v)) and 22.90% (straw + kenaf 1: 1 (v/v)); type of treatment used: between 20.30% (pasteurization and thermophilic conditions) and 21.70%

(benomyl dip and pasteurization). Higher values than those obtained in this Experiment were obtained by Bermúdez et al. (2007) on *Pleurotus* spp. in blends of coffee pulp + cedar chips with strains of CCEBI 3021 and CCEBI 3027: 27% and 34%, respectively; substrates on coffee pulp: 30% and 38%, respectively; and substrates based on cedar chips: 21% and 22%, respectively. Fonseca et al. (2009) also achieved slightly higher values in protein content than in this Experiment using a substrates mixture of rice bran (40%), rice straw (35%) and *Juncus effusus* L. (25%) in the growing of *P. ostreatus* (30.52%). These authors claim that the determined digestibility for *P. ostreatus* is comparable to that of *P. sajor-caju* (Fr.) Singer. Varnero et al. (2010), growing *P. ostreatus* on different lignocellulosic substrates, reached values of total protein content in mushrooms that ranged from 22.90% (aspen shavings) to 25.60% (WS); although these differences were not statistically significant. In *P. sajor-caju* (Fr.) Singer specie (Oyetayo & Akindahunsi, 2004), working with shredded ears, reached values of mushroom protein content of 17.49% vs. 14.94% in substrate without supplement. In *P. eryngii* (DC.: Fr.) Quel., Hassan et al.(2010) give results with significant differences for sawdust (22.17%), soybean straw (24.08%), sugarcane bagasse (21.33%) and rice straw (22.75%). Manzi et al. (2004) indicate default values for the fruiting bodies of *P. eryngii* (DC.: Fr.) Quel. of: dry matter (13.40%), fat (0.80%), crude protein (2.20%) and ash (1.20%); all with respect to fresh weight of fruit body. It is important to note how protein content during the growth of *P. ostreatus* on different substrates increases the most after the first harvest or post-harvest, according to the prepared mixtures (Kurt & Buyukalaca, 2010). These researchers obtained the maximum postharvest with sawdust and bran (2:1) with a figure of 5.23 mg mL^{-1}; while lower values were reached with the mixture of grape vine + WB (2:1), where they obtained only contents of 2.38 mg mL^{-1} (sesame straw) and 9.75 mg mL^{-1} (sawdust + WB (2:1)). In *P. sajor-caju* (Fr.) Singer, postharvest, mushrooms protein content ranged from 3.29 mg mL^{-1} (rice straw) to 8.13 mg mL^{-1} (WS), while after the first harvest, with lower figures oscillation was between 2.46 mg mL^{-1} (grapevines) and 5.92 mg mL^{-1} (sawdust and rice bran (2:1)). In other edible fungi, for instance, *Ganoderma lucidum* (Curt.: Fr.) P. Karst. (Peksen & Yakupoğlu, 2009), higher crude protein contents were reached when combined with supplements: sawdust (75%) + waste tea (20%) obtained values of 20.17% and 12.52% depending on the strain studied. When tea waste content was reduced to 10%, crude protein contents of 13.24% and 13.94% were obtained. When WB participated in 18% in the mix with sawdust, depending on mycelium, values of 12.91% and 16.93% were obtained.

The highest values of ash content in harvested mushrooms in this current Experiment are presented in substrates composed of WS + SPS (T5 to T7): from 6.76 g $(100\ g)^{-1}$ (T7) to 8.11 g $(100\ g)^{-1}$ (T6). Substrates supplemented with WB (dose of 600 g and 1,200 g) have a greater ash content in their mushrooms than commercial substrates (T13 and T14), although T7 substrate (6.76 g 100 g^{-1}) has a smaller ash content than the T13 commercial substrate (7.17 g $(100\ g)^{-1}$). As with crude protein content of the harvested mushrooms, only the dose of 1,800 g of WB in this study, has the lowest ash content. Standard means values given by Benavides & Herrera (2009) and Rodriguez Barreal (1987) are included in the ranges given above. This interval is extended by others working with *P. ostreatus* (Manzi et al., 1999; Wang et al., 2001; Shashirekha et al., 2002); these researchers reached values of ash content in mushrooms between 6.70% and 15.40%. Baena (2005), growing oyster mushroom in green bagasse manguey obtained ash content values in fruit bodies from 3.77% to 8.73% and Siwulski et al. (2009), in substrates based on sawdust alder supplemented with leaves of two different species of *Ginkgo biloba* L., concluded that the addition of the leaves of this plant does not affect the ash content: green leaves, between 6.90% (no leaves and a 10% of leaves) and 7% (a 1% of leaves); and yellow leaves, from 6.80% (no leaves) and 7.20% (with a 10% of leaves).

Table 3. ANOVA of the qualitative parameters of the Experiment. **5***

Sub-strate	Crude protein (g 100 g^{-1})	Ash contents (g 100 g^{-1})	Color			B_S (N)	C_E (mJ)
			L*	a*	b*		
T1	19.69abc	8.02a	62.99a	3.00b	12.59ab	250.93abc	1,022.77abcd
T2	23.05a	7.46a	63.22a	1.64d	10.25ab	142.27bcde	575.65bcde
T3	14.18abc	4.05abc	39.27ab	0.54e	5.67bc	96.25de	435.70de
T4	4.50c	1.38c	13.09b	0.18e	1.89c	32.08e	145.23e
T5	22.44a	7.01a	64.31a	2.92b	12.73ab	277.75a	1,241.95a
T6	24.49a	8.11a	73.76a	2.31bcd	12.90a	266.90ab	1,099.58abc
T7	21.03ab	6.76a	64.54a	1.66d	12.55ab	126.65cde	546.07cde
T9	19.30abc	7.88a	65.68a	2.78bc	12.40ab	305.12a	1,204.23a
T10	23.19a	7.67a	69.50a	2.28bcd	12.01ab	286.70a	1,217.95a
T11	26.30a	7.36a	78.60a	1.81cd	13.31a	219.28abcd	951.33abcd
T12	5.29bc	1.45bc	13.09b	0.18e	1.89c	32.08e	145.23e
T13	18.72abc	7.17a	62.02a	3.33ab	12.99a	262.95ab	1,376.38a
T14	17.39abc	6.19ab	60.29a	4.21a	13.76a	274.05a	1,170.43ab
Average	18.43	6.19	56.18	2.07	10.38	197.92	856.35
Fisher F	4.09	5.75	5.88	30.35	8.66	14.77	12.15
S_L	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***

WS, wheat straw; **SPS**, spent *Pleurotus ostreatus* (Jacq.) P. Kumm. substrate; **WB**, wheat bran; **T**, treatment; **T1**, WS 6,000 g; **T2**, WS 5,400 g + WB 600 g; **T3**, WS 4,800 g + WB 1,200 g; **T4**, WS 4,200 g + WB 1,800 g; **T5**, WS 3,000 g + SPS 3,000 g + $CaCO_3$ 60 g; **T6**, WS 2,700 g + SPS 2,700 g + WB 600 g + $CaCO_3$ 54 g; **T7**, WS 2,400 g + SPS 2,400 g + WB 1,200 g + $CaCO_3$ 48 g; **T8**, WS 2,100 g + SPS 2,100 g + WB 1,800 g + $CaCO_3$ 42 g; **T9**, SPS 6,000 g + $CaCO_3$ 120 g; **T10**, SPS 5,400 g + WB 600 g + $CaCO_3$ 108 g; **T11**, SPS 4,800 g + WB 1,200 g + $CaCO_3$ 96 g; **T12**, SPS 4,200 g + WB 1,800 g + $CaCO_3$ 84 g; **T13**, commercially controlled based substrates (Quintanar del Rey); **T14**, commercially controlled based substrates (Villamalea); **L*,** brightness; **a***, red-green color components; **b***, yellow-blue color components; **B_S**, breaking strength; **C_E**, compression energy, **S_L**, F significance level Fisher.
*** P-value < 0,001. For each column, values followed by different letters are significantly different from each other (p = 0.05, Tukey-HSD).

Pardo et al. (2005a), also in *P. ostreatus*, got different values in ash content of the fruit bodies, depending on the substrate type, treatment thereof, and mycelium used: cereal straw subjected to benomyl dip and pasteurization, between 6.83% (Gurelan mycelium) and 7.70% (Amycel mycelium); substrate used: between 7.16% (straw) and 7.44% (straw + kenaf 1:1 (v/v)); treatment used: between 7.33% (pasteurization and thermophilic conditions) and 7.24% (benomyl dip and pasteurization); and mycelium used: between 7.38% (Amycel mycelium) and 7.19% (Gurelan mycelium). In a subsequent experiment, Pardo et al. (2005b) present ash content values in mushrooms ranging from 6% (grape stalk + 'alperujo', pasteurization and thermophilic conditions and packaging in bags of 15 kg) and 7.50% (grape stalk + vine shoot, pasteurization and thermophilic conditions and packaging of 15 kg); when, as a main factor of ANOVA, only the substrate type is considered, consisting of grape stalk + 'alperujo' provides mushrooms with an ash content of 6.40% and, on the other hand, if the substrate was grape stalk + vine shoot the mixture from which the highest ash content is obtained (7.30%); treating substrates by pasteurization and thermophilic conditions favors this qualitative parameter production (7%) significantly against the treatments of immersion, benomyl dip, and pasteurization (6.60%); format packaging substrate (sacks of 5 kg and 15 kg) produced no significant difference: 6.70% and 6.90% respectively. Pardo et al. (2007), also in *P. ostreatus*, achieve different ash values in the carpophores, depending on the substrate type and treatment used: between 6% (straw, semi-anaerobic fermentation) and 7.14% (benomyl dip and pasteurization in substrate based on straw + vine shoot 1:1 (v/v) and in substrate based on straw + alperujo 1:1 (v/v)); substrate type used: between 6.54% (straw) and 6.88% (straw + vine shoot 1:1 (v/v)); treatment type used, between 6.47% (pasteurization and thermophilic conditions) and 7% (benomyl dip and pasteurization). Forero et al. (2008), also with *P. ostreatus*, but on waste chili, give a range of values between 8.81% and 9.84%, justifying these figures by the high ash content of supplied based substrates. Fonseca et al. (2009), using a mixture of substrates (rice straw, 35%; *Juncus effusus* L., 25% and rice bran, 40%), only reached an ash content of 6.38% in *P. ostreatus* mushrooms.

In other species of the genus *Pleurotus* as *P. eryngii* (DC.: Fr.) Quel., Manzi et al. (1999), in WS + sugar beets (15%) obtained ash content between 6.90% and 10.50%; Manzi et al. (2004) in the same fungus species, obtained ash content values of the carpophores of 1.20% based on a fresh product with 86.60% moisture. Also in *P. eryngii* (DC.: Fr.) Quel., Hassan et al. (2010) presented similar values to those achieved in the present Experiment: sawdust (6.94%), soybean straw (7.66%), sugarcane bagasse (6.54%) and rice straw (8.02%). In another of species of *Pleurotus*, specifically *P. sajor-caju* (Fr.) Singer, Oyetayo & Akindahunsi (2004) reached ash content values of 10.51% in mushrooms when the growing was carried out in substrates of grated ears, which decays to 7.41% if there is no such supplementation. In the consulted literature, there were significantly lower ash values when other species of edible mushrooms and substrates were used; for instance, Peksen & Yakupoğlu (2009), growing *Ganoderma lucidum* (Curt.: Fr.) P. Karst., reached values comprised between 2.09% (sawdust, 80%, and tea residue, 20%) and 4.67% (sawdust, 80% WB, 18%); these researchers found that the mycelium types have a great influence on the ash content of the fruiting bodies too.

There are significant differences in the brightness of the harvested mushrooms. Of all the tested treatments (between 60.29 and 78.60), the worst values were exhibited by a supplementation of 1,800 g of WB (T4, L* = 13.09). Rodriguez Estrada et al. (2009) investigated in mushrooms of *P. eryngii* var. *erynngii* grown on substrates made of straw; these researchers achieved brightness values in mushrooms ranging from 54.70 (substrate covered by a shell) to 74.10 (substrate not covered). Also, supplementation with WB reduced the value of red-green color components of mushrooms (a*) as WS as in the mixture of WS + SPS and SPS, and the reduction was greater as the dose is increased. This trend is also reflected in the value of yellow-blue color components of mushrooms (b*) (Table 3).

Mushrooms supplemented with 1,800 g of WB the worst texture and firmness significantly showed. There is a tendency, although not statistically significant, to decrease both parameters with each increasing dose of bran. Texture (hardness, cohesiveness, springiness and chewiness) was controlled in *Pleurotus* spp. grown on rice straw (Kotwaliwale et al., 2007); according to these authors, an increase of hardness, chewiness, and a decrease in cohesion and elasticity of the mushrooms can be attributed to a migration loss of moisture inside of them. Prepared unsupplemented substrates and commercial substrates, although statistically insignificant, obtained the highest values of Bs and compression energy (C_E).

Correlation matrix and 'step by step' regression models

In Table 4 is presented the correlation matrix between qualitative parameters of production and physicochemical properties of the substrates prepared in Experiment. All quality parameters of harvested mushrooms that have been analyzed are significantly and negatively correlated with total nitrogen contents, crude fat and NDS values of the substrates tested, but positively correlated with crude fiber and cellulose contents.

Table 4. Correlation matrix between production of quantitative parameters and physicochemical characteristics of the substrates

	Crude protein (g 100 g^{-1})	**Ash contents (g 100 g^{-1})**	**B_S (N)**	**C_E (mJ)**	**L***	**a***	**b***
pH	0.246 (0.466)	0.063 (0.853)	-0.243 (0.471)	-0.229 (0.498)	0.169 (0.620)	-0.265 (0.431)	0.062 (0.856)
$Nitrogen_T$[1]	-0.656* (0.028)	-0.815** (0.002)	-0.853*** (0.001)	-0.836*** (0.001)	-0.697* (0.017)	-0.922*** (0.000)	-0.756** (0.007)
C/N ratio	0.362 (0.274)	0.596 (0.053)	0.689* (0.019)	0.663* (0.026)	0.435 (0.181)	0.819** (0.002)	0.546 (0.083)
Crude fiber[1]	0.588 (0.057)	0.731** (0.011)	0.665* (0.025)	0.650* (0.030)	0.596 (0.053)	0.756** (0.007)	0.617* (0.043)
Crude fat[1]	-0.578 (0.062)	-0.757** (0.007)	-0.861*** (0.001)	-0.847*** (0.001)	-0.631* (0.037)	-0.927*** (0.000)	-0.711** (0.014)
NFE[1]	-0.211 (0.534)	-0.075 (0.825)	-0.118 (0.729)	-0.111 (0.744)	-0.190 (0.576)	0.139 (0.683)	-0.050 (0.885)
Cellulose[1]	0.700* (0.016)	0.853*** (0.001)	0.861*** (0.001)	0.843*** (0.001)	0.737** (0.010)	0.896*** (0.000)	0.773** (0.005)
NDS[1]	-0.713** (0.014)	-0.847*** (0.001)	-0.809** (0.003)	-0.772** (0.005)	-0.755** (0.007)	-0.778** (0.005)	-0.732** (0.010)

B_S, breaking strength; **C_E**, compression energy; **L*,** brightness; **a***, red-green color components; **b***, yellow-blue color components; **$Nitrogen_T$**, total nitrogen; **NFE**, nitrogen free extractives; **NDS**, neutral detergent-soluble; **[1], g kg^{-1} dry matter.**
Results in parentheses indicate statistical significance. No significant ($p > 0.05$) (non *); significant at 95% ($0.01 < p \leq 0.05$) (*); significant at 99% ($0.001 < p \leq 0.01$) (**); 99.9% significant ($p \leq 0.001$) (***).

Table 5 presents the correlation matrix between production and qualitative parameters germination index, the earliness and quantitative production parameters. All correlations obtained between germination index, earliness, number of mushrooms and biological efficiency and the quality parameters of harvested mushrooms are significant, although with varying degrees of significance, but with positive coefficients. The same is true when considering the correlation matrix between qualitative production parameters (Table 6), it is to say, there is a statistical significance between them with positive coefficients.

Table 5. Correlation matrix between production of qualitative parameters and the rate of germination, earliness, and production of quantitative parameters

	Crude Protein (g 100 g^{-1})	**Ash contents (g 100 g^{-1})**	**B_s (N)**	**C_E (mJ)**	**L***	**a***	**b***
Germination Index	0.920*** (0.000)	0.943*** (0.000)	0.905*** (0.000)	0.905*** (0.000)	0.929*** (0.000)	0.882*** (0.000)	0.922*** (0.000)
1rs Flush 'Seeding'	0.948*** (0.000)	0.926*** (0.000)	0.722** (0.012)	0.722** (0.012)	0.958*** (0.000)	0.730** (0.011)	0.926*** (0.000)
Total 'Seeding'	0.974*** (0.000)	0.985*** (0.000)	0.841*** (0.001)	0.837*** (0.001)	0.991*** (0.000)	0.848*** (0.000)	0.974*** (0.000)
Total quantity of mushrooms	0.731** (0.011)	0.841*** (0.001)	0.963*** (0.000)	0.958*** (0.000)	0.779** (0.005)	0.920*** (0.000)	0.812** (0.002)
BE	0.631* (0.037)	0.741** (0.009)	0.929*** (0.000)	0.937*** (0.000)	0.671* (0.024)	0.908*** (0.000)	0.734** (0.010)

B_S, breaking strength; **C_E**, compression energy; **L*,** brightness; **a***, red-green color components; **b***, yellow-blue color components; **BE**, biological efficiency (kg 100 kg^{-1} of dry substrate).
Results in parentheses indicate statistical significance. Significant at 95% ($0.01 < p \leq 0.05$) (*); significant at 99% ($0.001 < p \leq 0.01$) (**); 99.9% significant ($p \leq 0.001$) (***).

Table 6. Correlation matrix between production of qualitative parameters

	Crude protein (g 100 g^{-1})	**Ash contents (g 100 g^{-1})**	**B_s (N)**	**C_E (mJ)**	**L***	**a***	**b***
Crude protein (g 100 g^{-1})	1.000						
Ash contents (g 100 g^{-1})	0.945*** (0.000)	1.000					
B_s (N)	0.783** (0.004)	0.875*** (0.000)	1.000				
C_E (mJ)	0.793** (0.004)	0.863*** (0.001)	0.996*** (0.000)	1.000			
L*	0.987*** (0.000)	0.972*** (0.000)	0.837*** (0.001)	0.839*** (0.001)	1.000		
a*	0.775** (0.005)	0.901*** (0.000)	0.941*** (0.000)	0.935*** (0.000)	0.829** (0.002)	1.000	
b*	0.949*** (0.000)	0.972*** (0.000)	0.865*** (0.001)	0.867*** (0.001)	0.979*** (0.000)	0.901*** (0.000)	1.000

B_S, breaking strength; **C_E**, compression energy; **L*,** brightness; **a***, red-green color components; **b***, yellow-blue color components; **BE**, biological efficiency (kg 100 kg^{-1} of dry substrate).
Results in parentheses indicate statistical significance. Significant at 99% ($0.001 < p \leq 0.01$) (**); significant at 99.9% ($p \leq 0.001$) (***).

Table 7 presents the ‘step by step’ regression models for qualitative production parameters depending on the physicochemical properties of the substrates made, germination index, earliness and production characteristics of quantitative parameters. It is observed that the values of NDS made substrates define models that explain the variability of Bs and yellow-blue color components (b*) of harvested mushrooms. Also, as an independent variable, with a positive coefficient, the cellulose content of the prepared substrates defines the variability of the ash content of the harvested fruit bodies.

Table 7. Models obtained by regressing ‘step by step’

Explained variable	**Independent variable**	**Equation**	**R^2 corrected**	**SE**
Ash contents	PCC + QPP + CPP	Ash contents = -5.153*** + 0.137*** P4 + 0.020*** · cellulose	99.10***	0.24145
B_s	PCC + QPP + CPP	B_S = 86.865* + 0.223*** · C_E – 0.417* · NDS	99.40***	7.63723
C_E	PCC + QPP + CPP (– B_S)	C_E = 238.289** + 25.933*** · Nº mushrooms	90.80***	128.71255
L	PCC + QPP + CPP	L* = -5.723** + 0.985*** · P4 + 2.982** · DM	99.30***	1.96105
a*	PCC + QPP + CPP	a* = -5.42**1 + 0.010*** · B_S + 0.014** · NFE	93.70***	0.26359
b*	PCC+ QPP + CPP	b* = -6.005* + 0.154*** · L* + 1.502*** · a* + 0.026* · NDS	98.80***	0.49742

R^2, determination coefficient (%); **SE**, standard error of the estimate.

PHYSICO-CHEMICAL CHARACTERISTICS OF SUBSTRATE (PCC): pH (aq. 1:5, w/w), total nitrogen (g kg^{-1}, odm), ash (g kg^{-1}, odm), C/N ratio, crude fiber (CFi; g kg^{-1}, odm), crude fat (CFa; g kg^{-1}, odm), nitrogen free extractives (NFE; g kg^{-1}, odm), cellulose (g kg^{-1}, odm), neutral-detergent soluble (NDS; g kg^{-1}, odm), odm, on dry matter.

INDEX GERMINATION, EARLINESS AND quantitative production parameters (QPP): germination index (GI), days from inoculation to the formation of the first primordia (P2), days from inoculation to the onset of harvest (P4), nº mushrooms (quantity of mushrooms), biological efficiency (BE, kg 100 kg^{-1} of dry substrate).

QUALITATIVE production parameters (CPP): average unit weight of uncut mushrooms (g), dry matter (DM, g 100 g^{-1}), crude protein (g 100 g^{-1}), ash contents (g 100 g^{-1}), **B_S**, breaking strength; **C_E**, compression energy; **L*,** brightness; **a***, red-green color components; **b***, yellow-blue color components.

Significativo al 95% ($0,01 < p \leq 0,05$) (*); significativo al 99% ($0001 < p \leq 0,01$) (**); significativo al 99,9% ($p \leq 0,001$) (***). Regressions include only those whose coefficients accompanying the independent variables are significant, provided that the significance of the model is significant.

CONCLUSIONS

SPS unsupplemented, SPS supplemented with 600 g of WB, mixture WS + SPS unsupplemented and mixed WS + SPS supplemented with 600 g of WB, are produced substrates which have achieved acceptable crude protein contents in fruiting bodies, although with a loss in texture but not firmness. These substrates also favor brightness, and red-green (a*) and yellow blue (b*) chromacity color of the harvested mushrooms. Consequently these compost formulations based on degraded *Pleurotus ostreatus* could be a low cost substrate, with selective and balanced nutrients for the growth and development of oyster mushrooms.

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The evaluation of biomass yield and quality of *Phalaris arundinacea* and *Festulolium* fertilised with bio-energy waste products

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Abstract. Tall growing perennial grasses such as *Phalaris arundinacea* and *Festulolium* can be used as an alternative source for bioenergy production in northern latitudes as they can be grown in less cultivated areas and can be potentially used as a dual purpose crop (bioenergy and forage). The aim of studies was to investigate the effectiveness of using bioenergy waste products – fermentation residues (digestate) and wood ash as fertilisers for perennial grasses. The field experiment was conducted in the central part of Latvia (56°42' N and 25°08' E) from 2013 to 2015. For all fertiliser treatments (wood ash, digestate once per season; digestate twice per season and mineral fertilisers) the same amount of plant nutrients (N, P, K) was applied annually: N (100), P_2O_5 (80), K_2O (160); and the missing quantities of elements in ash and digestate were compensated by mineral fertilisers. Dry matter yield (DMY) in two harvest regimes (single cut and two cut) and chemical composition (ash content; total C and N) of grass biomass partitioning among tillers, leaves and panicles were estimated.
Biomass yield in the three years of use varied considerably depending on the fertiliser, harvest regime and species, ranging up to 10.0 Mg ha^{-1} for RCG and 7.73 Mg ha^{-1} for festulolium. All fertilisers provided a significant increase of DMY, however, better results for both species were obtained using wood ash and mineral fertilisers. The harvest regime and species affected directly the quality of biomass, single cut of RCG contained significantly less ash and more carbon. There were significant differences between sward fractions – culms in comparison with leaves contained less ash and nitrogen, and more carbon, what are desirable features for solid fuel.

Key words: perennial grasses, dry matter yield, chemical composition, fermentation residues, wood ash.

INTRODUCTION

Biomass is an abundant and renewable source of energy and its use for that purpose would diversify the energy supply and reduce dependency on fossil fuels. Furthermore biomass production may create additional jobs for the local economy in rural areas (Rancane et al., 2014b). Biomass yield and quality are the indicators which determine possible energy yield of biomass per unit and an optional species of plants for energy conversion (Pociene et al, 2013).

One of the most suitable sources for bioenergy in agriculture is perennial grasses (Ceotto, 2008; Bardule et al., 2013; Rancane et al., 2014a). Perennial grasses may provide a renewable source of biomass for energy production since they have many advantages including reduced cost of establishment and cultivation; relatively high yield potential on land not suitable for annual crops; soil and water conservation; increased carbon sequestration; and wildlife habitat conservation (McLaughlin et. al., 2002). Besides contributing to the reduction of anthropogenic carbon dioxide (CO_2) emissions, these alternative biomass materials show other ecological benefits. They prevent soil erosion and require limited soil management and a low demand for nutrient inputs (Fournel et al., 2015).

In addition to the traditional perennial grasses use for forage, they can be source of biofuel for direct burning to generate electricity or for fermentation to ethanol. Different requirements of biomass quality are for biogas production and solid fuels, but there is one, which is common for all bioenergy sources, namely biomass yield (Prochnow et al., 2009a). In addition, low moisture content, low levels of ash and alkali metals, and high fiber content are the desirable features of a crop to be used as a source of bioenergy (Tahir et al., 2011).

To be a potential perennial energy crop, a perennial species should be native, have high biomass yield potential, be harvested with typical farm equipment, and exhibit positive environmental attributes. In the regions of Northern Canada, Europe and Russia higher energy potential is achieved from the production of cold season (C3) perennial grasses, such as reed canary grass (*Phalaris arundinacea* L.) and tall fescue (*Festuca arundinacea* Schreb.) (Carlson, 1996; Samson et al., 2005).

Reed canary grass (RCG) is a perennial, heterogamous and stolonate grass from the *Poaceae* family. RCG produces high biomass yield in cool climates and wetlands. The number and timing of harvests during a growing season directly affected biomass yield and biofuel quality (Tahir et al., 2011). The suitability of reed canary grass as a source for energy or cellulose production also has been confirmed by many authors (Nixon & Bullard, 1997; Pahkala & Mela, 1997, Pedersen, 1997; Saijonkari-Pahkala, 2001; Lewandowski et al., 2003).

Festulolium is the hybrid perennial grass developed by crossing *Festuca pratensis* or *Festuca arundinacea* with *Lolium perenne* or *Lolium multiflorum*. This enables combining the best properties of the two types of grass: high dry matter yield, resistance to cold, drought tolerance and persistence, rapid establishment, good spring growth, good digestibility and high sugar content (Gutmane & Adamovics, 2006; Bardule et al., 2013). The individual festulolium varieties contain various combinations of these qualities, but all are substantially higher yielding than their parent lines. In our research was included *Festulolium pabulare* 'Felina' – hybrid of tall fescue type (*Festuca arundinacea* × *Lolium multiflorum*) and reed canary grass 'Bamse'. In addition to their use for direct burning or co-generation (producing electricity and heat), both species, when still green, can be used as fodder and for the production of biogas.

If biomass is used for combustion, quantitative parameters are relevant together with several indicators of the quality. The ash content of biomass is very important because when ash concentration is increased by 1%, the calorific value is reduced by 0.2 MJ kg^{-1} (Jenkins et al., 1998). Ash contributes to dust emissions and some operational problems such as fouling, slagging and corrosion. In small scale appliances, they may disturb the combustion process, reduce efficiency and lead to unwanted shutdowns and higher levels of compounds from an incomplete combustion including carbon monoxide (CO) (Obernberger et al., 2006; Tissari et al., 2011; Verma et al., 2011). The major components of ash are silica and potassium (Samson et al., 1999). Compared to wood, agricultural materials usually contain less carbon and have higher contents in ash and elements such as nitrogen, sulphur, chlorine, potassium and silicon. Carbon impact the higher heating value (Werther et al., 2000; Obernberger et al., 2006; Vassiliev et al., 2010). High amounts of N, S and Cl in energy crops increase the emissions of nitrogen oxides (NOx), sulfur dioxide (SO_2) and hydrogen chloride (HCl), respectively (Obernberger et al., 2006; Van Loo & Koppejan, 2008).

In the transition from fossil to a bio-based economy, it has become an important challenge to recuperate maximally valuable nutrients coming from waste products – digestate and wood ash. The use of them as fertilisers to offset artificial fertiliser is thus of major economic and ecological importance (Rancane et al., 2015). The application of digestate as a fertiliser for grasslands could be an effective way to utilize residues from biogas plants (Alburquerque et al., 2012). Efforts should be made to integrate the approach with beneficial uses of ash derived from biomass, including the potential for recycling of nutrients to the field (Bakker R.R & Elbersen, 2005).

The aim of this study were to evaluate biomass yield and quality of reed canary grass and festulolium as potential bioenergy crops related to grass species, harvest time and different fertilisers used with equal amounts of NPK.

MATERIALS AND METHODS

Two species of cool season perennial grasses were studied in a field experiment: reed canary grass (RCG) (*Phalaris arundinacea* L.) and festulolium (×*Festulolium pabulare*) from 2013 to 2015. The experiment was established in the central part of Latvia at the LLU Institute of Agriculture in Skriveri (56°41' N, 25°08' E), 86 m above the sea level. The soil pH KCl was 5.7 (LVS ISO 10390/NAC), total carbon – 24.3 g kg^{-1} (LVS ISO 10694), plant available phosphorus (P_2O_5) 95 mg kg^{-1} (in 0.2 M HCl extract spectrophotometrically – LVS 398), potassium (K_2O) 130 mg kg^{-1} (in 1.0 M CH_3COONH_4 extract using atomic-absorption spectrometer) and sulphur (S) 25 mg kg^{-1} (using ELTRA CS 530 element analyser). The soil of the experimental field was classified as *Endoluvic Epistagnic Phaeozem (Loamic)/Stagnic Retisol (Cutanic, Drainic, Loamic)*, fine sandy loam (WRB 2014).

Five fertilisation treatments of grasses were compated: C – control – not fertilised; MF – mineral fertilisers (ammonium nitrate, potassium sulphate and superphosphate); WA – wood ash; D1 – fermentation residues or digestate used once per season; D2 – fermentation residues or digestate used twice per season. In the sowing year before the establishment of experiment all fertilisers were incorporated in the soil; in subsequent crop years they were used to the surface of the swards. Two methods of digestate use were compared: 1) giving the full annual amount in the spring at the beginning of vegetation, and 2) one half of digestate at the beginning of vegetation and one half – at the end of vegetation after cutting of grasses. For all fertiliser treatments the same amount of plant nutrients: nitrogen (N); phosphorus (P_2O_5) and potassium (K_2O) was applied annually – 100, 80, 160 kg ha^{-1} accordingly. The amount of nutrients was decreased approximately by one half in the year of grass sowing (2012): 42 kg ha^{-1} N; 32 kg ha^{-1} P_2O_5 and 80 kg ha^{-1} K_2O. Every time before treatment fermentation residues and wood ash were analysed for NPK content and the missing quantities of elements on each plot, if necessary, were equalised by using mineral fertilisers – ammonium nitrate, potassium sulphate or superphosphate. Stabilized wood ash from the boiler house with average main plant nutrient content of NPK g kg^{-1} (0.5:11:32) was used. The neutralization value of wood ash was 47–53%. In treatment of grass swards the liquid fraction of separated fermentation residues with DM content from 4.4 to 5.4% and an average OM content 3.7% was used. The chemical content ranged between: 2.7 and 5.1 g L^{-1} N; 0.4 and 0.77 g L^{-1} P_2O_5; 3.3 and 3.7 g L^{-1} K_2O.

Pure stands of RCG (12 kg ha^{-1} seed) and *Festulolium* (15 kg ha^{-1} seed) were sown by drill. The experiment was designed as a randomized complete block with four replicates. Two harvest regimes for determination of dry matter yield were used: 1) one-cut per season or single harvest was taken in autumn at the stage of crop senescence (end of September – beginning of October), and 2) two-cut per season: first cut was taken at the full panicle emergence, the second – in autumn simultaneously with the single cut.

The meteorological conditions and distribution of rainfalls during experimental years were different, the average annual precipitation amount at the study site was: 698 mm or 102% from long-term average in 2013; 807 mm (118%) in 2014; and 549 mm (80%) in 2015. The monthly distribution of precipitation is shown in Fig. 1.

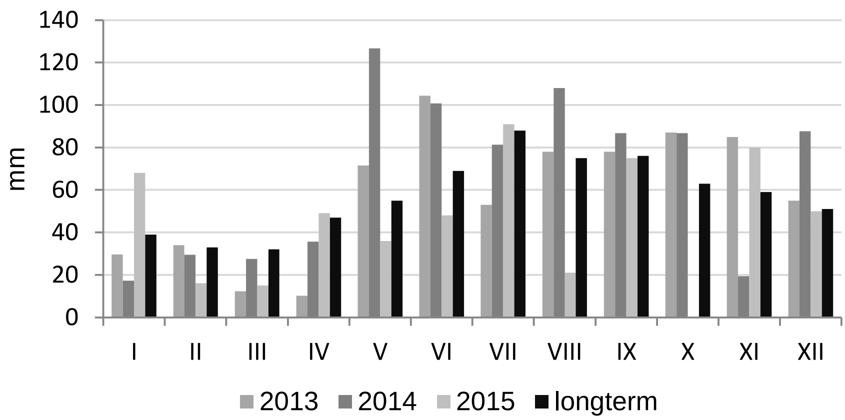

Figure 1. The monthly distribution of precipitation, 2013–2015, and long-term average.

For determination of sward structure the samples from each harvest were partitioned among tillers, leaves and panicles. The chemical composition of grasses was determined by using the following methods: dry matter – oven drying at the temperature of 105 °C; ash content – dry combustion (LVS CEN/TS 14775); total carbon – using elemental analyser LECO CR–12 (LVS ISO 106940; total nitrogen – Kjeldahl procedure (LVS ISO 11261).

The experimental data were processed by analysis of variance ($p < 0.05$), the differences among means were detected by LSD at the 0.05 probability level (Excel for Windows 2003). To determine the factor's influence multifactor analyze was used. Sums of squared deviations were calculated and interactions in equal shares were divided on the main factors.

RESULTS AND DISCUSSION

The dry matter yield (DMY) of grasses varied quite considerably depending on the fertiliser, harvest regime, species and year. In the first year of sward use the DMY of reed canary grass (RCG) ranged from 4.08 to 8.57 Mg ha^{-1} in two-harvest regime and from 6.36 to 10.00 Mg ha^{-1} in one-harvest regime (Fig. 2). Dry matter yields in all fertilised variants were significantly (*$P > 0.05$*) higher compared with control; the best results were provided by MF and WA fertiliser options, where DMY level was significantly higher than in options with digestate use once or twice per season (D1 and D2). It would be explained by a partial nitrogen losses using surface application of digestate. It is known that injection of liquid fertilisers directly into the soil significantly reduces NH_3 emissions (Ismail et al., 1991; Sigunga et al., 2002) compared with surface application, because gaseous NH_3 is bound to soil colloids and soil water (McDowell & Smith, 1958; Stanley & Smith, 1956).

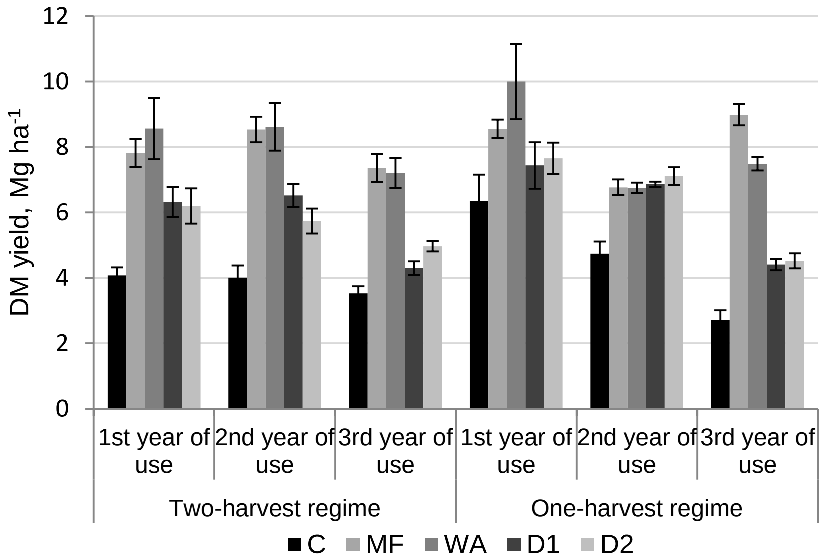

Figure 2. The DMY (Mg ha^{-1}) of reed canary grass, using two-harvest regimes.

In the 2nd year of sward use the biomass yield of RCG and fertiliser efficiency in two-harvest regime was similar to the first year: it ranged from 4.01 Mg ha^{-1} without use of fertilisers to 8.62 and 8.54 Mg ha^{-1} in WA and MF variants, respectively. However in one-harvest regime DMY was more similar among all fertilised variants, there were significant differences (*$P > 0.05$*) only between control variant and all fertilised variants, but DM yields among them did not differ significantly.

In the 3rd year of sward use DMY of RCG in general was slightly behind the yield level of the first two years with the exception of MF option in one-harvest regime.

The DM yields of festulolium in the 1st year of sward use ranged from 2.61 to 5.02 Mg ha^{-1} in two-harvest regime; and from 3.54 to 7.73 Mg ha^{-1} in one-harvest regime (Fig. 3). In the 2nd year of sward use DM yields of festulolium were slightly lower: from 1.11 to 3.78 Mg ha^{-1} in two-harvest regime and from 1.19 to 5.66 Mg ha^{-1} in one-harvest regime. In the 3rd year of sward use DM yield level did not differ significantly between harvest regimes: DMY ranged from 2.55 to 7.29 Mg ha^{-1} in two-harvest regime and from 2.57 to 7.86 Mg ha^{-1} in one-harvest regime. Similar to the RCG, the highest yields of festulolium were provided by using mineral fertilisers and wood ash, as well as digestate ensured significant increase of DMY compared with control variant.

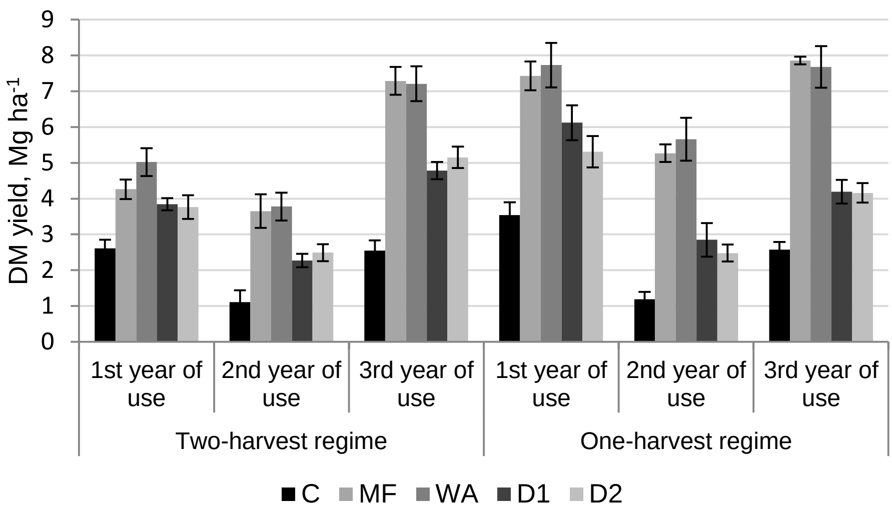

Figure 3. The DMY (Mg ha^{-1}) of festulolium, using two-harvest regimes.

In general, the biomass yields of RCG in a three-year period were relatively stable with a slight tendency to decrease – from 6.7/8.0 Mg ha^{-1} (two-harvest/one-harvest regime) on average in the 1st year of use to 5.5/5.6 Mg ha^{-1} (two-harvest/one-harvest regime) on average in the 3rd year of use. DMY of festulolium declined more in the 2nd year of use. One of the factors influencing the biomass yield of perennial grasses was meterological conditions during the experimental period. The yield reduction of RCG in the 3rd year of use was mostly influenced by unequal rainfall distribution (Fig. 1), there was insufficient rainfall in May, June and August. The decline in yield of festuloliums in the 2nd year of use can be explained by long-term black frost period in the previous winter. Festulolium in such circumstances was less winter-hardy, part of plants died. Festulolium has very high forage quality and good summer production, but has greatest value in multiple-species mixtures because of its relatively low cold tolerance.

One of indirect indicators of sward productivity is plant length; there exists a strong correlation between the length of grass and biomass yield. In our trials it was confirmed by measurements of plant length before the first mowing of sward in two-harvest regime (Fig. 4). The tallest swards were in WA and MF variants, and a higher dry matter yield was also obtained.

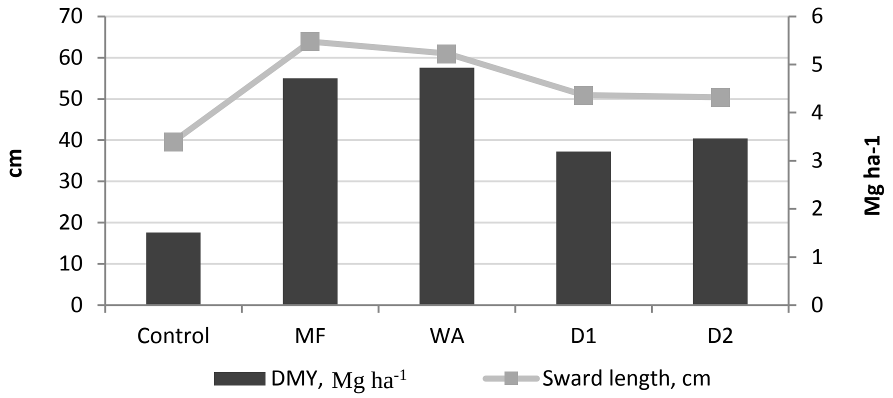

Figure 4. Correlation of festulolium plant length and DM yield of the 1st cut.

The sward of each harvest was evaluated by partitioning of grass biomass among tillers, leaves and panicles. The highest content of leaves was in the sward of the 2nd mowing for both species, particularly high percentage of leaves in the 2nd cut was for festulolium (Fig. 5), as this species has a feature to form only few culms in the aftermath, it mostly consisted from leaves. In our experiment the percentage of leaves in the 2nd cut of festulolium was 90% on average.

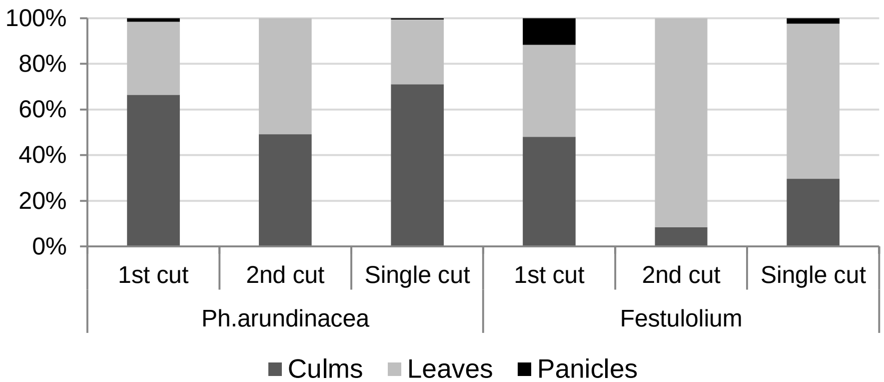

Figure 5. Grass sward structure on average in all fertiliser options.

Whereas the swards of RCG were more abundant in culms, it was particularly pronounced within one-harvest regime, when mowing was done in late autumn at crop senescence. The content of culms was 73% on average. Slightly smaller percentage of culms was in RCG sward of the 1st mowing, it contained 66% of culms on average. The ratio of leaves and culms in the 2nd cut of RCG sward was almost equal – it contained 49% of culms and 51% of leaves on average.

The analysis of grass structure by fertilisation variants show that the higher culms percentage is for more productive swards. Thus MF and WA fertiliser variants, which provided the highest DM yields, ensured greater percentage of culms, too. Considering that in general the culms contain relatively less ash and more carbon (C) it could be concluded that swards with higher percentage of culms have higher heat output and less residue of ash, so they are more suitable for solid fuel production.

Higher content of panicles was in the first mowing for both species: 1.6% for RCG and 11.7% for festulolium. Neither RCG nor festulolium develop any panicles in the aftermath. The small proportion of panicles in the sward of one-harvest regime was due to the fact that the seed was already scattered out in late autumn and therefore panicles had become much lighter.

To decide on the suitability of grass as a raw material for the production of energy it is important to assess the quality of herbaceous biomass (Rancane et al., 2015).

For each fraction of the swards of the first and single cut the chemical composition was determined. The distribution and composition of ash varies among different plant fractions. Ash levels usually are lowest in grass stems and highest in leaves (Lanning & Eleuterius, 1989). The analysis showed that in our trial the ash content of culms was approximately 1.5 times lower in comparison with leaves (Table 1). Whereas most of the 2nd mowing grass consists of leaves, the ash content of it was significantly higher compared to the 1st cut, and especially to the single cut.

Chemical composition was different also between grass species: swards of festulolium contained greater amount of ash. It could be explained by a higher percentage of leaves in the sward. Furthermore festulolium leaves were richer in ash if compared to RCG, the difference was approximately 1.4%: 9.5 and 7.9% in the 1st cut; 7.1 and 6.0% in single cut, respectively. There was no significant difference between ash content in culms of RCG and festulolium.

Ash is an inorganic constituent of plant biomass and it cannot be converted to energy, therefore biomass with less content of ash is preferred. On average single cut of both species contained considerably less ash compared with the 1st cut: approximate reduction was 25% in leaves and 35% in culms. Harvesting biomass with higher stem content can reduce the plant's ash concentration, thus improving the biomass quality for combustion. Several studies (Burvall, 1997; Hadders et al., 1997; Prochnow et al., 2009a; Heinsoo et al., 2011) revealed that fuel quality is improved with delayed harvest, because of a 20–80% reduction of the concentrations of most elements that lead to environmentally harmful emissions or ash-related problems during combustion.

The higher carbon (C) content leads to a higher heating value. The carbon content of biomass is around 45%, while coal contains 60% or greater (Demirbas, 2004). The carbon (C) content of our swards on average in all treatments for both species varied around 476 g kg^{-1} for leaves and around 494 g kg^{-1} for culms of the 1st cut (Table 1). A slightly higher C content was for single cut: around 487 g kg^{-1} for leaves and 532 g kg^{-1} for culms on average. Obviously the carbon content in the culms was higher than in the leaves in general, it was notably expressed in festulolium.

Fuel-bound nitrogen is responsible for most nitrogen oxide (NO_x) emissions produced from biomass combustion. The fuel nitrogen content is responsible for nitrogen oxide formation and should not exceed 0.6% w/w in dry matter (DM) (Obernberger et al., 2006). Lower nitrogen content in the fuel should lead to lower NO_x emissions. The nitrogen (N) content in leaves was 2–3 times higher compared to culms, it varied around 25 g kg^{-1} in leaves and around 9 g kg^{-1} in culms on average of both species in the 1st cut.

Table 1. Chemical composition of the 1st and single cut leaves and culms; and the 2nd cut swards

Species	Fertiliser variant	1st cut		Single cut		2nd cut
		Leaves	Culms	Leaves	Culms	Sward
Ash content, %						
Phalaris arundin.	Control	7.76	5.93	6.75	4.86	11.19
	MF	8.10	5.57	6.47	3.07	9.48
	WA	8.09	6.35	6.88	3.68	9.01
	D1	8.06	5.73	5.33	4.23	10.52
	D2	7.72	5.49	4.75	4.18	10.52
Festulolium	Control	9.20	5.61	7.59	3.77	10.59
	MF	9.51	6.89	7.02	3.65	9.22
	WA	9.88	6.72	7.30	4.21	8.70
	D1	9.80	6.99	7.24	3.34	8.27
	D2	8.95	6.15	6.48	4.01	9.64
On average		8.71	6.14	6.58	3.90	9.71
$LSD_{0.05}$		1.41	1.41	1.41	1.41	2.51
Carbon content, g kg^{-1}						
Phalaris arundin.	Control	480.60	487.10	498.27	515.25	497.61
	MF	490.45	492.11	506.89	538.18	508.10
	WA	497.68	497.37	498.45	526.49	511.90
	D1	482.84	495.49	505.22	535.85	501.35
	D2	494.62	491.65	497.87	537.12	508.79
Festulolium	Control	460.60	499.34	477.62	528.79	501.13
	MF	458.61	505.28	470.31	543.29	510.51
	WA	474.82	492.36	467.34	528.15	503.32
	D1	467.15	491.55	473.27	539.08	504.55
	D2	456.28	487.34	477.63	526.44	493.88
On average		476.37	493.96	487.29	531.86	504.11
$LSD_{0.05}$		23.54	23.54	23.54	23.54	13.53
Nitrogen content, g kg^{-1}						
Phalaris arundin.	Control	22.33	8.53	11.51	5.10	13.88
	MF	29.20	9.93	17.61	5.68	14.97
	WA	35.68	13.52	15.53	5.33	13.43
	D1	25.83	9.64	10.16	6.87	15.32
	D2	23.15	8.85	10.48	3.46	15.26
Festulolium	Control	14.76	7.19	12.77	3.65	12.02
	MF	25.54	13.24	15.08	5.11	13.15
	WA	28.91	9.08	13.70	5.33	11.96
	D1	23.35	6.91	12.06	3.30	11.74
	D2	18.63	5.27	11.51	4.17	13.19
On average		24.74	9.22	13.04	4.80	13.49
$LSD_{0.05}$		4.41	4.41	4.41	4.41	1.52

In single cut the nitrogen content was almost two times lower – around 13 g kg^{-1} in leaves and around 5 g kg^{-1} in culms, on average. All fertilised variants contained significantly (*P > 0.05*) more nitrogen compared to control, particularly MF and WA. Obviously it was due to mineral N fertiliser use that facilitated the highest nitrogen accumulation in biomass. It is also confirmed by studies results elsewhere which show that N content increases with higher N fertiliser doses and early cutting period (Nilsson et al., 2011). In the studies in Lithuania with *Dactylis glomerata* the swards treated with mineral fertiliser exhibited significantly higher nitrogen concentration compared to those fertilised with digestate (Tilvikiene et al., 2014).

The quality of biomass is mostly dependent on growing conditions, grass species, cutting frequency and fertilisation (Prochnow et al., 2009b). The factor impact analysis by summing both cutting regimes in our experiments is summarized in Table 2. The ash content was mostly influenced by sward fraction (impact factor – 49.2%) and harvest regime (34.2%). In the culms of single cut there was lower ash content for both species, what is a positive feature for combustion material.

Table 2. The influence of various factors on the chemical composition of the herbaceous biomass

Factors	Factor influence (%) on the content of		
	ash	carbon	nitrogen
Harvest regime	34.2	26.3	27.9
Sward fraction	49.2	43.9	54.9
Species	6.1	10.3	2.4
Fertiliser	3.3	2.8	9.6
Other (environment etc.)	7.2	16.7	5.2

The similar pattern was also for carbon and nitrogen content – it was mostly influenced by sward fraction (43.9 and 54.9%, respectively) and harvest regime (26.3 and 27.9%, respectively). Leaves contained 2 to 3 times more nitrogen than culms; and swards of two-harvest regime had almost two times higher N content. But contrary to ash and nitrogen, more carbon was accumulated in the culms of a single cut. The content of nitrogen was greatly influenced by fertilisers applied (impact factor 9.6%), the highest nitrogen content was in MF and WA variants.

CONCLUSIONS

DM yield ranged over the years between harvest regimes, but summarising the data of three years significant differences were not found. Relatively higher biomass yield was provided by reed canary grass.

All types of fertilisers provided an increase of dry matter yield; however better results for both grass species were ensured by the usage of mineral fertilisers and wood ash.

The harvest regime and species affected directly the quality of biomass. The single cut of reed canary grass contained significantly less ash and more carbon, therefore more appropriate raw material for solid fuel could be obtained by harvesting reed canary grass once per season as late as possible in the autumn.

There were significant differences between sward fractions – culms contained less ash and nitrogen, and they had significantly higher carbon content than leaves. It can be concluded that more suitable for solid fuel are swards with the higher proportion of culms, which provides greater heat output and less atmospheric pollution.

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Ergonomics risk analysis in construction operations

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Abstract. The research focuses on analysis of ergonomics risks among construction workers in different operations at work. The aim of the research is to carry out ergonomics risk analysis in various construction operations and to prove that physically hard manual work and application of force in manual work operations affect muscular fatigue, using objective and subjective risk assessment methods, including extended version of Nordic musculoskeletal questionnaire, myotonometric measurements, muscle's force determination with dynamometer. During the research it was proved that the combination of objective and subjective ergonomics risk analysis methods provides holistic approach and reliable ergonomics risk analysis results.

Key words: Ergonomics, construction, risk, hand grip

INTRODUCTION

In Latvia, number of employees in construction works is one of the highest in comparison to other branches of the national economics. In this branch, number of occupational diseases caused by overload has grown rapidly regardless of the automation and mechanization of many processes. In the last decade work related musculoskeletal disorders (WRMSD) every year comprise about 65% of the total number of occupational diseases in the country. Analysis of literature reveals that such diseases are more common in construction than in any other industrial sector, except transportation, and that construction workers comprise the highest risk group for work related musculoskeletal disorders, including lower back pain (Goldsheyder et al., 2002; Henker et al., 2005). Review of the injury data showed that construction workers experience musculoskeletal injuries at a rate about 50% higher than manufacturing workers (Sneider, 2001). In a British study, the 1-year cumulative incidence of lower back pain was 40% among construction workers as compared with 28% among foremen (Macfarlane, 1997). Construction workers are usually engaged in an uncomfortable posture. They lift and move heavy loads with hands, as well as often perform repeated actions and during the work apply considerable hand forces. These conditions are intensified by work in unstable environment. Studies show that grip force declines after midlife, with loss, accelerating with increasing age and through old age (Roberts et al., 2011). Grip force is related to other health conditions, but the relationship has not been stated to be causative (Bohannon, 2008). Hand grip force is negatively associated with physical frailty, even when the effects of body mass index (BMI) and arm muscle circumference are removed (Syddall et al., 2003). Hand grip force can be quantified by measuring the amount of static force with which the hand can squeeze around a dynamometer (Lescinskis et al., 2012). Hand grip force is a reliable measurement when standardised methods and calibrated equipment are used, even when there are different assessors (Mathiowetz, 2002) or different brands of dynamometers (Schmidt et al., 2002). Researchers have suggested that the factor, related to frailty and disability in later life, is the manner in which muscles are used, and this can be measured by hand dynamometry that will be applied in this research. WRMSDs cause deterioration of health, which manifests as chronic pain in certain body parts and premature muscle fatigue, thus increasing the costs of absenteeism due to less productivity at work (Punnett & Wegman, 2004; Roja et al., 2006; Kalkis, 2014).

Therefore ergonomics intervention in construction processes is important in order to promote employees' health, safety and to increase productivity (Lussier, 2014). Ergonomics risk analysis at work and work processes ensures employee's wellbeing, sense of belonging and trust to the organisation (Kalkis., 2008; Roja, 2008; Kalkis, 2014).Various studies in the world prove that the effectiveness of the organisation is closely related to a human as the performer of work duties, and his or her skills and health affect business results of organisation (Sperry, 2002).

The research focuses on analysis of ergonomics risks among construction workers in different operations at work.

The aim of the research is to carry out ergonomics risk analysis in various construction operations and to prove that physically hard manual work and application of force in manual work operations affect muscular fatigue, using objective and subjective risk assessment methods.

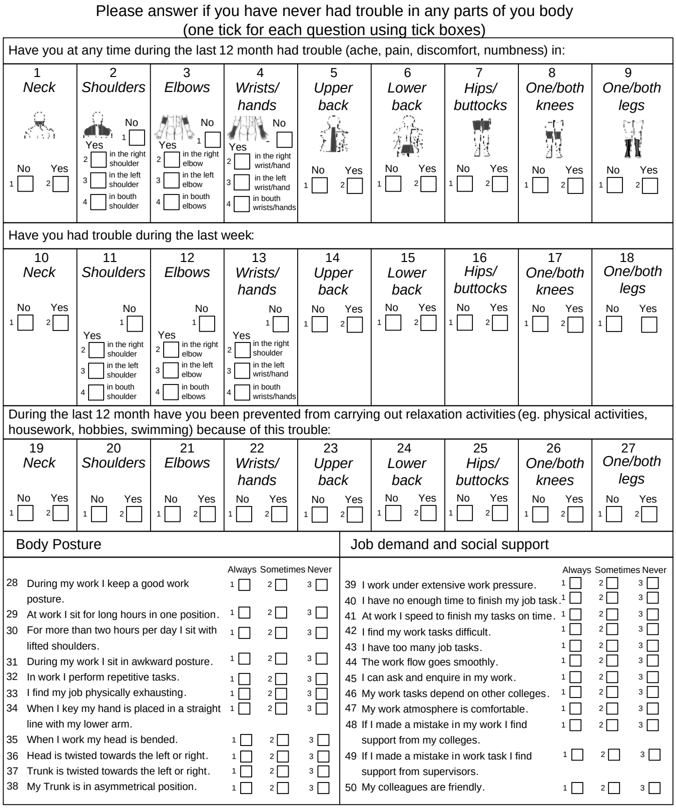
The study was conducted in one of the Latvian construction organisations. The study involved 7 assemblers and 8 building workers (see Table 1). All of them agreed to participate in the experiment with objective evaluation methods. Criteria for selection of the persons to be studied were: whether the person has been suffering from persistent pain in musculoskeletal system for more than three months according to complaints and objective findings during compulsory check-ups, length of service in the profession, employee's consent to participate in the study. None of the research participants had any upper limb pathology or dysfunction. All persons were right-handers. Persons were excluded from the study in such cases: the employees not having health checkups, persons with acute pain and with specific muscular and skeletal diseases.

This study was conducted in accordance with ethical standards and was approved by the Riga Stradins University Ethical Committee in 2015.

MATERIALS AND METHODS

1. Extended version of Nordic musculoskeletal questionnaire (NMQ-E). This questionnaire was used to assess musculoskeletal problems in construction workers and assemblers (the nature and severity of self-rated musculoskeletal symptoms, including items inquiring about the experience of problems in nine body areas) (Kuorinka et.al.,

1987). In our study, the extended version of NMQ-E contains some additional questions regarding body postures, job demands and social support (see Fig. 1).


Please answer if you have never had trouble in any parts of you body
(one tick for each question using tick boxes)

Have you at any time during the last 12 month had trouble (ache, pain, discomfort, numbness) in:

1 *Neck*	2 *Shoulders*	3 *Elbows*	4 *Wrists/ hands*	5 *Upper back*	6 *Lower back*	7 *Hips/ buttocks*	8 *One/both knees*	9 *One/both legs*
No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐ in the right shoulder 3 ☐ in the left shoulder 4 ☐ in bouth shoulder	No 1 ☐ Yes 2 ☐ in the right elbow 3 ☐ in the left elbow 4 ☐ in bouth elbows	No 1 ☐ Yes 2 ☐ in the right wrist/hand 3 ☐ in the left wrist/hand 4 ☐ in bouth wrists/hands	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐

Have you had trouble during the last week:

10 *Neck*	11 *Shoulders*	12 *Elbows*	13 *Wrists/ hands*	14 *Upper back*	15 *Lower back*	16 *Hips/ buttocks*	17 *One/both knees*	18 *One/both legs*
No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐ in the right shoulder 3 ☐ in the left shoulder 4 ☐ in bouth shoulder	No 1 ☐ Yes 2 ☐ in the right elbow 3 ☐ in the left elbow 4 ☐ in bouth elbows	No 1 ☐ Yes 2 ☐ in the right shoulder 3 ☐ in the left wrist/hand 4 ☐ in bouth wrists/hands	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes ☐

During the last 12 month have you been prevented from carrying out relaxation activities (eg. physical activities, housework, hobbies, swimming) because of this trouble:

19 *Neck*	20 *Shoulders*	21 *Elbows*	22 *Wrists/ hands*	23 *Upper back*	24 *Lower back*	25 *Hips/ buttocks*	26 *One/both knees*	27 *One/both legs*
No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐	No 1 ☐ Yes 2 ☐

Body Posture	Always	Sometimes	Never
28 During my work I keep a good work posture.	1 ☐	2 ☐	3 ☐
29 At work I sit for long hours in one position.	1 ☐	2 ☐	3 ☐
30 For more than two hours per day I sit with lifted shoulders.	1 ☐	2 ☐	3 ☐
31 During my work I sit in awkward posture.	1 ☐	2 ☐	3 ☐
32 In work I perform repetitive tasks.	1 ☐	2 ☐	3 ☐
33 I find my job physically exhausting.	1 ☐	2 ☐	3 ☐
34 When I key my hand is placed in a straight line with my lower arm.	1 ☐	2 ☐	3 ☐
35 When I work my head is bended.	1 ☐	2 ☐	3 ☐
36 Head is twisted towards the left or right.	1 ☐	2 ☐	3 ☐
37 Trunk is twisted towards the left or right.	1 ☐	2 ☐	3 ☐
38 My Trunk is in asymmetrical position.	1 ☐	2 ☐	3 ☐

Job demand and social support	Always	Sometimes	Never
39 I work under extensive work pressure.	1 ☐	2 ☐	3 ☐
40 I have no enough time to finish my job task.	1 ☐	2 ☐	3 ☐
41 At work I speed to finish my tasks on time.	1 ☐	2 ☐	3 ☐
42 I find my work tasks difficult.	1 ☐	2 ☐	3 ☐
43 I have too many job tasks.	1 ☐	2 ☐	3 ☐
44 The work flow goes smoothly.	1 ☐	2 ☐	3 ☐
45 I can ask and enquire in my work.	1 ☐	2 ☐	3 ☐
46 My work tasks depend on other colleges.	1 ☐	2 ☐	3 ☐
47 My work atmosphere is comfortable.	1 ☐	2 ☐	3 ☐
48 If I made a mistake in my work I find support from my colleges.	1 ☐	2 ☐	3 ☐
49 If I made a mistake in work task I find support from supervisors.	1 ☐	2 ☐	3 ☐
50 My colleagues are friendly.	1 ☐	2 ☐	3 ☐

Figure 1. Musculoskeletal questionnaire (Roja et al., 2013).

2. Assessment of the functional state of skeletal muscles and muscle fatigue was carried out using myotonometric measurements with the MYOTON-3 device. (Vain, 1995; Roja at al., 2006).

3. Grip force as assessment technique is recommended for the measurement of muscle strength, and is one of the simplest methods for assessment of muscle function (Bohannon, 2008).The Camry Electronic Hand Dynamometer for Hand Grip Force evaluation was used in the study. With Dynamometer high-precision power gauging gives momentary digital readouts of gripping power and auto capturing of maximum achieved grip power and display of the value. The testing has been done in the standing position with the examinee holding the dynamometer: the person, at shoulder height, stretches out the arm to the side and holds the dynamometer in the hand; not bending the arm, the person squeezes the digital spring of the dynamometer with maximum strength. On its scale the examiner reads the amount of the applied muscle force (kg). Muscle force was determined 3 times for each arm separately and the average result recorded (Roberts et al, 2011).

The room temperature was 22 °C. The average value of the three repetitions has been calculated and used in this study. Measurements were made with measure tape with 0.1cm precision.

Each worker was tested individually in the morning before the shift and in the evening after the work shift at the same time of the day during 1 week cycle. The same examiner performed all measurements.

RESULTS AND DISCUSSION

Background factors of the research group are shown in Table 1.

Table 1. Background factors of the research groups, mean age and range, length of service, mean height, mean weight, mean body mass index (BMI)

Professions	n	Mean age ± SD	Range	Mean length of service ± SD	Mean height, cm ± SD	Mean weight, kg ± SD	Mean BMI, kg m^{-2} ± SD
Construction worker	8	35.3 ± 5.8	26–45	6.8 ± 3.5	176.2 ± 6.3	79.4 ± 11.2	25.5 ± 3.3
Assembler	7	36.4±7.7	23–38	6.8 ± 4.6	178.0 ± 9.5	76.1 ± 5.1	24.2 ± 2.1

The main duties of construction workers were the following: loading and unloading of construction supplies with hands, making of building structures, carrying of construction supplies and taking away of waste materials. Generally, construction workers' hands were loaded with physically hard work. The main duties of assemblers were related with drilling, tightening of screws assembling building structures, and utilities. Generally, assemblers' work is performed in awkward postures, very often with arms raised above the shoulder level.

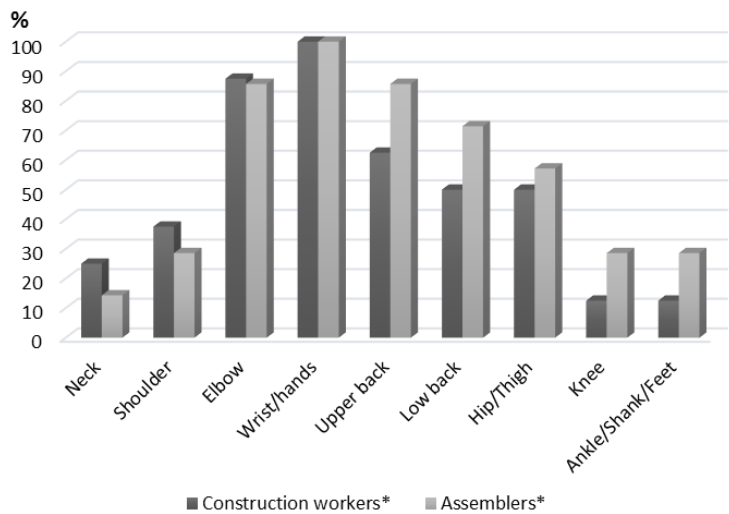


Figure 2. Distribution of persistent complaints in different parts of the body of construction workers and assemblers (*Multiple answers were possible).

The distribution of persistent complaints in each part of the body, separately for construction workers and assemblers, according to the extended version of Nordic musculoskeletal questionnaire NMQ-E was shown in the Fig. 2.

The acquired survey results suggest that during work construction workers' and assemblers' arms are most loaded in the area of elbows and base of the hand, respectively 87.50% and 85.71%. All employees (100%), involved in the study, complain of the load of arms. Construction workers complain also of the load in the upper and the lower back, respectively, 85.70% and 71.40%. Distribution of postures, job demand and social support for construction workers and assemblers are shown in Fig. 3.

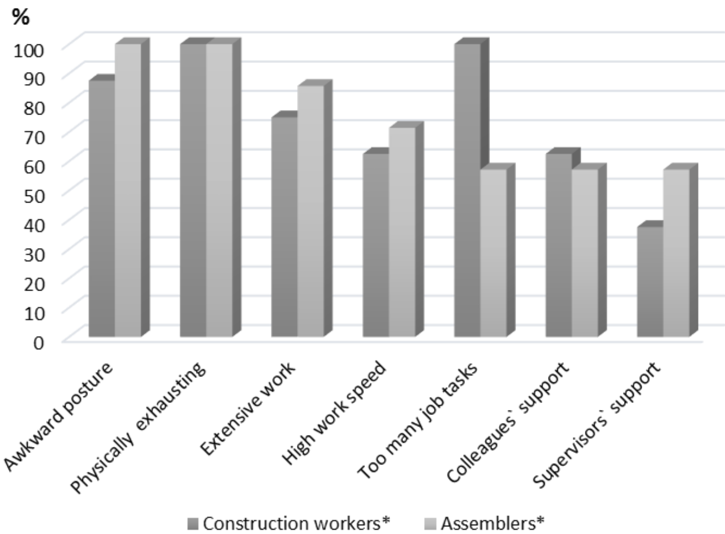


Figure 3. Distribution of postures, job demand and social support for construction workers and assemblers (*****Multiple answers were possible).

It should be noted that employees of both professions work in awkward posture (see Table 3). Generally, all employees have high work intensity (85.71% and 75.00%) at high speed of work. Half of the employees mention insufficient support from colleagues and management.

Using the Myoton-3 device and gathered investigation data during the one week work cycle (from Monday to Friday), it is possible to determine change in muscle tone, the workers' capacity for work, the ability to adapt to the work rhythm and work load, as well as the moment when muscle fatigue sets in. It is noted that the natural oscillation frequency of muscles in their functional state of relaxation is usually 11−16 Hz (contracted 18−40 Hz), depending on the muscle. The stiffness values depend significantly on the muscle under investigation, their usual range is 150−300 N m^{-1}. For the contracted muscles the stiffness value can be higher than 1,000 N m^{-1}. The decrement values, calculated from the measurement results, are usually not higher than 1.0−1.2, depending on the muscle. In case of trained muscles, the decrement of contracted muscles decreases (e.g. from 1.0 to 0.6), i.e. the muscle elasticity increases.

According to regression analysis, the trend line reflects the condition of the muscles after one week work cycle for all workers and can be subdivided into several MYO categories (Roja at al., 2006):

Category I – absolute muscle relaxation with the ability to relax;

Category II – a state of equilibrium, when muscles are able to adapt to the work load and are able to relax partly;

Category III – muscle fatigue and increase in tone.

Since representatives of both professions mainly complain of pain or discomfort in the arms and upper back, it was decided to make objective measurements with Myoton-3 equipment, evaluating adaptability of the muscles (*m. extensor digitorum*, *m. flexor carpi radialis*, *m. trapezius*) to work load. In the 'Results and discussion' section all pertinent results should be presented in a logical order and discussed. Discussion portion could also include significance of the results in context of the research field, and suggestions for the future research.

The comparison of different muscle groups after one-week work cycle, when the frequency and stiffness go beyond the norm, is represented in Table 2. Subjective viewpoint of the workers is pronounced as acceptance (pac, %).

Table 2. Percentage of workers whose muscle frequency exceeds the norm (>16 Hz) after one-week work cycle.

Muscle groups	Construction workers (n = 8)			Assemblers (n = 7)		
	%	κ	p_{ac}	%	κ	p_{ac}
m. extensor digitorum	75.00	0.64	62.50	85.71	0.59	71.43
m. flexor carpi radialis	87.50	0.51	75.00	85.71	0.65	71.43
m. trapezius	87.50	0.70	87.50	85.71	0.53	85.71

Analysis of the data shows that for the construction workers and assemblers the greatest load was put on arm muscles *m. extensor digitorum* and *m. flexor carpi radialis*. In this case, the normal frequency was exceeded by 75.00%–87.50% in construction workers, and by 85.71% in assemblers. Myotonometric measurements also showed that *m. trapezius* frequency exceeded the norm in both groups respectively, 87.50% in construction workers and 85.71% in assemblers.

The percentage of the construction workers and assemblers with difference in their muscle tone (MYO categories) before and after one work-cycle is shown in Table 3.

Table 3. Percentage of construction workers (n = 8) and assemblers (n = 7) with difference in their muscle tone (MYO Categories) before and after one work-cycle, and Cohen's Kappa (κ)

Category	κ
Construction workers:	
I –12.50%	0.33
II − 37.50%	0.68
III − 50.0%	0.51
Assemblers:	
I –14.29%	0.86
II − 28.57%	0.69
III − 57.14%	0.75

Myotonometric analysis shows that nearly in all employees muscles are not able to adapt to the work load, which corresponds to II and III MYO Category. In 37.50% of construction workers and 28.57% of assemblers muscles are able to adapt to the work load and are able to relax partly, but in 50.00% of construction workers and 57.14% of assemblers muscle fatigue and muscle tone drastically increased. It should be noted that the mentioned changes occurred in younger employees with length of service 0-5 years. It could be explained by the fact that the younger employees are beginners and have not used to physical work load and they have not had physical work experience.

Since most of the employees in the survey complain of the load on the hands, in order to find out hand grip muscle force dynamometric method was applied. Acquired results are shown in Table 4.

Table 4. Hand grip muscle force measurements in one -week work cycle for construction workers and assemblers

Days	Hand grip muscle force, kg in one-week cycle (Monday till Friday) Construction workers				Hand grip muscle force, kg in one-week cycle (Monday till Friday) Assemblers			
	Morning		Evening		Morning		Evening	
	Right	Left	Right	Left	Right	Left	Right	Left
Monday	52.6 ± 3.9	52.4 ± 4.2	52.6 ± 5.6	49 ± 6.9	48.5 ± 4.5	46± 4.2	43.3 ± 3.1	33.6 ± 6.1
Tuesday	54 ± 5.3	53.6 ± 8.7	55.8 ± 7.3	44 ± 3.8	59.2 ± 3.2	50.6 ± 5.2	40 ± 5.7	36.4 ± 3.5
Wednesday	54 ± 5.6	49.9 ± 5.1	52.5 ± 2.6	39.7 ± 5.3	48.8 ± 3.3	47.4 ± 4.9	36.8 ± 4.8	42.4 ± 7.1
Thursday	59.9 ± 6.4	58.4 ± 4.6	44.1 ± 4.8	44.5 ± 3.6	59 ± 5.2	50.3 ± 4.1	42 ± 3.7	41.3 ± 3.5
Friday	54.4 ± 8.7	47.8 ± 3.5	53.1 ± 5.5	45.3 ± 4.5	50.9 ± 6.9	56.2 ± 6.3	49.6 ± 5.8	47 ± 4.6

Analysis of hand grip muscle force shows that before and after carrying out of work duties within the period of one week hand grip muscle force of nearly all employees was in norm, except in one construction worker (aged 43, length of service 10 yrs) and in one assembler (aged 38, length of service 8 yrs). In most of the employees (7 construction workers and 6 assemblers) hand grip muscle force results in the right hand are higher than in the left hand. In few cases, though none of the employees is a left-hander, hand grip muscle force in left hand was greater than that in the right hand. In general, the acquired results suggest that hand grip force within the one-week work cycle decreases.

The acquired results correspond with published normative data for hand grip force available from many countries, and in most cases, data are divided into age and gender subgroups (Mathiowetz et al, 1985). Analysis of grip force by gender shows higher grip by males at all ages, and analysis by age group demonstrates high grip force in the age group starting from 40 years (Bohannon et al, 2006). Such trend has also been found in other studies that divide participants by age, gender, by right and left hand, dominant and non-dominant hand.

CONCLUSIONS

Research proved that construction workers are subjected to various ergonomic risks, including long and intensive work hours, awkward postures, and frequent movements. Construction workers and assemblers have persistent complaints in various body parts (highest scores by NMQ-E questionnaire: wrists, hands, upper back, low back), lack social support (colleagues` and supervisors` support) and have high work speed and too many job tasks that results in negative effect on physical and mental workload.

The acquired results with dynamometer on hand grip muscle force correspond with myotonometric measurements of muscle fatigue and prove that in construction workers muscle tone within one-week work cycle decreases, and hand grip muscle force decreases as well. It proves the setting in of muscle fatigue in construction workers and assemblers in various construction operations.

Objective measurements with devices Myoton-3 and Dynamometer are suitable for determination of the muscle fatigue and the applied force in construction workers and assemblers in various construction operations. The combination of objective and subjective ergonomics risk analysis methods provides holistic approach and reliable ergonomics risk analysis results.

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Distribution of mating types, metalaxyl sensitivity and virulence races of *Phytophthora infestans* in Estonia

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Abstract. Potato late blight, caused by the oomycete *Phytophthora infestans*, is a destructive potato disease, causing considerable crop loss worldwide. As the late blight pathogen population is diverse and variable in Estonia, changes in the population should be monitored regularly. In this study, the Estonian population of *P. infestans* was characterised with mating type, sensitivity to metalaxyl and virulence on potato R-gene differentials. During the growing season 2013, 110 isolates were collected from nine potato fields. The frequency of A2 mating type was on average 29%, and varied significantly between different fields from 7% to 78% ($p = 0.001$). On all studied potato fields, both mating types were recorded, suggesting continuous sexual reproduction of *P. infestans* and possible risk of oospore production and early attacks of late blight in Estonian potato fields. The prevalence of metalaxyl sensitive isolates in the population (64%) differed from results from previous research. Thus changes have occurred in the *P. infestans* Estonian population. There were no significant differences in metalaxyl sensitivity between studied fields ($p = 0.073$). The Estonian race structure was highly diverse and complex, on average 7.2 virulence factors per isolate, but varied between fields from 5.6 to 9.0. 42 virulence races were found; the four most common were 1.2.3.4.5.6.7.8.10.11, 1.2.3.4.6.7.8.10.11, 1.2.3.4.7.10.11 and 1.2.3.4.7.8.10.11, which comprised 46% of the population. The overall normalized Shannon's diversity index was 0.69, confirming the high diversity of the population. Continuous pathogen population studies describing the contemporary *P. infestans* population are essential in order to advise potato breeders and growers accordingly.

Key words: mating type, metalaxyl, *Phytophthora infestans*, population variation, potato late blight, virulence testing.

INTRODUCTION

Potato late blight is caused by the oomycete pathogen *Phytophthora infestans*; it first appeared in Europe more than 160 years ago but remains a major threat to potato crops both in Europe and worldwide. Despite recent active research and progress, late blight still requires vigilance and often numerous applications of fungicide for effective control (Cooke et al., 2011). It is a serious problem for Estonian potato production, particularly under favourable conditions, when it can destroy the whole potato haulm and the average loss due to late blight can reach 20–25% and in untreated fields even more (Runno-Paurson et al., 2010). Fungicides are used routinely in conventional potato production, but under favourable conditions for the disease, with heavy pressure from the pathogen, protection of large areas is complicated (Runno-Paurson et al., 2010).

Potato late blight pathogen *P. infestans* is an heterothallic organism with two mating types A1 and A2. The pathogen is able to reproduce sexually and asexually. During the 1980s, *P. infestans* populations containing both mating types migrated from Mexico apparently in 1976/77 into Europe giving rise to sexually reproducing populations (Fry & Goodwin, 1997). New diverse *P. infestans* genotypes were very adaptable and spread quickly all over Europe displacing the old clonal lineage which is now found only rarely (Carlisle et al., 2002; Cooke et al., 2011). *P. infestans* benefits from sexual reproduction by increased adaptability of the pathogen and production of oospores that can survive in the soil for several years (Turkensteen et al., 2000; Yuen & Andersson, 2013). While low temperature could even conserve the viability of the oospores (Turkensteen et al., 2000; Hannukkala, 2012) the pathogen benefits from it in Estonia during cold winters. Furthermore, genotyping *P. infestans* Estonian isolates with SSR markers revealed high genetic diversity and provided evidence that sexual reproduction and recombination are common in this population (Runno-Paurson et al., 2016).

While the late blight pathogen population is diverse and variable in Estonia, changes in the population should be monitored regularly. Therefore, in this study, potato late blight pathogen *Phytophthora infestans* isolates collected in 2013 from different potato fields in Estonia were characterised with phenotypic characteristics such as mating type, metalaxyl sensitivity and virulence to Black's differentials.

MATERIALS AND METHODS

Collection and isolation of *P. infestans* strains

Potato leaves infected by *P. infestans* were collected in 2013 from nine sites from five counties in Estonia (Table 1). The samples were taken from large scale conventional and small scale conventional growers' potato fields, potato field trials and an organic field (Table 1). In large scale conventional productions farmers used high-quality certified seed potatoes and applied fungicide 6–8 times per season. The metalaxyl-based fungicide Ridomil Gold MZ 68 WG was applied at the beginning of disease infection at least twice. Rotation varied between 0–2 years on these farms. Small scale conventional farmers used uncertified seed potatoes and no fungicides routinely for late blight control. The interval between growing potato crops was 1–2 years. At the potato field trials in Reola and at the Estonian Crop Research Institute in Jõgeva fungicide was not used, but at Lepiku field trial fungicides were applied three times per season. At the organic field and field trials growers rotated fields and grew potatoes every 3–4 years.

Nine to fifteen isolates were cultured from each sampling site (Table 1). The sampled plants were located at a random distance from field edges. Only single lesion leaves were collected from each plant, taken randomly; any leaves with several or no lesions were excluded. Isolations were carried out and maintained using methods described by Runno-Paurson et al. (2009). All phenotypic tests were carried out immediately after the isolations were finished (October to January). *P. infestans* isolates of this study are preserved at Tartu Fungal Collection (TFC).

Table 1. The number of *Phytophthora infestans* isolates collected in 2013 and tested for mating type, metalaxyl sensitivity and virulence phenotype

Sampling site	County	Crop type*	Tested for		
			Mating type (n)	Metalaxyl (n)	Virulence (n)
Jõgeva 1	Jõgeva	Trial field	12	12	12
Jõgeva 2	Jõgeva	Organic	14	14	14
Antsla	Võru	LSC	14	14	13
Lepiku	Tartu	Trial field	15	15	13
Reola	Tartu	Trial field	11	11	11
Sürgavere	Viljandi	LSC	9	9	8
Tilga	Tartu	SSC	11	11	11
Verioramõisa	Põlva	LSC	14	14	14
Võnnu	Tartu	SSC	10	10	8
Total			110	110	104

* - LSC (large scale conventional), SSC (small scale conventional).

Phenotypic analyses

Mating types were determined by the method described in Runno-Paurson et al. (2009). The tester isolates were 90209 (A1) and 88055 (A2) as described in Hermansen et al. (2000). Isolates forming oospores on plates with the A1 mating type were registered as A2; isolates that formed oospores with the A2 mating type were registered as A1.

P. infestans isolates resistance to metalaxyl was tested using a modification of the floating leaflet method (Hermansen et al., 2000). Leaf disks (14 mm diameter) were cut with a cork borer from leaves of five-week-old greenhouse-grown potato plants. The susceptible cultivar 'Berber' was used. Six leaf disks were floated abaxial side up in Petri plates (50 mm diameter) each containing 7 mL distilled water or metalaxyl in concentrations of 10.0 or 100.0 mg L^{-1} prepared from technical grade metalaxyl-M (Syngenta experimental compound (metalaxyl-M), CGA 329351A). The inoculation and trial incubation was done as described by Runno-Paurson et al. (2009). The isolates were rated resistant if they sporulated on leaf disks in 100 mg L^{-1} metalaxyl (Hermansen et al., 2000). Those sporulating on leaf disks in a metalaxyl concentration of 10 mg L^{-1}, but not on leaves floating on 100 mg L^{-1} were rated intermediate, and those sporulating only in water were rated sensitive.

The virulence pathotype was determined with detached leaflet set of Black's differentials of potato genotypes containing resistance genes R1–R11 from *Solanum demissum* (Malcolmson & Black, 1966) (provided by the Scottish Agricultural Science Agency). Laboratory procedures were as described in Runno-Paurson et al. (2009).

Data analysis

Statistical analyses were performed with the SAS/STAT version 9.1 (SAS Institute Inc., Cary, NC, USA). Differences in the prevalence of the two mating types of *P. infestans* isolates between study sites were tested using a logistic analysis (GENMOD procedure in SAS) with a multinomial response variable (A1, A2, or both). Analogous logistic procedures were used to examine the differences in the resistance to metalaxyl (a multinomial response variable: resistant, intermediate or sensitive) between sites and also between different mating types. The dependence of specific virulence (percent of isolates that show virulence against particular R-genes) on site and R-genes was analysed with type III ANOVA and Tukey HSD post-hoc tests ($\alpha = 0.05$). In all analyses, 'site' was treated as a categorical variable.

Race diversity was calculated with the normalized Shannon diversity index (Sheldon, 1969). The differences in the Shannon index values between sites was analysed with one-way ANOVA and Tukey HSD test.

RESULTS AND DISCUSSION

Both A1 and A2 mating types were found among *P. infestans* isolates collected in Estonia in 2013. Out of 110 tested isolates, 71% were classified as A1 mating type and 29% were classified as A2 mating type (Table 2). There were considerable differences in the proportion of A1 and A2 between sampling sites (*Chi-square* = 25.44, $df = 8$, $p = 0.001$), with the frequency of A2 mating type varying between different potato fields from 7 to 78% (Table 2).

Table 2. Percentages of mating types among isolates of *Phytophthora infestans* in Estonia in 2013

Site	Mating type (%)		Number
	A1	A2	of isolates
Jõgeva 1	75	25	12
Jõgeva 2	71	29	14
Antsla	43	57	14
Lepiku	93	7	15
Reola	91	9	11
Sürgavere	22	78	9
Tilga	73	27	11
Verioramõisa	93	7	14
Võnnu	60	40	10
Total	71 ± 7.6*	29 ± 7.6*	110

* – mean ± SE.

The average percentage of A2 mating type was a bit lower than previously recorded in Estonia (Runno-Paurson et al., 2010; Runno-Paurson et al., 2013; Runno-Paurson et al., 2014), but temporal fluctuation has been noticed before (Runno-Paurson et al., 2012). However, our findings on mating types in the Estonian population are generally comparable with populations described recently in studies from the Nordic countries Finland, Denmark, Norway and Sweden (Lehtinen et al., 2008; Hannukkala, 2012), Latvia (Aav et al., 2015), Lithuania (Runno-Paurson et al., 2015), Poland (Chmielarz et al., 2014) and the north-western part of Russia (Statsyuk et al., 2013). In this study both mating types were recorded from all studied potato fields (Table 2), indicating continuous sexual reproduction of *P. infestans* and possible risk of oospore production and early attacks of late blight in Estonian potato fields. As a result of sexual reproduction high genetic diversity in the population can also be expected as shown in the previous *P. infestans* collection from 2004 characterized with SSR markers (Runno-Paurson et al., 2016).

Of the 110 isolates tested for metalaxyl response, 64% were sensitive, 20% were intermediate and 16% were resistant to metalaxyl (Table 3). Significant differences were not found between sampling sites (*Chi-square* = 24.83, $df = 16$, $p = 0.07$).

Table 3. Metalaxyl sensitivity among isolates of *Phytophthora infestans* from Estonia in 2013

	Percentage of isolates			Number of isolates
	S*	I*	R*	
Jõgeva 1	75	8	17	12
Jõgeva 2	57	7	36	14
Antsla	64	36	0	14
Lepiku	67	20	13	15
Reola	100	0	0	11
Sürgavere	78	11	11	9
Tilga	55	36	9	11
Verioramõisa	36	36	28	14
Võnnu	50	20	30	10
Total	64 ± 5.8**	20 ± 4.4**	16 ± 4.1**	110

* – S, metalaxyl sensitive; I, intermediate metalaxyl sensitive; R, metalaxyl resistant;
** – mean ± SE.

The prevalence of metalaxyl sensitive isolates in the population showed clearly different results compared to previous research done in Estonia (Runno-Paurson et al., 2010; Runno-Paurson et al., 2014). This suggests changes in the *P. infestans* Estonian population. These results are similar to recent findings from Latvia (Aav et al., 2015), Lithuania (Runno-Paurson et al., 2015), Poland (Chmielarz et al., 2014) and other European populations of *P. infestans*. The significant association between response to metalaxyl and mating type was not found (*Chi-square* = 1.11, *df* = 2, *p* = 0.57).

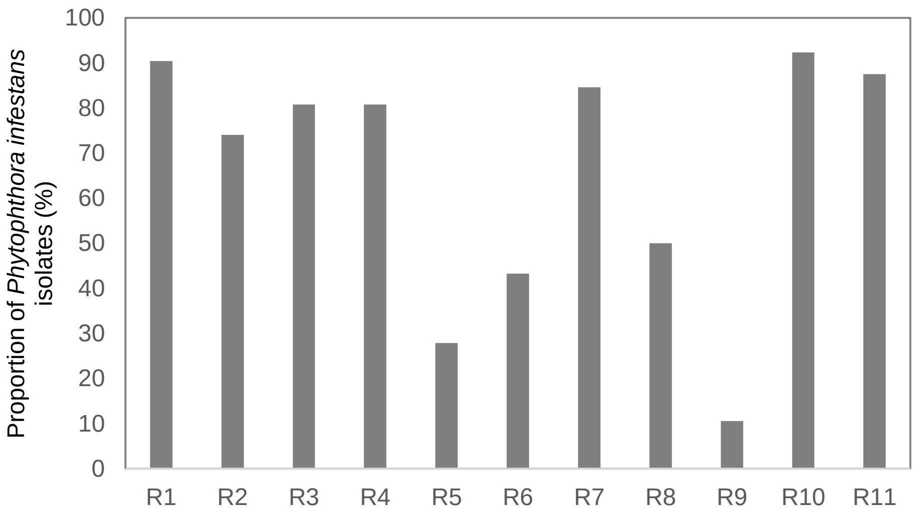

Figure 1. Frequency of virulence to potato R-genes in the Estonian population of *Phytophthora infestans* in 2013.

All 11 known virulence factors were found among the 104 *P. infestans* isolates tested for virulence (Fig. 1). Almost all isolates were virulent on differentials with genotypes R1, R2, R3, R4, R7, R10 and R11. Virulence factors 9 (11%) and 5 (28%) were relatively rare (Fig. 1). No significant differences in virulence factors were found between field sites ($F_{(8,80)}$ = 2.64, p = 0.11). The Estonian race structure was highly complex, on average 7.2 virulence factors per isolate, but varied between fields from 5.6 to 9.0. The overall normalized Shannon's diversity index was 0.69 and varied between potato fields from 0.43 to 0.95 (Table 4), confirming the high diversity of the population. 42 virulence races were found and the four most common virulence races were 1.2.3.4.5.6.7.8.10.11, 1.2.3.4.6.7.8.10.11, 1.2.3.4.7.10.11 and 1.2.3.4.7.8.10.11, comprising 46% of the population (Table 5). Twenty-six races were unique and found only once (Table 5).

Table 4. Racial diversity of *Phytophthora infestans* from different sites in Estonia in 2013

Site	Hs*
Jõgeva 1	0.43
Jõgeva 2	0.87
Antsla	0.75
Lepiku	0.72
Reola	0.58
Sürgavere	0.75
Tilga	0.95
Verioramõisa	0.80
Võnnu	0.92
Total	0.69

* – the normalized Shannon diversity index for race diversity calculation.

Table 5. Race frequencies among isolates of *Phytophthora infestans* from Estonia in 2013

Races	Number of virulence factors	Number of isolates
1.2.3.4.5.6.7.8.10.11	10	16
1.2.3.4.5.6.7.9.10.11	10	3
1.2.3.4.5.6.7.10.11	10	3
1.2.3.4.6.7.8.10.11	9	11
1.2.3.4.6.7.9.10.11	9	3
1.2.3.4.5.7.8.10.11	9	2
1.2.3.4.7.8.10.11	8	10
1.2.3.4.6.7.10.11	8	3
1.2.3.4.5.7.10.11	8	2
1.2.3.4.7.10.11	7	11
1.3.4.7.8.10.11	7	2
1.3.4.7.10.11	6	4
1.4.7.10.11	5	2
1.7.10	3	2
1.10	2	2
10	1	2
Races found once		26
Total number of isolates		104
Total number of races		42

The frequencies of virulence factors in this study were similar to those reported recently in Estonia (Runno-Paurson et al., 2009; Runno-Paurson et al., 2010; Runno-Paurson et al., 2014), except for virulence factor 2, the frequency of which has increased over the years. The prevailing race 1.3.4.7.10.11 of *P. infestans* in most European populations (Hermansen et al., 2000; Lehtinen et al., 2008; Hannukkala, 2012; Chmielarz et al., 2014; Runno-Paurson et al., 2014) was found only four times (3.8%) from the Estonian population. The average number of virulence factors per isolate was 7.2, which is quite similar to that found in other populations from Estonia in previous long-term studies (Runno-Paurson et al., 2012; Runno-Paurson et al., 2014) and also among Eastern European populations (Śliwka et al., 2006; Statsyuk et al., 2013; Aav et al., 2015; Runno-Paurson et al., 2015).

CONCLUSIONS

In this study both mating types of *P. infestans* were recorded in all studied potato fields, indicating continuous sexual reproduction and possible risk of oospore initiated early attacks of late blight in these fields. As metalaxyl-sensitive isolates dominated in the pathogen population sensible and moderate use of metalaxyl based fungicides in most fields could be employed. Overall, the *P. infestans* population in Estonia is highly diverse and complex, characterised by high virulence race diversity. Continuous pathogen population studies describing the contemporary *P. infestans* population are essential in order to advise potato breeders and growers accordingly.

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Effect of broiler chickens living conditions on results of fattening

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Abstract: This work was aimed to monitor outdoor temperature, air humidity and internal microclimate conditions in broilers house during summer days, the temperature and the quality of bedding material as well as bird density. To evaluate the quality of litter we set three-tier system. If the litter dry and hard - value was '1' if it was moist and supple - value was '2', and if it was wet – value was '3'. The measurements were carried out on the 10th and 20th days of chickens age. Air temperature was monitored by (logger Comet R 3120) thermometer and for the measurement of the litter temperature used a non-contact thermometer (Raytek Raynger ST). To find out the birds density a thermocamera (Guide TP8S) for thermal imaging was used and subsequent shots are evaluated the birds stocking density. If the bird density high, value was '1', if the bird density median, value was '2' and if the density low, value was '3'. The hall was divided into 33 rectangular shapes. Results showed that the bedding quality averageed 1.2 on day 10 and 1.3 on day 20 of fattening (dry and hard). By comparing the P values and the significance level α (0.05), the value of 0.651 and 0.820 was found respectively for both age. No significance was detected between the litter temperature and the litter quality, also between bedding temperature and birds density. Intercomparison for bedding temperature and quality on days 10 and 20 a significant difference ($0.000 < 0.05$) was observed.

Keywords: broiler, litter, temperature, humidity.

INTRODUCTION

Litter quality and suitable climatic conditions are among the key factors in assessing the costs and benefits. In broilers, at the first fattening period (approximately 14 to 21 day) suitable temperature and humidity of the environment must be ensured according to the hybrid. In the second half fattening period, it is important not to exceed a temperature above 25 °C and maintain intensive ventilation and relative humidity below 70%, in the same time not exceeding the permitted levels of harmful gases (Brouček, 2014). Attention should be given to the flock density in the rearing area, which is given either in birds per 1 m^2 surface area of the house, or kilograms of chickens live weight per 1 m^2 at the end of the fattening period. This amendment according to Council Directive 2007/43/EC, which was taken over Slovak Republic and Regulation no. 275/2010 Coll. 9 June 2010 of Slovak Government. Poultry suffering from the summer heat stress from high temperatures. In poultry, neutral zone temperature generally is between 13 to 24 °C. Feed consumption reduced slightly at temperatures between 24 to 29°C, and decreases at temperatures from 29 to 32 °C, while reduces dramatically when temperature rise more than 35°C, and increasing mortality, especially in broilers (Brouček, 2014). The high moisture content of the litter increases the microbial activity, leading to an increase in the temperature and the concentration of ammonia in the hall, as well as the increase of incidence of dermatitis. On the other hand, dry litter has a lower specific density and better thermal performance which affecting the comfort when birds are lying. Aggressive wet environment creates hygiene risks for animals as well as for people and reduce the life of buildings (Szabóová et al., 2013). The high flock density in the house prevents heat transfer from the surface litter into the atmosphere in the hall. This limits the effectiveness of conventional ventilation systems to alleviate heat stress. Heat produced by the animals is influenced mainly by live weight and activity (Bessei, 2006). If the flock density on the surface is high the temperature can be dangerously increased because they produce more metabolic heat especially the ventilation of the halls has not been prepared for older types or reconstructed halls (Pogran, et al., 2011). This is critical if the ventilation is inadequate or if the existence of non-ventilated places with motionless hot air zone (Karandušovská et al., 2009). According to Knížatová et al. (2009), not only temperature, humidity and pH, but also the time of using of the litter plays an important role. As the Butcher & Miles (2014) stated the optimal moisture of the litter is between 25 and 35% RH. Despite the fact that animals spend their short life in a specified area should not cause suffering to the animal (Webster, 1999). The aim of this study was to monitor microclimate conditions in the selected fattening poultry hall and their influences on the quality of the litter and flock density.

MATERIALS AND METHODS

In this work, we focused on monitoring the external temperature and air relative humidity during the summer days, microclimate conditions in the hall for broilers included the temperature, stocking density and bedding material quality. For the litter quality we have established a three-stage system of subjective evaluation indication (Weaver & Maijerhof, 2015), if the litter dry and hard – value was '1', moist and supple '2', wet '3'. To assess stocking density, we used the same method, by using TIC photo technic assumed for the determination of high stocking density – value was '1', median stocking density '2' and when stocking density was low '3'. This experiment was performed in the selected farm for fattening chickens, which is located in Nitra Region. The main production programme of the poultry farm where measurement was performed is production of 650,000 broiler chickens annually, i.e. approximately 1,300 t of meat. The measurement conducted on the 10^{th} and 20^{th} days of chicken age. Monitored hall, had dimensions of 100 x 10 m, and 17,280 chicks stocked. The hall was established in late sixties of the 20^{th} century. Air inlets were made in the side walls of the hall. Ventilation was provided by 5 ceiling fans with the capacity of 13,800 $m^3\ h^{-1}$ and 3 wall fans with capacity of 35,000 $m^3\ h^{-1}$. The litter consisted of 3.5 kg chopped straw on one m^2 of the floor space. For the feeding and watering, the pan feeders and nipple drinkers systems were used. Measurement of external and internal temperatures was achieved by Comet logger R 3120 and for the measure of litter temperature a non-contact thermometer Raytek Raynger ST was used. Deployment of broilers in the hall monitored using thermal imagers Guide TP8S with display range of 8 to 14 μm. Data were statistically processed in Excel program and statistics and maps of the litter temperature, litter quality and stocking density were processed using the Surfer program.

RESULTS AND DISCUSSION

Even though it was summer, high differences was noted in temperature and humidity during the monitoring period (Table 1 and Fig. 1).

Table 1. Average values of monitored indicators

Hall	10 day age chickens	20 day age chickens
The average outdoor temperature, °C	36.5	14.0
Outside RH%	33.3	75.8
The average inside temperature, °C	32.3	24.3
RH% in the hall	42.8	55.7
The average litter temperature, °C	28.9	26.4
Average litter quality	1.2	1.3
The average stocking density	2.1	1.2
The number of chicks	16,853	16,705

The outside air average temperature at the 20th day of chickens age decreased sharply (from 36.5 °C to 14.0 °C), and the relative humidity is increased rapidly (from 33.3% to 75.8%). This change was also reflected in the microclimate conditions in the rearing hall.

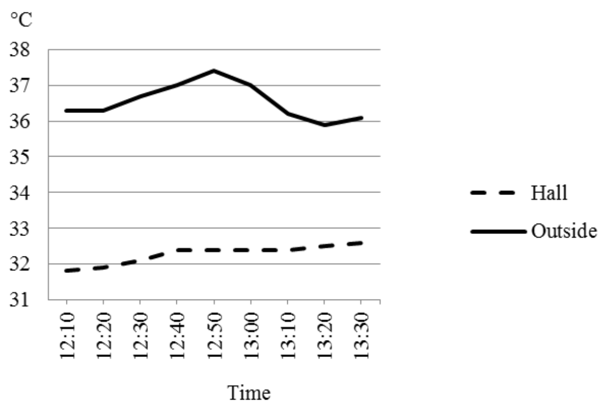


Figure 1. Shows the course of the air temperature on day 10 of chickens' age.

Regression line for the relationship between the outside and inside air temperature on the 10th day of chickens age is presented by the equation $y = 0.5561x + 11.691$ (Fig. 2), when the outside air temperature increased by 1 °C the internal temperature of the air increased by 0.556 °C. The determination coefficient ($R^2 = 0.8955$) indicates that 89% of indoor air temperature variability is explained by the influence of the outside temperature.

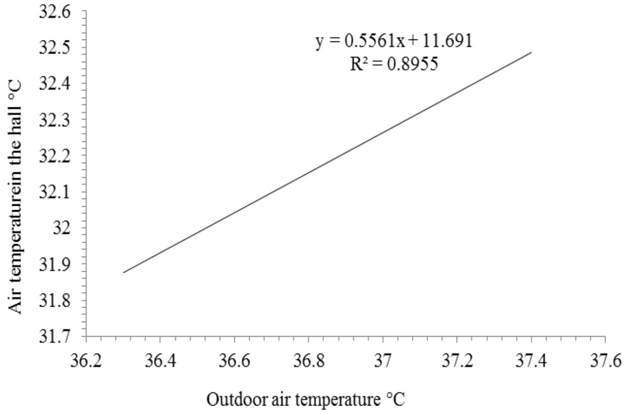


Figure 2. Influence of outdoor temperature on the 10th day of chickens age.

During measurement of litter temperature on the 20th day, the outside air temperature reached the value of 13.5°C and the relative humidity reached 79.1%, while during the day raised up to 86% (Fig. 3), this required minimum ventilation with respect of limited harmful substances in the hall, also continuous reduction of light intensity decreased chickens activity in the rearing hall, after the decreasing of outdoor relative humidity, the ventilation restored again.

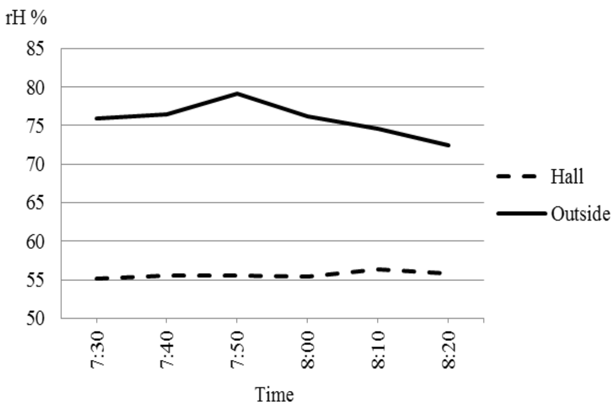


Figure 3. The course of relative humidity on the 20th day of age chickens.

Regression line relationship between external and the hall humidity on the 10th day of chickens age is represented as y = 0.978x + 10.298 in Fig. 4. From the regression equation concluded that the increase in outside air humidity by 1%, increase the humidity in the hall by 0.978%. The coefficient of determination R^2 (0.7017) indicates that 70% of the variability of internal relative humidity is explained by the influence of the outside relative humidity.

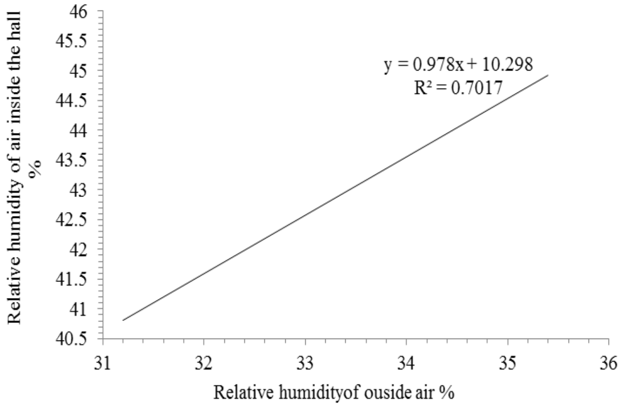


Figure 4. Influence of relative humidity on the 20th day of age chickens.

It showed from the map of the litter temperature in the hall at the 10th and 20th days of chicken's age, that on day 10 some places showed lower litter temperature affected by the high humidity in Figs 5, 6. The same pattern was observed on the 20th day which affected by the high letter moisture in which caused by the water leakage of the drinkers. By comparing the P values and the significance level α (0.05) it found that the value of P is (0.000) < α (0.05) which mean that the values of litter temperature on day 10 and 20 was statistically significant.

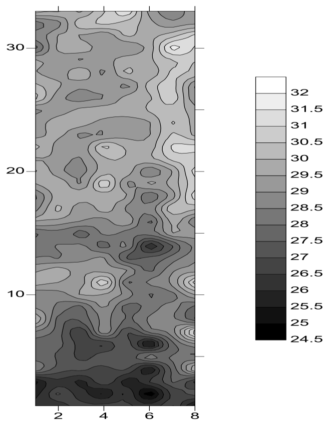


Figure 5. The litter temperature zones map on the 10th day of chickens age.

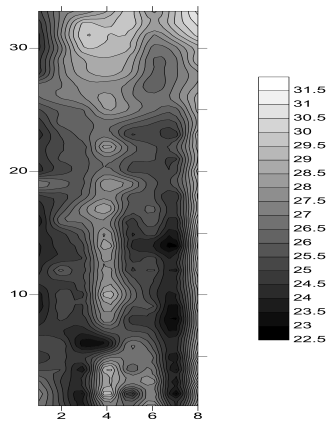
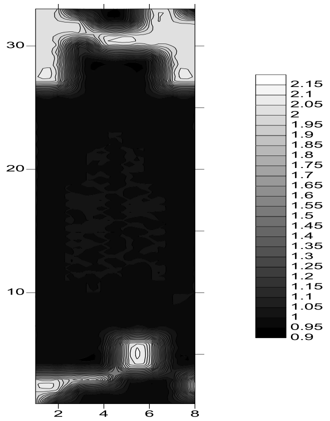


Figure 6. The litter temperature zones map on the20th day of chickens age.

In Figs 7, 8 can be concluded that the value of litter quality on day 10 varied from the value 1 to 2. On the 20th day found places with lower bedding quality caused by the spillage of water from the drinkers where chickens not present on these arias. With the comparison of the 10th and 20th days found significant difference (value of P = 0.000 < α 0.05).



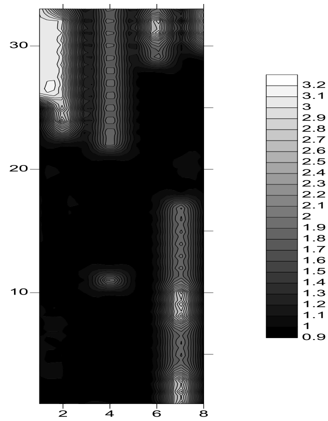
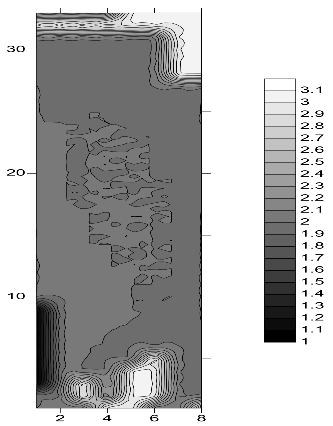


Figure 7. Map of bedding quality on the 10th day of chickens age.

Figure 8. Map quality bedding on the 20th day of chickens age.

On day 10, Figs 9, 10 show the empty places where chickens are not found on moist litter places because enough dry litter places are available. The map of litter quality and density on the 20th day show that chickens occupied the whole area of the hall except for places near the feeders. For the above can be deduced that values at 10 and 20 days are not significant ($P = 0.091$).



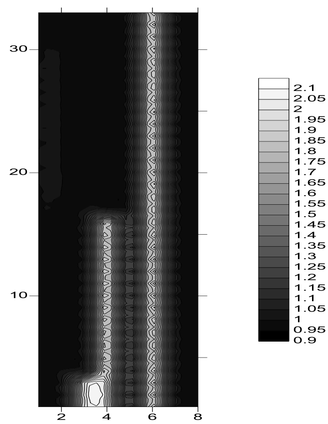


Figure 9. The map of stocking density per m^2 on 10th day of chickens age.

Figure 10. The map of stocking density per m^2 on 20th day of chickens age.

As long as the litter quality deteriorates rapidly due to the seepage of ground water into the bedding material, or due to the drinkers dis-function, therefore chickens search for suit places. Despite it was summer season, the registered data not exceed the reference temperatures according to Brouček (2014). In case of high humidity it requires regulation of the ventilation system. It is important to monitor constantly the air quality in the hall so as not to exceed the levels of harmful substances in the air and minimize of birds activity. In some places litter humidity exceeded the allowable limit which recommended by Butcher & Miles (2014). At the end of fattening period chickens located on the waterlogged litter also due to lack of space on the appropriate litter. Here it is necessary to pay special attention to proper operation of drinkers.

CONCLUSION

The aim of our study was to monitor the microclimate conditions in the hall for fattening chickens and the results highlighted their impact on the quality of the bedding and the stocking density of chickens. Summer in Slovakia was rainy with fluctuating temperatures, this had effects at the first half of the fattening period which temperature was high and in the second half of the fattening period a low temperature and high relative humidity were registered. The results obtained concluded that:

– The data of litter temperature at the 10th and 20th days of chickens age detected statistical dependence ($P = 0.000 < \alpha = 0.05$);

– The litter quality of 10th and 20th day of chickens age detected statistical dependence ($P = 0.000 < \alpha = 0.05$);

– The stocking density on the 10th and 20th day of chicken age has not been established statistical dependence ($P = 0.091) < \alpha$ (0.05);

– In terms of improving the living conditions of chickens recommended to focusing more attention to the drinkers and the structure of the floor and outer wall during the fattening cycle to avoid water seepage through cracks.

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Changes in air ions concentration depending on indoor plants activity

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Abstract. Lack of negative ions in the air can cause deterioration of the health which is described in many scientific articles. At the same time, an air saturated with negative ions can improve the state of health and provide a comfortable indoor environment. In addition, there are considerable evidences that drowsiness, apathy, headache etc. get even worse indoors, and these health problems may be effectively eliminated with a help of moderate concentrations of negative ions. Literature sources and earlier researches state that plants may be able to produce a variety of air ions, including negative light ions. The most plants emit different types of volatile organic compounds, and the indoor plants can improve the air quality: they effectively remove organic pollution and reduce the number of microorganisms in the air by releasing phytoncides. In this article, the regularity of influence of plants on the number of ions in the room is being proved, basing on a series of experiments performed with the following plants: Spathiphyllum, Pinus mugo, Aloe arborescens, Chlorophytum comosum, Cactaceae opuntia.

Key words: air ions, plants, microclimate.

INTRODUCTION

In fact, air ions are charged air gases molecules appearing as a result of ionisation. The physical essence of the air ionisation process is connected with the influence of different physical factors on the air gasses molecules (solar radiation, space emanation, electrical field of high tension, radioactive emanation and others). It results in the molecule tearing off the electron and it becomes positively charged, but the torn off free electron, having joined the neutral molecule, imparts it the negative charge. This results in the formation of the negative air ion. Thus, both positively and negatively charged ions are formed in the atmosphere air. Their existence habitat- air determined their spread name- air ions. Under normal conditions, 1 cm^3 of air contains about 750 positive and 650 negative air ions (Ulascik, 2008).

Air ions are constantly created, but outside of the premises. Given the average air ions age in urban areas (about 10 seconds), it can be concluded that closed areas are almost devoid of charged particles. If a healthy person after work has the ability to walk in the street, to receive the necessary amount of ions, the patient is forced to spend much time in 'dead' air (Ponomarenko, 2015).

The presence of negative air ions (NAI) in the inhaled air is essential for normal functioning of human and animal organisms (Charry & Kvet, 1987). Scientific research indicates that the air within homes and other public or office buildings can be more seriously polluted than the outdoor air. Public concern about the effects of indoor air pollution on health has resulted in expanded research of the topic (Wang et al., 2005). Some countries have already elaborated legal framework for air ion concentration in work rooms. On 16 June 2003, sanitary and epidemiological rules and regulations 'Hygienic Requirements for the Air-Ion Level of Industrial and Public Facilities SanPin 2.2.4 1294-03' (Санитарно-эпидемиологические правила и нормативы 'Гигиенические требования к аэроионному составу воздуха производственных и общественных помещений СанПин 2.2.4 1294-03') entered into force in the Russian Federation. According to these Requirements, optimal concentration of light negative ions amounts to 3,000–5,000, while concentration of positive ions should be half as much. However in most cases, the concentration of favorable light, negative air ions indoors does not exceed few dozens, while the concentration of harmful positive ions is growing rapidly, especially if there are people, TVs, computer monitors and similar devices in the room.

Besides, practical field testing reveals that the somnolence, apathy, headaches, etc. ascribed to the 'dead' air in enclosed spaces can be conquered effectively by supplying moderate concentrations of negative ions (Krueger, 1985). Air ions may be healing or may harmfully affect human health. This effect depends on ion concentration in the air and on proportions of positive and negative ions. These proportions are characterized by unipolarity coefficient

$$K = \frac{n^{+}}{n^{-}} \tag{1}$$

where n+ and n- mean concentration of positive and negative cluster ions.

Sanitary-hygienic characteristics of plants include their ability to release a special volatile organic compound called phytoncides, which kill pathogenic bacteria or delay their development. These properties become especially valuable in urban conditions where the air contains 10 times more pathogenic bacteria than the air of fields and forests.Most plants emit different types of volatile organic compounds (Bio VOCs) and even micro-amount of Bio VOCs have a great impact on formation processes of cluster ions (Duddington, 1969). This effect is reinforced when volatile compounds are emitted from the plant in ionic form, e.g., Bio VOCs emitted from the needles of conifers are ionized because of charges accumulated in the sharp tips of the needles. Ions of volatile compounds are very good condensation nuclei in the atmosphere that contribute to further formation of mist and clouds. Thus, coniferous forests can affect even the global climate (Kulmala et al., 2000). To a certain extent, most of the plants are air ion generators. Intensity of such generation depends on the daily intensity cycle of metabolic process in these plants (Cibula & Fershalova, 2000).

Despite that aeroionizers are always present in places with artificial atmosphere, in submarines, and long-term space stations. Although today the saturation of air ions of the air we breathe at work and at home, is becoming a more urgent problem (Ponomarenko, 2015).

We have tried to model the artificial air ionisation using indoor plants. For this purpose, a special experimental stand was constructed. (Fig. 1).

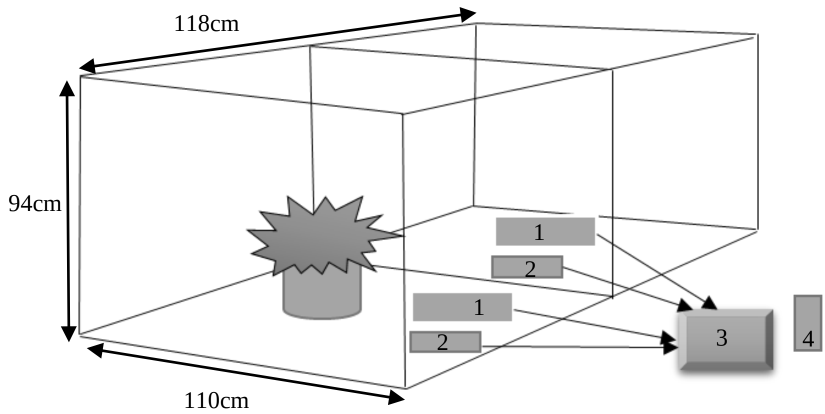

Figure 1. Schematic drawing of the experimental stand, consisting of two equal sectors: one with plants, other without plants. 1 – air ion counter, 2 – microclimate multi-meter, 3 – laptop computer, 4 – radioactivity meter.

It has been determined that the plants are able to reproduce negative air ions, flowing down the leaves into the surrounding air without any stimulation with electric impulses (as it was done by the previous researchers). The greatest ability for artificial air ions generation possess pointed leaves or sharp thorns (for example, Pinus Mugo, Aloe arborescens, Cactaceae opuntia). These plants are able to maintain medium concentration (with some spontaneous fluctuation) for a long period of time. It would be perspective to develop technology for artificial greening that would ensure air ion concentration and microclimate conditions indoors optimal for human organism. In order to develop such technology, it is necessary to find out changes in air ion concentration depending on indoor plants and microclimate.The aim of this research is to explore the impact of indoor plants and microclimate on air ion concentration in order to find opportunities to use plants for air quality improvement.

MATERIALS AND METHODS

We used the same plant species as the Tikhonov et al. (2004) article and found similar species-dependent differences in the ability to generate NAI. The data presented in this paper prove that the capacity of plants to generate NAI differs. The aim of the experiments was to find the species with the most expressed capability to generate NAI.

In order to perform this study, several plants were selected which, by their nature and taking into account the impact of external factors, can affect the air ion concentration indoors. Therefore, plants with the following characteristics were chosen: large area of leaves, leaves with a pointed tip and hair shaft; developed transpiration function (as a result of transpiration a lot of water is vaporized from plants), dust particle absorption, expressed phytoncide features (Table 1).

Table 1. Plants properties

Latin Name	Phytoncide features*	Intensity of oxygen generation*	Efficiency of air purification from gas admixtures (relative values) 0–10*	Substances absorbed efficiently *	Size, H/D, cm
Chlorophytum	*	**	7.8	Formaldehyde, carbon dioxide	35/40
Aloe arborescens	**	**	7.8	Formaldehyde, carbon dioxide	40/50
Cactaceae opuntia	**	***	6.9	Formaldehyde,	35/45
Pinus mugo	***	**	8	Formaldehyde, acetone, benzene	35/45
Spathiphyllum	*	**	7.5	Formaldehyde, acetone, benzene	50/55

***high efficiency; **efficient; *average efficiency low efficiency;*(Cibula & Fershalova, 2000).

In order to research the influence of plants on ions concentrations indoors we have constructed an experimental stand made of 10 mm thick veneer. The general dimensions of the box are 118 cm x 110 cm x 94 cm. The box is divided by the partition into two equal sectors. A plant was placed in one sector but the other stayed without any plants. Every sector contained devices for measuring microclimate parameters. The box itself was placed in the basement type premises with natural air ventilation, without any windows, the walls covering- processed concrete. In addition, outside the box the radiation background was measured. During the experiment there were no people in the premises. The premises were entered to change plants and save meters' data. Air ion concentration was measured with the portable bipolar air ion counter 'Sapfir-3м'. This device provides simultaneous measuring of positive and negative air ions with minimum resolution of 10 ions per 1 cm^{-3}. The device measures air ion concentration in the air (mobility $k \geq 0.4$ cm^2 $V^{-1}s^{-1}$). This mobility interval is close to the class of cluster ions. During the measurements, air ions, according to their polarities, are channelized to positive or negative aspiration collector in aspiration chamber and, after coming into contact with this collector, the ions are discharged. Afterwards, the charge is sent to amplifiers and then the impulses are counted and displayed. The device counts the charges of air ions, therefore if an ion has more than one charge, it is counted as several ions.

Indoor climate parameters were determined using the multi-meter 'Easy Sense Q'. Systematic measurement error of this device for temperature is ± 0.3 °C, whereas error for relative humidity is ± 5%. Error for lighting is not specified. The total amount of radioactive α, β and γ radiation was measured in μSvh^{-1} with the portable device 'Gamma-Scout' with systematic measurement error less than 5%. For all devices, the average value of each measurement point was 10 minutes. Each time the measuring devices were placed in a distance of approximately 40 cm from the plants.

The measurements were carried out in automatic mode for each species of plants individually constantly within 66 hours.

RESULTS AND DISCUSSION

The experimental data (Table 2) show that the number of positive air ions in the box is higher than the number of negative air ions: 9% (without houseplants) and 21% (with houseplants). Maximum / minimum concentration of positive air ions: 1,693 cm^{-3} 350 cm^{-3} (without houseplants) and 2,345cm^{-3} 292 cm^{-3} (with houseplants). Maximum / minimum concentration of negative air ions: 1,282 cm^{-3} 411 cm^{-3} (without houseplants) and 1,503 cm^{-3} 263 cm^{-3} (with houseplants). These data reveal that, basing on the air ion concentration and unipolarity coefficient, the box used for the experiments is not recommended for human health (if not ventilated).

Table 2. Average ions concentration and Indoor climate parameters

Conditions/ Parameters	*Spathiphyllum*		*Pinus mugo*		*Aloe arborescens*		*Chlorophytum comosum*		*Cactaceae opuntia*	
	Without plants	With plants	Without plants	With plants	Without plants	With plants	Without plants	With plants	Without plants	With plants
N^{-} (cm^{-3})	439	294	920	1,282	1,503	1,106	535	395	411	263
N^{+}(cm^{-3})	473	292	1,033	2,345	1,693	1,462	518	491	350	317
$N^{(total)}$(cm^{-3})	912	586	1,953	3,627	3,196	2,568	1,053	886	761	580
K	1.01	1.05	1.14	1.74	1.13	1.40	1.08	1.34	0.79	1.25
T (°C)	21.78	21.99	22.61	21.57	21.91	21.57	22.66	22.39	22.05	22.38
RH(%)	27	36	45	50	30	34	28	36	31	33
Sv(μSvh^{-1})	0.38	0.38	0.38	0.38	0.39	0.39	0.39	0.39	0.39	0.39

The box has very low concentration of positive and negative air ions and inadequate unipolarity coefficient, because, basing on the SanPin 2.2.4 1294-03, minimal admissible concentration of positive air ions is 400 cm^{-3}, negative air ions 600 cm^{-3}, admissible values of unipolarity coefficient $0.4 < K < 1.0$. During the experiment, the temperature and relative humidity in the box increases. The measured average ambient temperature in the room with plants is about 0.5 °C higher than in the room without plants. The average humidity is up to 15% higher in the room with plants than in the room without plants. It means that plants increase the air humidity (the water is evaporated through leaf pores). As the natural radiation level fluctuates chaotically around the average value 0.39 μSvh^{-1} and the amplitude of these fluctuations is less than 10%, the level of radiation can be considered as constant; fluctuations of radioactive background do not affect daily changes of air ion concentration.

The indicated concentration of negative ions in air in the presence of plants (Fig. 2) allow us to conclude that fluctuations in the number of ions depends on the time of day. These changes are well seen on the example of Aloe arborescens and Chlorophytum comosum. The maximum number of ions was observed during the day (9:00–10:00 a.m.), at the same time the decline of the ions occurred in the evening hours (5:00–10:00 p.m.). Although the experiment was conducted in complete darkness, i.e. without the influence of daylight or artificial light.

Plants used in the experiments are producers and absorbers of positive and negative air ions. During the night, the process of plant's metabolism and ion emission into the air slows down; during the night, the plants mainly adsorb air ions. Therefore, during the night a significant decrease in air ion concentration can be observed in the room with plants. During the day metabolic processes in plants are activated; plants emit positive and negative ions into the air and simultaneously adsorb these ions. These electrons increase the amount of negative air ions. At the same time the surfaces of plants are charged positively; it increases the adsorption of negative air ions and decreases the absorption of positive ones. As a result, during the day the room with plants has increased concentration of air ions (especially positive ones).

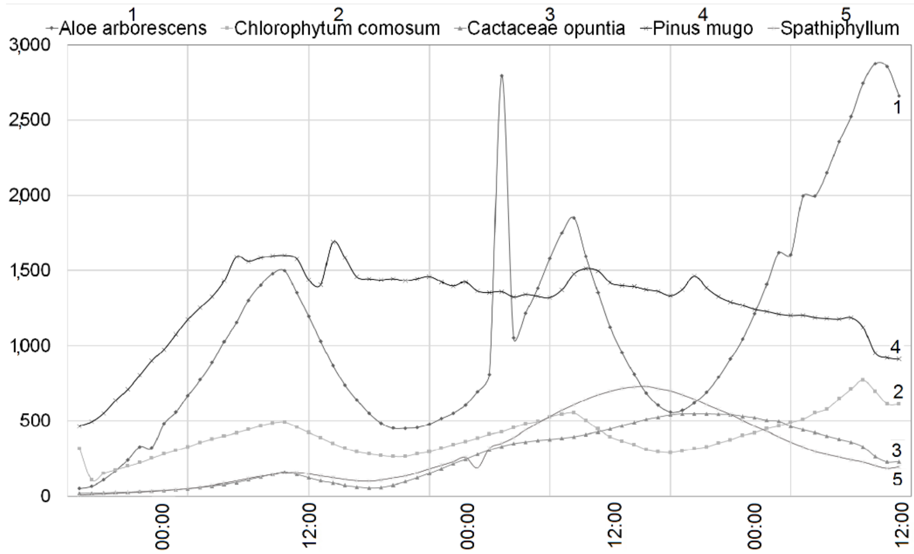

Figure 2. Concentration of negative ions in the air in box with plants, cm^{-3}.

The room has good ventilation. Air ions from the outside infiltrate into the experiment room. The measurements in the box without plants show on the quantity of the ion outside air. If in the room completely close ventilation, it is possible that there would not be the cyclical changes in the graphs. Comparing the graphs with the plants and without the plants can make conclusions how the plants change the ion number in the diurnal period.

Presence of plants in the room can significantly stabilize uncontrolled fluctuations of ion concentration, however the necessary level of ionization was not reached. As indicators for the generation of negative ions by plants depend on the time of day it is important to know in what areas you plan to use them.

For example, according to the results of experiment Aloe arborescens is recommended for use in office where work is during the day. In order to maintain the level of negative ions while sleeping (at night) above mentioned plants are not suitable.

CONCLUSIONS

The positive and negative air ions concentration indoors (with plants and without plants) varies periodically during twenty-four hours - Aloe arborescens (Fig. 3, A) and Chlorophytum comosum (Fig. 3, B): in day time - increases, in night time – decreases.

In some cases, there are identified deviations from the periodicity. It is possibly related of the changes of Solar radiation activity.

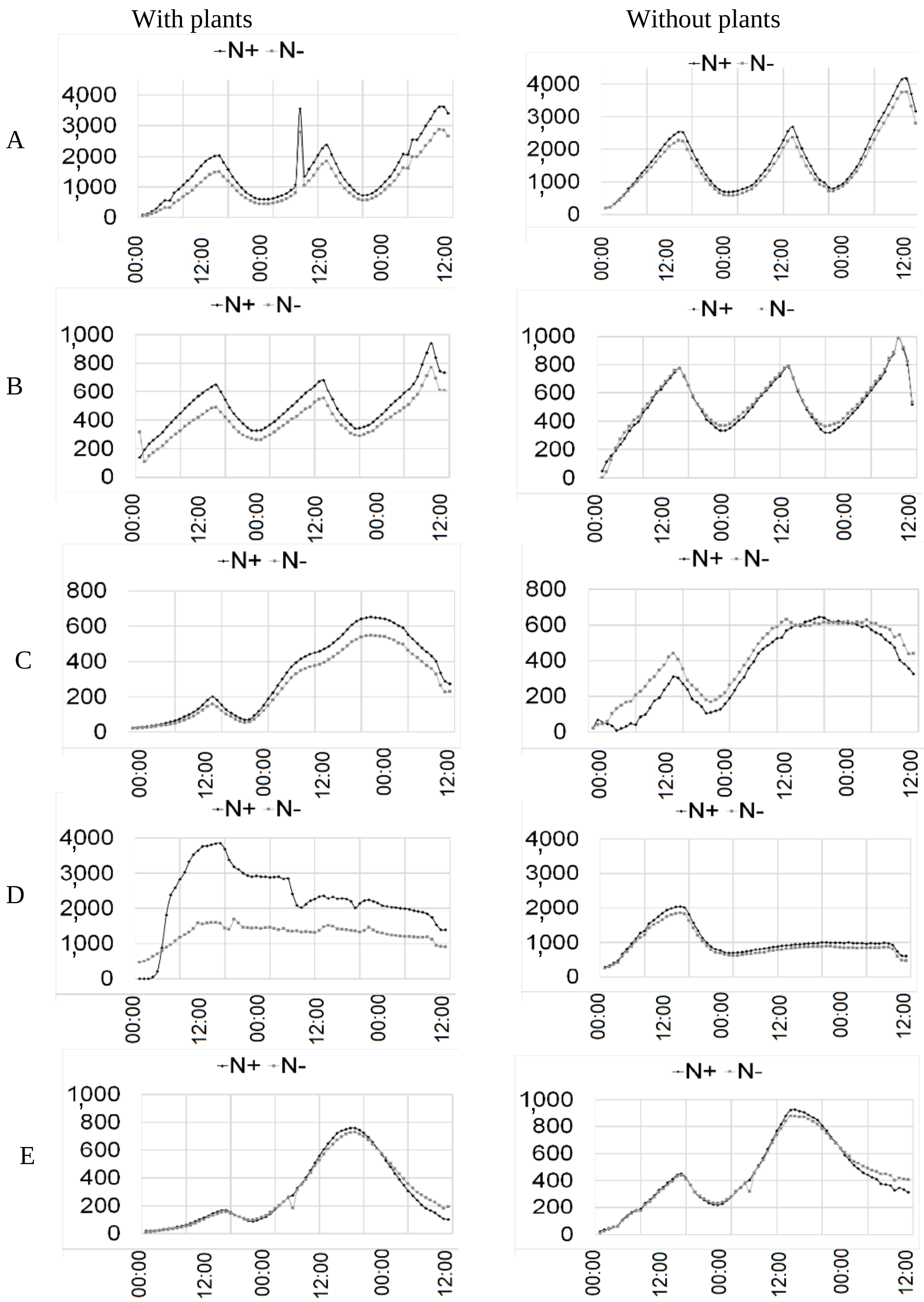

Figure 3. Concentration of negative and positive ions in the air in box without and with plants, cm^{-3}: A – Aloe arborescens; B – Chlorophytum comosum; C – Cactaceae opuntia; D – Pinus mugo; E-Spathiphyllum.

After conducting a series of experiments with five species of plants, it was concluded that the best among them is the ability to generate negative ions has Pinus mugo (Table 2, Fig. 2). If in the room are plants, the positive and negative air ions concentration decreases. Pinus Mugo is exception - about 2 times more the positive and 1.4 times more negative ions. In the room with Pinus Mugo negative ions concentration during the twenty-four hours remains constant. This means that the Pinus Mugo could be used as a source of negative air ion.

Further experiments could be related to changes in air ion concentration depending on electrization of soil by high voltage pulses, thus providing for the high level of air ion.

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The effect of sulphur content on B20 fuel stability

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Abstract. The aim of this study was to investigate if a high amount of sulphur is favourable for the fuel blends' storage stability. The parameters that correlate with the storage stability of the fuel blends were compared with two B20 fuel samples consisting of 20 vol% biodiesel and 80 vol% fossil diesel. The studied parameters were the oxidation stability (OSI), acid number and kinematic viscosity. The measurements were carried out straight after mixing the blends, and again after 4 and 9 weeks. One of the B20 samples was prepared from rapeseed methyl ester (RME) and fossil diesel fuel containing 6.6 mg kg^{-1} sulphur and the other from the same RME but the fossil diesel fuel contained 186 mg kg^{-1} of sulphur. According to the results of this study, the fuel containing less sulphur had slightly better quality during the entire study. Though, the OSI of the fuel containing more sulphur decreased less in percentages than it did for the fuel containing less sulphur. As a conclusion, the study gives a reason to assume that the sulphur may be favourable to fuel blends' storage stability but it should be studied for a longer time to confirm this statement.

Key words: FAME, fuel blends, B20, diesel fuel, storage stability, sulphur.

INTRODUCTION

During the recent decades, the sulphur content of liquid engine fuels has drastically decreased to reduce harmful effects of exhaust sulphur compounds both on the engine components and pollutant emissions. At the same time, the need to increase the use of renewable fuels has grown to also reduce greenhouse gas (GHG) emissions.

Fuel sulphur increases soot and particulate matter emissions in the exhaust of all kind of internal combustion engines, causes corrosion and also has a deleterious effect on advanced after treatment systems used for CO, HC, NOx and particulate reduction. (Kalghatgi, 2014) The fuel sulphur also causes corrosion inside the engine cylinder. In combustion, it will oxidize to sulphur dioxide. SO_2 will be further oxidized to SO_3 and then again react with water. Formed sulphuric acid, H_2SO_4, will condensate on the metal surfaces and cause corrosion. (Heywood, 1988) This aspect makes the desulphurization important but refining processes which remove the sulphur from the fuel simultaneously reduce fuels lubricity. After processing, the lubricity may be returned by adding certain additives. However, fatty acid methyl esters, i.e. biodiesels, are found to enhance the lubricity when they are mixed together with diesel fuel oil. (Guibet, 1999; Kalghatgi, 2014).

In Europe, the automotive diesel fuel standard, EN 590:2013 allows the fuel to contain a maximum of 10 mg kg^{-1} sulphur (EN 590: 2013, 2013) but elsewhere in the world the limitations are not as strict. Diesel fuels containing 100–500 mg kg^{-1} sulphur are commonly in use in many regions outside Europe. E.g. Brazil has two diesel types which are divided by the sulphur content to S10 and S500, whose limits are 10 mg kg^{-1} for bigger cities and 500 mg kg^{-1} for rural areas (ANP #50, 2013). Non-road diesel in Brazil has a limit of 300 mg kg^{-1} (ANP#71, 2011). Though, the levels all over the world have been reduced considerably after the 1990's (Guibet, 1999; Kalghatgi, 2014).

Sulphur emissions, both gaseous and particles, are harmful for human health. An acute exposure can cause trouble in breathing and a long-time exposure for those emissions can cause heart disease, pulmonary illness or even untimely death. In the environment sulphur oxides are reactive and form H_2SO_4 which comes down with the rain and the acid rain again depletes the nature in many ways. Moreover, buildings disintegrate because of the acid rain (Pan, 2011).

When increasing the share of renewable fuels, fuel blends form a realistic and feasible way and therefore, different blends of bio- and fossil fuels are becoming more frequent. In Europe, the maximum fatty acid methyl esters (FAME) content in diesel fuel is 7 vol% according to the: 2013 but higher percentages are also available and targeted around the world. Storage stability is one of the main quality parameters related to biodiesels. The deterioration of the properties of FAMEs during storage is more serious than for fossil fuels. Improving oxidation and storage stability is an important issue for commercializing the biodiesel. (Bouaid et al., 2009) Some studies have indicated that higher sulphur contents may affect beneficially the oxidation stability of the fuel blends (McCormick & Westbrook, 2007).

The aim of this study was to investigate if a high amount of sulphur is favourable for the fuel blends' storage stability. The parameters that correlate with the storage stability of the fuel blends were compared in two B20 fuel samples consisting of 20 vol% biodiesel and 80 vol% fossil diesel. One of the samples was mixed with rapeseed methyl ester (RME) and distillate fuel oil (DFO) containing 6.6 mg kg^{-1} sulphur (later in text: B20 (6.6 mg kg^{-1} S)) and the other was mixed using the same RME but DFO which contained 186 mg kg^{-1} sulphur (later in text: B20 (186 mg kg^{-1} S)). The fuel containing 6.6 mg kg^{-1} sulphur did not contain any bio component before mixing it with RME. The information about added biodiesel for DFO which contained 186 mg kg^{-1} sulphur was not available but the supplier assumed that it did not contain any biodiesel before mixing it with RME.

The analyses carried out for these two samples were oxidation stability (OSI), acid number (AN) and kinematic viscosity (KV). The samples were analysed straight after mixing, after 4 weeks and after 9 weeks of storage. The storage conditions were not specified extremely accurately but the samples were similarly placed in a dark cupboard at room temperature (around 20 °C). These mentioned properties (OSI, AN, KV) of RME were measured before mixing it with DFOs. The measured properties of RME fulfilled the requirements set for FAME fuel in Standard EN 14214:2012.

MATERIALS AND METHODS

RME used as the bio component in fuel blends was a product of ecoMotion GmbH, Germany. RME is ISCC EU certified and meets Standard EN14214:2012. Fuel had been produced three years before this study and delivered to the University of Vaasa in 2012. Still the fairly old RME fulfilled the requirements for Standard EN 14214:2012 in terms of the properties measured in this study. The information about added antioxidant was not available.

DFO containing 6.6 mg kg^{-1} sulphur was a product of Neste and it was produced in Finland. It did not contain any bio component before mixing it with RME. DFO containing 186 mg kg^{-1} sulphur was Rubilene 813 fuel and it was produced in Brazil. The information about added biodiesel was not available but the supplier assumed that it did not contain any biodiesel before mixing it with RME.

Acid number

The acid number was analysed by a titrator Metrohm Titrando 888. The method is a potentiometric titration method. The sample is diluted with iso-propanol and titrated by potassium hydroxide. The measurement was produced according to Standard EN 14104:2003 (SFS-EN 14104, 2003).

Oxidation stability

The oxidation stability was measured by a Biodiesel Rancimat 873 instrument. The method describes the accelerated oxidation stability of biodiesel. The sample is heated and air flow is conducted through it. Vaporizing compounds of the sample drift with air into water and the conductivity of the water is measured. The end point is achieved when the conductivity increase is at its highest. The method is described in Standard EN 15751:2014 (SFS-EN 15751, 2014).

Viscosity

The viscosities were measured by a Stabinger SVM 3000 rotational viscometer. The measurement is based on torque and speed measurements. The device calculates the dynamic viscosity from the rotor speed. The device also has a density measuring cell that employs an oscillating U-tube principle. The kinematic viscosity is calculated automatically based on these measurements (Anton Paar, 2012).

RESULTS AND DISCUSSION

The results of kinematic viscosity, acid number and oxidation stability measurements are presented in Table 1. All the obtained results are arithmetic means of two replicate measurements.

The kinematic viscosity of both samples remained constant during the 9 weeks of time (Fig. 1). During the whole study, the viscosity of the sample B20 (6.6 mg kg^{-1} S), 3.7 mm^2 s^{-1}, was higher than it was for B20 (186 mg kg^{-1} S), 3.4 mm^2 s^{-1}.

Table 1. The analyses results for B20 fuels

Property	B20 (6.6 mg kg^{-1} S)	B20 (186 mg kg^{-1} S)	RME
Kinematic viscosity, 40 °C (mm^2 s^{-1})			
Fresh	3.7	3.4	4.5
4 weeks	3.7	3.4	
9 weeks	3.7	3.4	
Acid number (mgKOH g^{-1})			
Fresh	0.07	0.08	0.19
4 weeks	0.06	0.09	
9 weeks	0.07	0.09	
Oxidation stability (h)			
Fresh	36	29	9.5
4 weeks	34	29	
9 weeks	33	28	

The relative standard deviations are: kinematic viscosity 1%, acid value 7.9% and oxidation stability 4.5%. These had been determined for the analysis methods earlier.

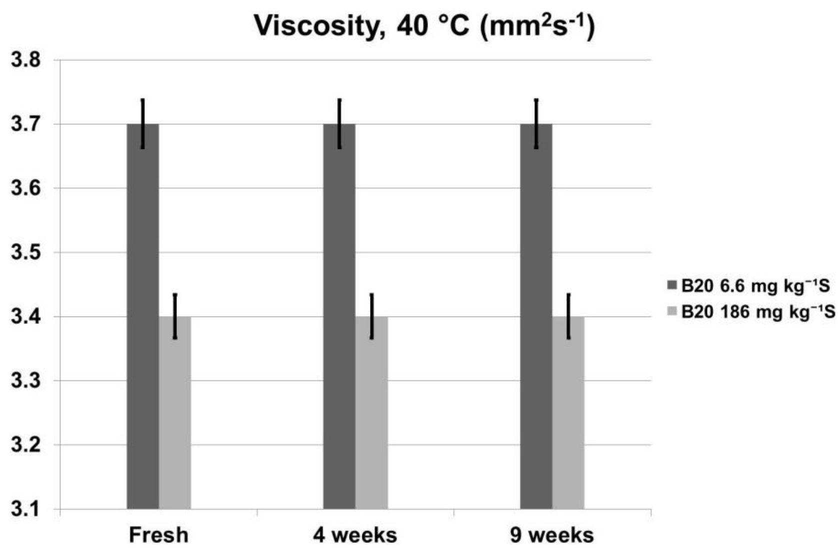

Figure 1. The results of viscosity measurements.

The acid number of the sample B20 (186 mg kg^{-1} S) was higher for fresh sample and it increased more than it did for the sample B20 (6.6 mg kg^{-1} S) (Fig. 2). The result of the sample B20 (186 mg kg^{-1} S) increased from 0.08 to 0.09 mg KOH g^{-1}. For the B20 (6.6 mg kg^{-1} S) the result seemed at first to decrease from 0.07 to 0.06 mg KOH g^{-1} but it increased back to the level of 0.07 mgKOH g^{-1} after 9 weeks of storage. This phenomenon happened probably due to the measurement precision.

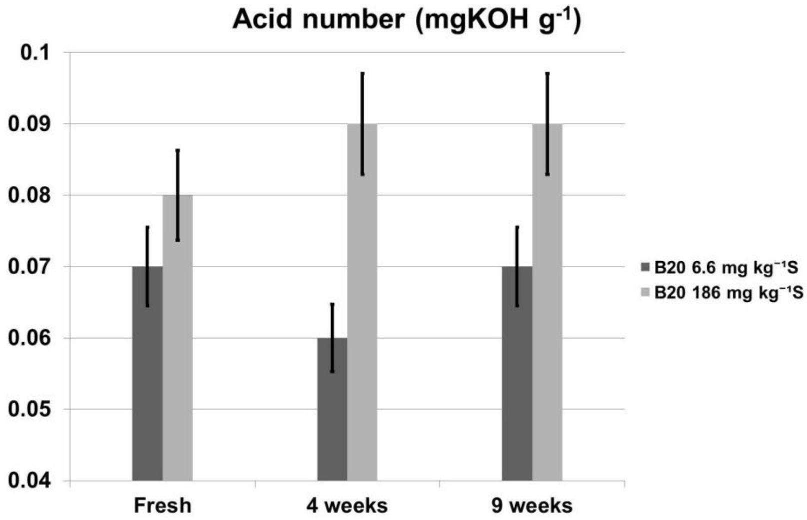

Figure 2. The results of acid number measurements.

Fig. 3 shows that the oxidative stability of the sample B20 (6.6 mg kg^{-1} S) (36, 34, 33 hours) was higher during the whole study than it was for the sample B20 (186 mg kg^{-1} S) (29, 29, 28 hours). The decrease in OSI was 8% for the sample B20 (6.6 mg kg^{-1} S) when it was only 3% for the sample B20 (186 mg kg^{-1} S).

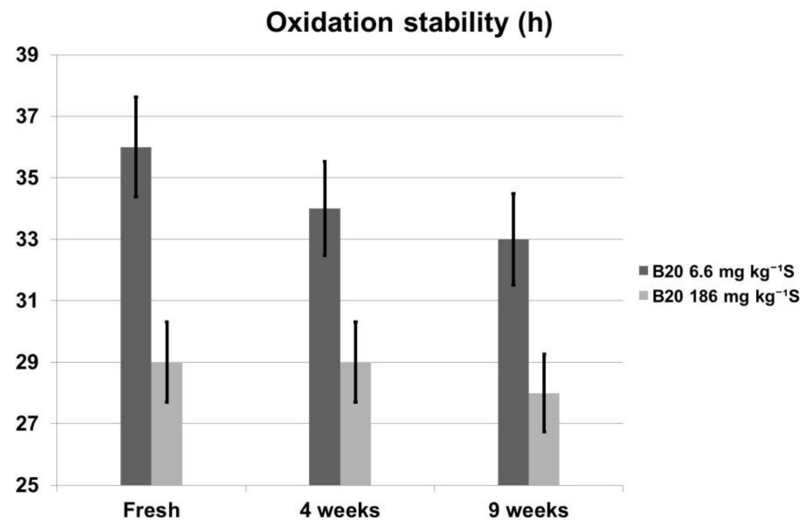

Figure 3. The results of oxidation stability measurements.

Karavalakis et al. (2010) have studied the oxidation stability of biodiesel blends and they have found it a very complicated process. They say that the most important factors affecting the blends' stability are the biodiesel composition and used antioxidants. Also, according to McCormick & Westbrook (2007), the stability of the biodiesel is the most important factor which affects the blends storage stability.

In this study, the biodiesel in both samples was the same and the reason for the difference in OSI of the fresh blend samples was more likely caused by the diesel fuel which also is conceivable according to Karavalakis et al. and McCormick & Westbrook. However, as mentioned, the process is so complex that analyses made in this study are not comprehensive enough to reveal the reason for the quality difference between the diesel fuels. Most probably, the difference is due to oxidative and thermal stability of the diesel fuel (McCormick & Westbrook, 2007). The OSI results of the both DFOs used in this study would have been useful as refence measurements and the OSI analyses of DFOs have necessarily to be included in the future investigations.

McCormick & Westbrook mentioned that sulphur compounds can work as antioxidants and the same conclusion is also supported by the study of Karavalakis et al. (McCormick & Westbrook, 2007; Karavalakis et al., 2010). As mentioned above, here the decrease in OSI was 8% for the sample B20 (6.6 mg kg^{-1} S) when it was only 3% for the sample B20 (186 mg kg^{-1} S). This may indicate the antioxidative effect sulphur has. To prove this thesis, also indicated by the current study, a longer follow-up study should, however, be implemented.

Karavalakis et al. (2011) showed in another study, that even 4–6 weeks storage time may cause OSI to decrease under the 20 hours limit due to natural ageing. The 20 hours limit is set in Standard EN 590: 2013 for automotive diesel fuels. In this study, both the samples remained clearly above the 20 hours limit for 9 weeks. The other measured properties were also at a proper level though the adopted RME was produced 3 years before this study.

CONCLUSIONS

As one conclusion, the study gave a reason to assume that the sulphur may be favourable to fuel blends' storage stability. The decrease in OSI was 8% for the sample B20 containing less sulphur when it was only 3% for the sample B20 containing more sulphur. This may indicate the antioxidative effect sulphur has. The phenomenon should, however, be studied for a longer time to confirm this statement.

As another conclusion, it can be stated that even a long time stored RME had a sufficiently good quality to use as a biocomponent in blending. In this study, the OSI of both the B20 samples remained clearly above the 20 hours limit for 9 weeks even though they were prepared using RME which was produced 3 years ago.

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Impact of browsing damages on growth and quality of silver birch plantations in Latvia

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Abstract. Silver birch is widely used both in forest regeneration and afforestation of abandoned agricultural lands, since it has high productivity and phenotypic plasticity and is relatively seldom damaged by biotic or abiotic factors. In Baltic States significant browsing damage of this tree species had not been noted in contrast to other countries with notably higher ungulate population densities. Therefore the aim of our study was to evaluate the impact of browsing damages on tree and stand parameters as a basis for further recommendations for stand protection. Data for the analysis were collected in central Latvia (56°22´N, 23°7´E) in a large plantation with areas of different browsing intensity. At the age of 16 years, tree height and diameter was measured and traits characterising damages were assessed. Browsing had caused a significant decrease in survival: from 87% survival in areas with light browsing to 56% survival in areas with heavy browsing. Browsing had caused a reduction of tree growth: mean tree height in areas with slight browsing was 13 ± 0.4 m, but only 2 ± 0.3 m (i.e. reaching height of red deer and moose) in areas with heavy browsing. Heavy browsing had created irreversible loss of productivity: even if browsing would not continue, it would take double as much time for the birches in these areas to reach target diameter for cutting (27 cm) than in slightly browsed areas. Frequency of spike knots and crooked stems was statistically significantly higher for trees with browsing damage.

Key words: browsing, ungulates, spike knots, stem straightness, rotation period, *Betula pendula*.

INTRODUCTION

Wood from plantations is an important source of renewable material and energy and, therefore, can contribute to carbon sequestration both in forest products and in soil (Bardulis et al., 2016) and to the accomplishment of the emission reduction targets of the European Union. Silver birch (*Betula pendula*) is one of the tree species that can be used for the establishment of such plantations. This tree species currently dominates in afforestation (in total, including both planting and natural regeneration) of abandoned agricultural lands in the Baltic States (Liepins et al., 2008; Lazdins et al., 2010). In the context of climatic changes meteorological factors determining growth (radial or height increment) of trees have been tested for various species in Latvia (Jansons et al., 2013a; 2013b; 2015a; 2015b; Šēnhofa et al., 2016) but not for Silver birch. However, its high phenotypic plasticity is known from various trials (Silfver et al., 2009) and, therefore, use of Silver birch is recommended to minimize potential climate-related risks. Even so climate change might not be so beneficial in terms of (predicted) increase of productivity for this tree species in comparison to coniferous trees (Briceño-Elizondo et al., 2006; Jansons, 2012). Productivity of Silver birch, as for other tree species, is at least partly genetically determined (Jansons, 2005; Jansons et al., 2006); it can be significantly boosted by use of improved (bred) plant material: for example, stem volume of seed orchard progenies exceeded that of stand progenies by 26–29% in Finland (Hagqvist & Hahl, 1998). Financial efficiency of birch breeding is high and might exceed that of other broadleaved tree species; however, the efficiency is heavily dependent on the level of deployment of improved plant material in the annual area of regeneration or afforestation (Gailis & Jansons, 2010; Jansons et al., 2011). The choice of regeneration method depends on cost and expected benefits (on growth and quality), as well as risks, including browsing (Lazdina et al. 2013). For example, in Finland browsing by roe deer (*Capreolus capreolus*) or moose (*Alces alces*), as well as (locally) white-tailed deer (*Odocoileus virginianus*) and reindeer (*Rangifer tarandus*), is a common reason for the failure of birch regeneration and, therefore, a dramatic reduction of planting (both in forest and abandoned agricultural lands) of this tree species (Van Hees et al., 1996; Helle, 2001; Viherä-Aarnio & Heikkilä, 2006). Browsing damages not only reduces survival of trees but also stem quality, leading to crookedness and, due to infection by fungi, also wood discoloration and decay (Heikkilä et al., 1993; Arhipova et al., 2015). Generally, browsing damages have not been a significant problem in birch stands in the Baltic States and therefore have not been analysed before; however, the density of ungulate populations is increasing rapidly (similar to other European countries) and this trend is expected to continue. Therefore the aim of our study was to evaluate the impact of browsing damages on tree and stand parameters as a basis for further recommendations for stand protection.

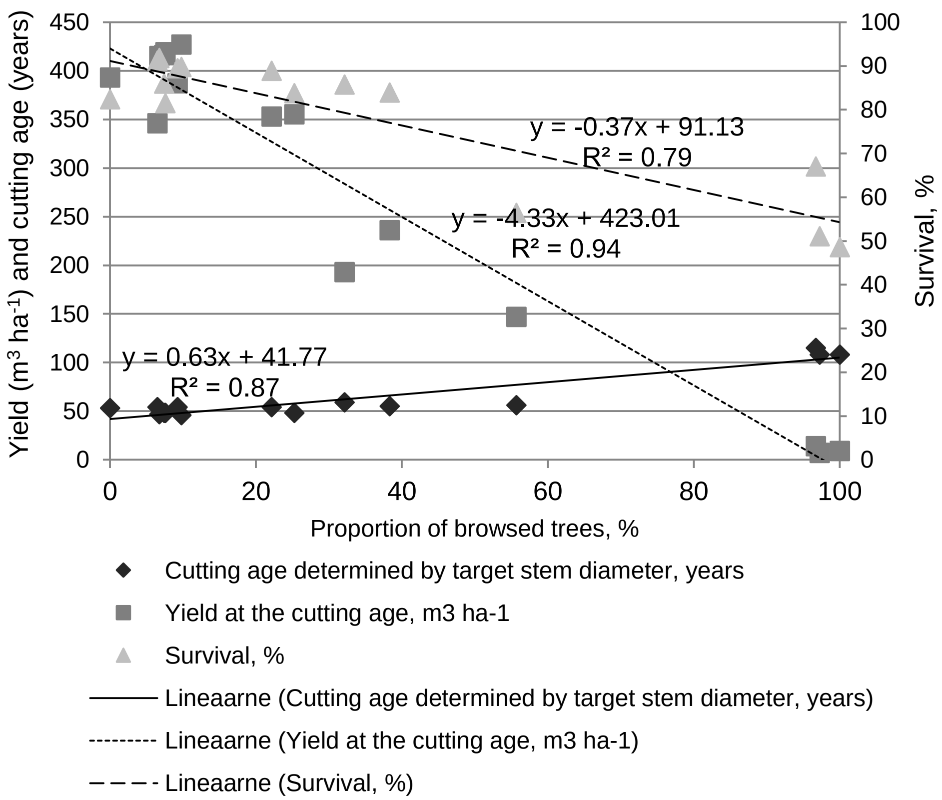
MATERIALS AND METHODS

Study site was located in large birch plantation (total area > 20 ha) in central part of Latvia (56°22´N, 23°7´E). One-year old containerized birch seedlings, grown in the same nursery from the same seed lot were planted in autumn of 1999 in former agricultural land (flat relief, no changes of soil type within the area) in prepared soil (ploughing) with spacing 2 x 2 m (density 2,500 trees ha^{-1}). Based on visual assessment the site was divided into 3 parts: limited browsing (< 10% of trees with browsing damage), medium browsing (10–90%) and heavy browsing (> 90% of trees browsed). Browsing of each tree was classified as 'yes' or 'no'. Presence of browsing for the tree was noted, if tree top and/or more than 1/3 of side branches and/or bark more than 2/3 of stem circumference were damaged and it was not possible to attribute the particular damage to any other cause then browsing by cervids (*Cervidae*). Accumulated damage was assessed. Plots with an area of 0.1 ha, separated by a distance from 50 to 460 m, were established in each of the parts of the area in randomly selected location, the number of plots being proportional to the size of area in each browsing level: 11 in light (limited) browsing, 6 in moderate and 3 in heavy. In plots for each tree at the age of 16 years the presence of browsing damages, spike knots (separately for stem section below or above 2 m height) and multiple stems or tops (below or above 2 m height) were assessed. Stem straightness was evaluated in 5 grade scale, where 1 – straight, 2 –slightly bent, 3 – at least one bend – deviation from supposed vertical line along the stem edge exceeding 5 cm, 4 – two bends, 5 – more than two bends. Tree height and diameter at breast height measured. Further development of plots (stands) was estimated using growth models based on National forest inventory data (Donis, 2014; Zeps et al., 2016a) and assuming cutting by target diameter (≥ 27 cm).

Linear regression was used to calculate the trends in the data (plot or individual tree level) and ANOVA was used to test significance of differences between categories (i.e. height of browsed and not-browsed trees), χ^2 – between proportions. Analysis was carried out in SPSS.

RESULTS AND DISCUSSION

Browsing damages had a statistically significant ($P < 0.05$) negative influence on survival of trees: in plots with light browsing (total number of measured trees n = 1,273) survival was 87%, indicating good planting and tending quality, but in plots with heavy browsing (n = 221) survival was on average only 56% (Fig. 1).



Plot mean values used in regression

Figure 1. Yield, cutting age (determined by target stem diameter) and survival (at age of 16 years) in plots with different proportion of browsed trees.

Even such a low survival rate would be sufficient for the establishment of a productive stand, since it corresponds to 1,400 trees ha^{-1} i.e. similar to the initial density recommended for birch plantations in Finland (Hynynen et al., 2010) and it has been found that density not exceeding 1,000 trees ha^{-1} is optimal to maximize diameter growth of dominant trees in birch plantations (Niemistö, 1995). However, in our trial heavy browsing had not only reduced the survival of trees, but also dramatically and significantly ($P < 0.05$) impacted on their height and diameter (Fig. 2). In plots with light browsing the mean height was 13 ± 0.4 m (here and further in text ±95% confidence interval), and mean diameter was 10 ± 0.4 cm, but in plots with heavy browsing the respective figures were only 2 ± 0.3 m and 2 ± 0.3 cm. Also, analysis of variance of data on a tree basis revealed that height and diameter for birches without browsing damage were significantly ($P < 0.05$) higher than for birches with damage: 12 ± 0.1 m and 10 ± 0.2 cm *vs.* 5 ± 0.2 m and 5 ± 0.2 cm. This was in accordance with earlier finding demonstrating that birch is capable to survive even in sites with very high browsing pressure (Heikkilä et al., 1993). Birch has high capacity to recover after damages of foliage alone, as found by studies on insect herbivory (Silfver et al., 2009). However, ungulates (especially moose) have much more pronounced impact on tree growth, since, while reaching for leaves and young twigs, they often break larger branches or even the stem of relative large saplings (Löyttyniemi & Lääperi, 1988). Speed et al. (2013) found that browsing of approximately half of shoots of 1 m high saplings prohibited their height growth. Noticeably in our study, the mean height of birches in the most heavily browsed plots was 2 ± 0.3 m – the reaching height of large ungulates (moose or red dear) during feeding, confirming, that further height growth of these trees was deterred. In these plots 17.6% of trees were lower than 1 m (and height was between 1 m and 1.5 m for of 35.6% of trees), while in the rest of the plantation – only 0.4% of the trees were lower than 1 m.

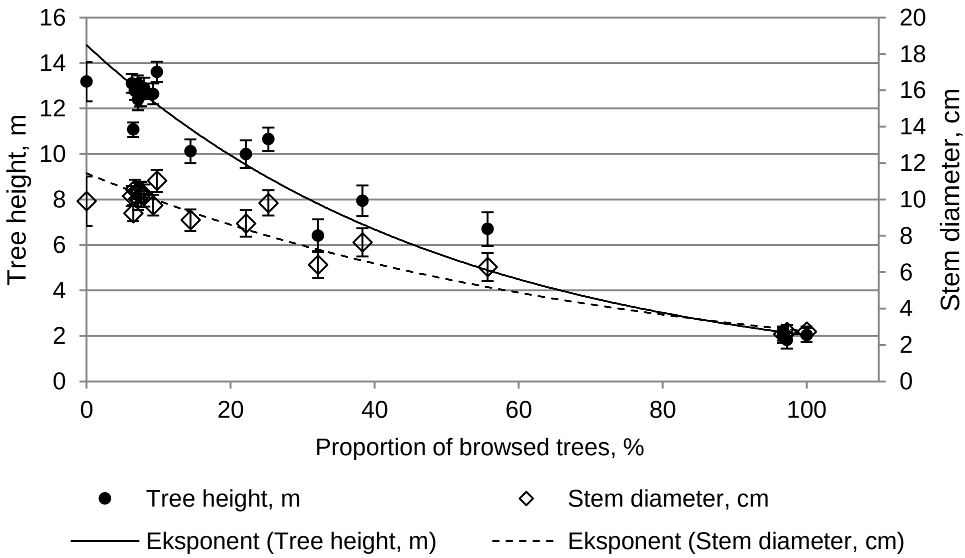


Figure 2. Tree height and stem diameter in plots with different proportion of browsed trees (± 95% confidence interval of respective trait).

Long-term consequences of the browsing on the development of plantation was predicted using growth models with the assumption that browsing will not be continued and that trees will grow normally (according to soil conditions). Modelling revealed, that with this assumption and current parameters, more than 100 years will be required (110 ± 10.3) for the trees in the heavy browsed plots to reach the mean target diameter for cutting (27 cm). In the light browsed plots, applying the same thinning criteria – the time was less than half that (50 ± 3.2 years) (Fig. 1). It indicated that maintenance of the most heavily browsed birches was not a sensible decision. Similar long-term negative effect of browsing on survival and increment of trees, increasing the cutting age of the stands, had been found for Sitka spruce (Scott et al., 2009).

Browsing damage affected not only growth of the trees, but also stem quality and therefore the potential assortment structure. A statistically significantly ($R^2 = 0.92$, $P < 0.05$) higher proportion of trees with spike knots below 2 m height (mostly indicating notable damage at least once before the tree exceeded this height) had been found in heavily browsed plots (Fig. 3). Similar conclusion on negative effect of browsing on quality of trees can be drawn from the positive and statistically significant link between browsing damages and stem straightness ($R^2 = 0.80$, $p < 0.05$). In contrast, no relationship between the proportion of trees with browsing damage and the proportion of trees with stem defects higher than 2 m (multiple leaders or spike knot above 2 m) were detected ($R^2 = 0.003$, $P > 0.05$), indicating, that browsing was most likely the cause of these defects in the lower (most valuable) part of the stem.

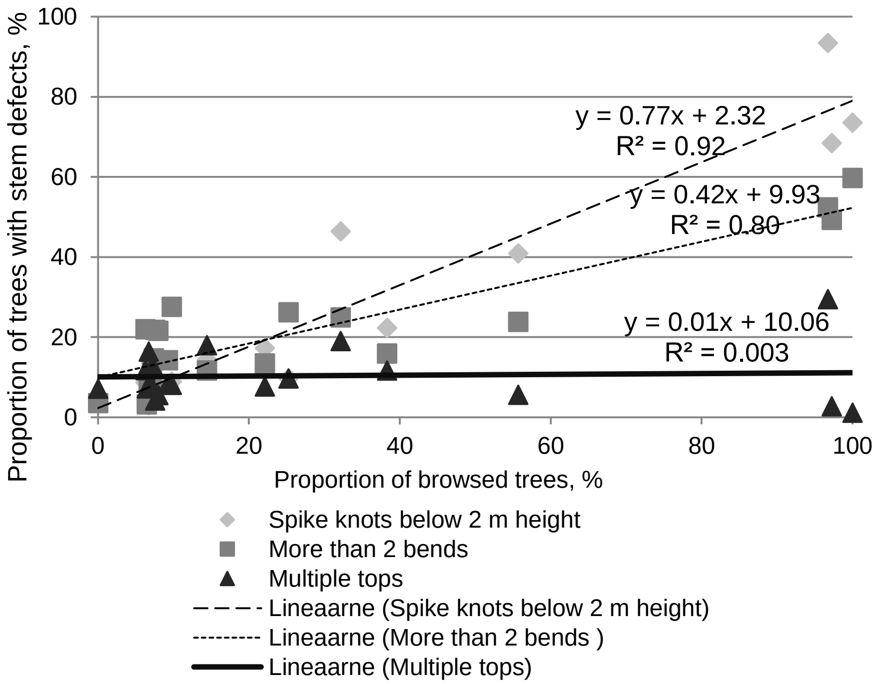


Figure 3. Proportion of trees with stem defects (spike knots, multiple tops, heavy crookedness) in plots with different proportion of browsed trees.

Analysis of data on a tree basis revealed a similar trend: trees with browsing damages had spike knots in up to 2 m height in 50% of cases, trees without browsing damages – in 10% (difference significant, $P < 0.05$). This result also indirectly indicated that trees with currently visible damages had been browsed several times (all types of recent damages correlated positively with the extent of previous damages). Similar conclusions – both on repeated damages of the same trees and negative effect of browsing damage on stem quality were reached in a comprehensive evaluation of Scots pine in Sweden (Bergqvist et al., 2001).

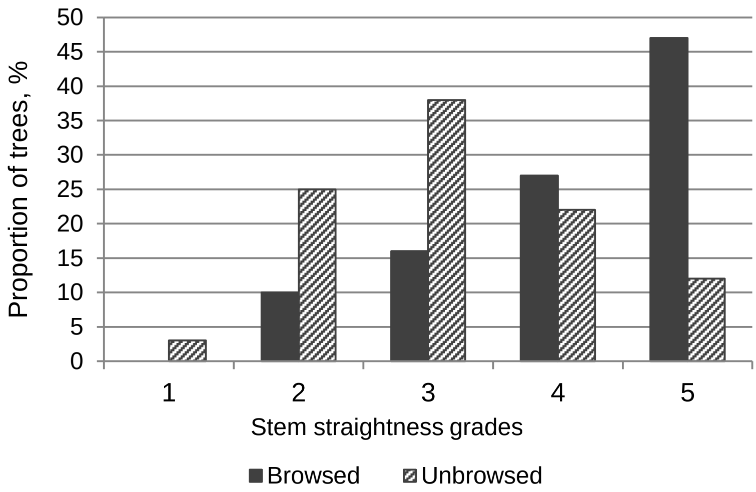


Figure 4. Distribution of browed and unbrowsed trees in different stem straightness grades.

Browsing had a negative effect on stem straightness: the proportion of trees with very crooked stems (grade 5) reached 47% for birches with browsing damage and 12% for birches without them (difference statistically significant, $P < 0.05$) (Fig. 4). Stem breakage (during browsing by moose) had been linked to crookedness in analysis of silver birch in Finland (Heikkilä et al., 1993). Stem quality reduction due to browsing damages (all aspects together) had lead to a 10–28% decrease of timber value for Sitka spruce in Scotland (Scott et al., 2009). Browsing causes not only easily observable stem defects, but also discoloration and decay of wood, further reducing its value, and, in contrast to similar damages caused by insects – also contributing to reduction of tree growth (Heikkilä et al., 1993; Zeps et al., 2016b).

The Results clearly demonstrated the significant negative influence of browsing damage on tree quality both at stand and indivudual tree level.

CONCLUSIONS

Heavy browsing damage of birch had caused statistically significant decrease of survival and growth of trees up to a point where the predicted rotation age was more than double that of the slightly browsed areas and maintenance of the plantation was no longer financially viable. Browsing had a notable and significant negative effect on the occurrence of spike knots below two metres in height and on the stem straightness of affected birches.

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Investigations of fibre plants preparation and utilization of solid biofuels

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Abstract. Presented research results of technological-technical means and operations for solid biofuel preparation: chopping, milling, pelleting and burning of fibre plants – 3 sorts of fibre hemp (Beniko, Bialobrzeskie and Epsilon 68) and fibre nettle (sown in 60 x 60 cm). These fibre plants were grown in the experimental fields of Lithuanian Research Centre for Agriculture and Forestry, Upytė Experimental Station, and in Aleksandras Stulginskis University were investigated the technical means of these plants preparation and usage for energy purposes. It was used the standard methodology for solid biofuel preparation of fibre plants, and was investigated the technique for plant chopping, milling and pelleting. There were determined fibre plant mill fractional composition while usage the hummer miller prepared mill. There were determined the fibre plant pellet quality indicators – moisture content and bulk density. The fibre plant pellet moisture content ranged from 6.4% to 8.8%, and pellet density reached 1,082.7–1,186.2 kg m^{-3} DM (dry matter). Pellet elemental composition, ash content and calorific value were determined at the Lithuanian Energy Institute. The ash content after the burning of fibre plant pellet was not high and varied from 3.6 to 5.9%. Determined net calorific value of fibre hemp and fibre nettle dry mass was relatively high 17.2–17.5 MJ kg^{-1}, it was close to calorific value of some wood species.

Key words: Fibre hemp, fibre nettle, pellets, elemental composition, ash content, calorific value.

INTRODUCTION

One of the most important renewable energy sources in Lithuanian is plant biomass, which is an eco-friendly local fuel: wood, specially cultivated trees, straws, tall grasses, triticale and other unconventional energy crops). These energy resources already make a big part of the local fuel. Plant biomass compared with fossil fuels has many advantages: relatively low costs, less dependence on weather changes, the promotion of local economic structures' development and alternative sources of incomes for plant growers. As renewable energy sources can be grown and fibrous plants – fibre hemp and fibre nettle. These plants grow well in Lithuanian climatic conditions (Jankauskiene et al., 2006; Jasinskas & Scholz, 2008; Jankauskiene & Gruzdeviene, 2010).

The market of energy fuel in Lithuania highly depends on import. There is no any fossil fuel except small amount of oil and peat in Lithuania. The biofuel as wood and wood residues, straws and energy plants is the most interesting sphere how to increase renewable resources in the energy balance. Electricity generation from biofuel was 6.1% in 2014 year (Sabaliauskas, 2015). There is an intention to develop energy plant plantations, also better use forest wastes and agricultural crops residues – straws. Till 2020 year heat generation from solid biofuel will reach 67% in Lithuania (Verbickas et al., 2013).

There is big potential of crops wastes, but the straw is not so friendly for combustion equipment, because the content of chlorine compare with wood is 7–10 times bigger and nitrogen 10–12 times. These materials stimulate corrosion (Verbickas et al., 2013). Therefore, the cultivation of energy plants has perspective due to its closeness to wood.

Plants as fibrous hemp and fibrous nettle were chosen for it's productivity and high calorific value. Hemp originated in Central Asia. The most useful is seeding hemp (Cannabis sativa L.). It is an annual plant. This type is used for seeds and fibre. Scientists also suppose it usage for energy purposes. Ability of fibrous hemp to yield more than 24 tons of green biomass per hectare (corresponding to 10.9 t ha^{-1} of dry biomass) within 140 days (Kolarikova et al., 2014). The green biomass can be used for biogas production, seeds for biofuel and stems for briquetting and pelleting production. Hemp is not climate demanding and prefer wet and rich soils. It can be grown in dried peat bogs. The wet clay soil is not recommended. Hemp also can be used in crop rotation due to its ability to enrich soil in form of leaves and roots. Moreover, it has heavy metal absorption properties so it can be used to renew contaminating fields (Jasinskas & Scholz, 2008).

Three varieties of fibre hemp were chosen for this research: polish cultivars Beniko and Bialobrzeskie, which are medium-early and French cultivar Epsilon 68 – late, maturing.

The great nettle (Urtica Dioica L.) is common perennial plant in Lithuania. It is not soil and climate demanding. The nettle is used in textile, medical, cosmetic and food industries. There are possibilities to use nettle for biofuel production as briquettes or pellets. The annual dry matter yield (DMY) of nettle ranged from 6 to 10 t ha^{-1} (Butkute et al., 2015).

Harvesting technologies of unconventional energy plants depends on many factors: the biological properties of plant maturity, humidity, and weather conditions. For plant harvesting can be used two technologies: direct – plant harvesting and milling, or indirect – removal of plant stems and pressing or loose stems harvesting, storage and chopping (Faber et al., 2007; Borkowska & Molas, 2012; Jasinskas et al., 2014). Naturally, the direct stem harvesting technology prevails, in which the plant stalks are cut, chopped and pressed into bales or bundles of chaff and are removed from the field. Indirect harvesting technology is used less frequently.

Plant chaff use for biofuel is not convenient; therefore, it is expedient to mill and press this chaff into briquettes or pellets and to determine the mechanical and energetic properties of pellets produced from plant biomass. It is convenient to use the pellets in small and medium thermal plants because the operations of pellet supply and combustion can be fully automated (Sultana & Kumar, 2012; Cherney & Verma, 2013; Niedziołka et al., 2015). Therefore, it is appropriate to determine the technological-technical parameters of fibre plants chopping, milling and pellet preparation of biofuel.

The possibilities of fibre plants utilization and usage for energy purposes in Lithuania has been poorly investigated, researches have been carried out in the Institute of Agricultural Engineering and Safety, Aleksandras Stulginskis University.

The aim of this work – to investigate the technical means of fibre plants mass preparation for biofuel, to assess quality indicators of these energy plants' chopping, milling and pelleting, to determine pellet the basic properties: density, elemental composition, ash content and calorific value.

MATERIALS AND METHODS

There were investigated three sorts of fibre hemp: Beniko, Bialobrzeskie and Epsilon 68, and one sort of fibre nettle (sown in 60 x 60 cm). These plants were grown in the experimental fields of Lithuanian Research Centre for Agriculture and Forestry, Upytė Experimental Station, and in Aleksandras Stulginskis University were investigated the technical means of these plants preparation and usage for energy purposes. It was investigated the technique for plant chopping, milling and pelleting.

The chopping and milling quality of fibre plant, produced for biofuel, should satisfy the requirements of the combustion chamber, chopped mass transportation machinery and storage. For the first step of stem chopping was used a drum chopper of Maral 125 forage harvester (Jasinskas et al., 2014). Before the production of biofuel pellets, the prepared chaff should be chopped to the form of the mill. For the chaff milling a Retsch SM 200 mill was used.

The milling quality was determined using the standard methodology (DD CEN/TS 15149-1:2006). The fractional composition of the chopped plants was determined using a set of 200 mm diameter sieves with round holes of diameters 0 mm, 0.25 mm, 05 mm, 0.63 mm, 1 mm and 2 mm. The mass remaining on the sieves was weighed, and the sample fraction percentages were calculated. Each test was repeated 5 times (DD CEN/TS 15149-1:2006).

For pellet production was used a small capacity granulator 'Peleciarka' (produced 2011 by Company *POLEXIM*, Poland), 7.5 kW with a horizontal granulator matrix, the diameter of the pellets was 6 mm granulated milled plants (Fig. 1). Main constructive parameters of granulator are as follows: the distance between the flat die and rollers is 0.05–0.3 mm; the rotation speed of die is 3,000 min^{-1}; the mass flux is 200–350 kg h^{-1} (Instruction manual, 2011).

The moisture content of milled raw material is determined: the fibre hemp 'Beniko' 7.8 ± 0.1 %, the fibre hemp 'Bialobrzeskie' 8.3 ± 1.2 %, the fibre hemp 'Epsilon 68' 7.4 ± 0.4 % and the fibre nettle 7.9 ± 0.2%.

The mill was granulated in the traditional way: before the mill entered the granulator, the mill was mixed thoroughly to achieve homogeneity. Next, the raw material was moistened, and the dosage unit was supplied to the press chamber, wherein the mill was moved by rollers through the matrix holes of 6 mm diameter. The biomass was pressed through holes to form of pellets. The pellet cooling period was 24 hours, and after a full pellet cooling and relaxation process their biometric parameters:

dimensions, humidity, volume and density, were evaluated. The pellet parameters were determined by measuring their height and diameter (accurate to 0.05 mm). Experimental trials were randomly selected for each plant species with 10 pellets.

Figure 1. Small capacity granulator with a horizontal granulator matrix.

Pellets weight was assessed by KERN ABJ scales (accurate to 0.001 g). The weights were calculated for each type of plant using 10 of the granules with the average meaning the error.

Pellets moisture content was determined in a laboratory drying chamber oven according to the standard method (CEN/TC 14774-1:2005). The pellet volume was calculated using the pellet size (diameter and length).

Pellet density was calculated after determination of pellet volume and pellet size (diameter and length) and pellet mass. It also was determined the bulk density of pellet, granules poured into 5 dm^3 container, weighing and calculating the bulk density (Niedziołka et al., 2015).

Pellet elemental composition, ash content and calorific value were determined at the Lithuanian Energy Institute (LEI) Thermal equipment research and testing laboratory in accordance with the valid Lithuania and EU countries standard methodology:

- using the basic elements analyser Flash 2000, Nr. 2011 F0055,
- according to LST EN 14774-1:2010 standard, in moisture test rig Nr. 8B/1,
- according to LST EN 14775:2010 standard, in ash content test rig Nr. 8B/5.

Calorific value (KJ kg^{-1}) of the plant chaff was determined by a IKA C 5000 calorimeter (IKA, Germany) by the standard methodology (BS EN 14918:2009).

RESULTS AND DISCUSSION

There were determined the fractional composition of chopped by drum chopper and milled by hammer mill fibre plants – fibre hemp (Beniko, Bialobrzeskie and Epsilon 68) and fibre nettle (sown in 60 x 60 cm). The fractional composition was determined applying methodology widespread in EU countries, using sieves with holes of various diameters. Fractional composition of prepared mill (%) dependence on sieves holes diameter (mm) is presented in Figs 2–5.

Dependance of a part of fibre hemp Beniko mill fraction (%) from the holes of sieves is presented in Fig. 2. Having evaluated fraction composition of mill, we can see that the highest mill fraction was on 0.25 mm sieves (37.8 ± 2.0%). There was no fraction on a sieve with holes 2 mm diameter, and too big amount of dust was found – 27.6 ± 1.9%.

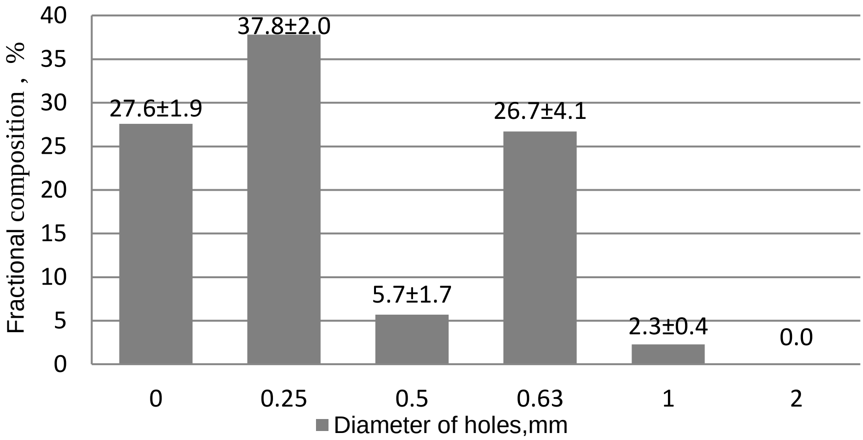

Figure 2. Fraction composition of fibre hemp Beniko mill.

Dependance of a part of fibre hemp Bialobrzeskie mill fraction (%) from the holes of sieves is presented in Fig. 3. After evaluation of mill factional composition from the chart, we can see very similar view like of the fibre hemp Beniko. The highest fraction of plant mill accumulated on a sieve with holes 0.25 mm diameter – 38.7 ± 1.8%, and a little less on 0.63 mm diameter holes sieve – 26.6 ± 4.3%. There was no fraction on a sieve with holes 2 mm diameter, and as well as for hemp Beniko, too much amount of dust was found – 27.0 ± 1.8%.

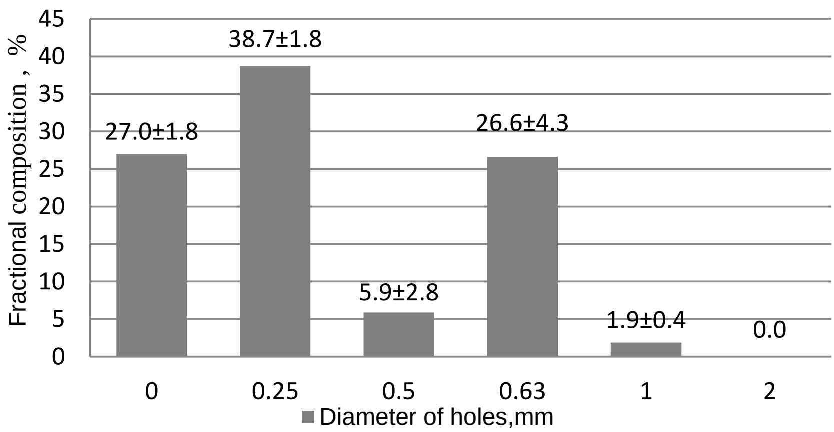

Figure 3. Fraction composition of fibre hemp Bialobrzeskie mill.

Dependance of fibre hemp Epsilon 68 mill fraction (%) from the holes of sieves is presented in Fig. 4. The highest fraction of plant mill also accumulated on a sieve with holes 0.25 mm diameter – 36.6 ± 1.8%. There was no fraction on a sieve with holes 2 mm diameter, and too big amount of dust was found – 25.1 ± 0.5%.

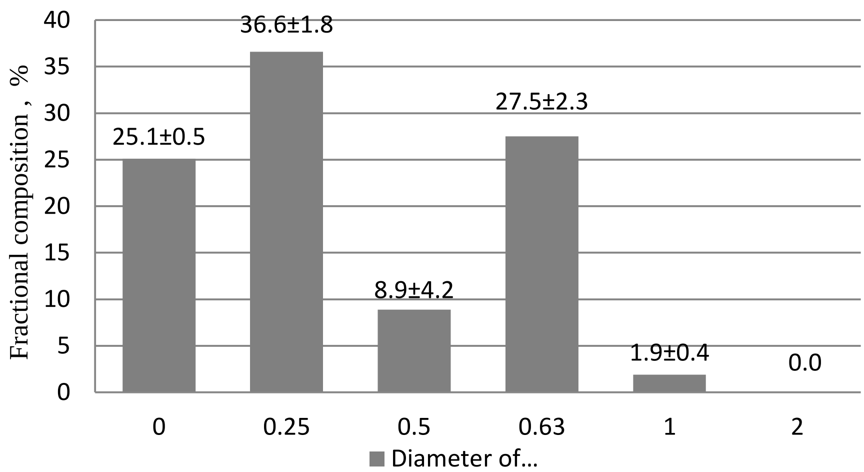

Figure 4. Fraction composition of fibre hemp Epsilon 68 mill.

Dependence of a part of fibre nettle mill fraction (%) from the holes of sieves is presented in Fig. 5. Having evaluated fraction composition of mill, from the chart we can see very similar view like of the fibre hemp research results. The highest mill fraction was on 0.25 mm sieves (38.7 ± 2.6%). There was no fraction on a sieve with holes 2 mm diameter, and too big amount of dust was found – 27.0 ± 2.7%.

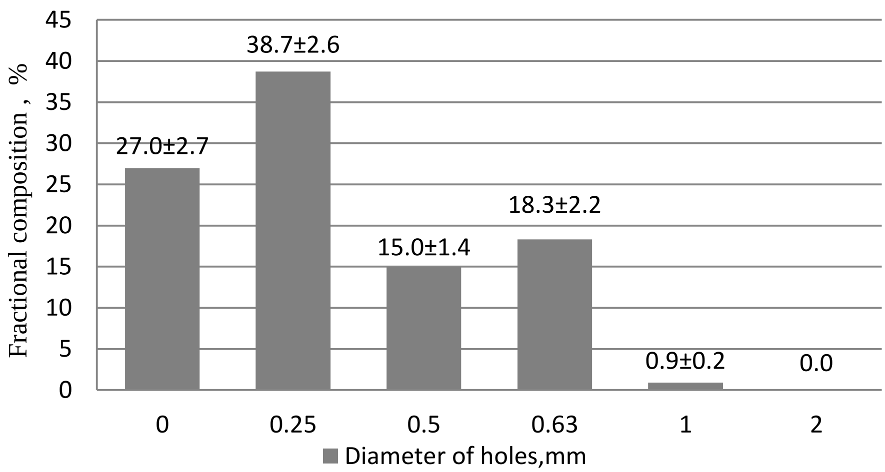

Figure 5. Fraction composition of fibre nettle mill.

Evaluating milling quality of fibre hemp (Beniko, Bialobrzeskie and Epsilon 68) and fibre nettle mill it can be stated that all plants were milled into too small fraction. There were determined, that the biggest mill fraction was on 0.25 mm sieves – from 36.6 ± 1.8% to 38.7 ± 2.6%, and too big amount of dust was found – from 25.1 ± 0.5% to 27.6 ± 1.9% (recommended maximum amount of dust 10–15%). There was no fraction on a sieve with 2 mm diameter holes.

All investigated fiber plants are suitable for burning after appropriate preparation. Investigated fiber plants were pressed into pellets of 6 mm diameter and were determined pellet physical-mechanical properties: moisture content and bulk density (Table 1).

Table 1. Physical-mechanical characteristics of fibre plant pellets

Fiber plant pellets	Moisture content, %	Bulk density, kg m^{-3}
Fibre hemp Beniko	6.8 ± 0.1	1,203.1 ± 35.7
		1,121.3 ± 35.7 DM
Fibre hemp Bialobrzeskie	7.8±0.1	1,247.2 ± 45.2
		1,149.9 ± 45.2 DM
Fibre hemp Epsilon 68	8.8 ± 0.1	1,187.2 ± 30.2
		1,082.7 ± 30.2 DM
Fibre nettle	6.4 ± 0.1	1,267.3 ± 36.8
		1,186.2 ± 36.8 DM

Determined pellet moisture content ranged from 6.4 to 8.8%. Bulk density in dry matters (DM) of fibre hemp Epsilon 68 pellets was the smallest – 1,082.7 ± 30.2 kg m^{-3} DM, and the density of fibre nettle was the biggest – 1,186.2 ± 36.8 kg m^{-3} DM. Density of all investigated fibre plants was sufficiently high, it has exceeded 1 t m^{-3} DM.

Research results of other non-traditional energy plants pellet biometrical content data shows that the virginia mallow and cup plant pellet moisture contents ranged from 9.6% to 11.6%. The virginia mallow pellet density was also big – 969.3 kg m^{-3} DM, but cup plant pellet density was significantly lower than fibre plant and reached only 788.5 kg m^{-3} DM (Siaudinis et al., 2015).

Determined elemental composition of three sorts of fibre hemp and one sort of fibre nettle shows that were received similar amounts of elements for all sorts of plants: C (carbon) content was the biggest and reached 45.9–46.7%, H (hydrogen) content varied from 5.2 to 5.9%, and other chemicals composition of N (nitrogen) and S (sulphur) was small in volume % (Table 2).

The ash content of fibre nettle was the biggest and reached 5.9%, lower ash content was of the hemp, it varied from 3.6 to 3.8% and was about 1.6 times lower than fibre nettle biofuels. The high ash content indicates that investigated of fibre nettle pellets burned insufficiently.

The average calorific value when burning of all investigated sorts of fibre hemp and fibre nettle pellets of DM was very similar and varied from 17.2 to 17.5 MJ kg^{-1}. This calorific value of fibre plant pellets was relatively high, close to calorific value of some wood species.

According to other sources, the calorific value of fibre hemp variety 'Bialobrzeskie' was 17.76–18.98 MJ kg^{-1} DM (Poisa & Adamovics, 2011).

Table 2. Pellet elemental composition, ash contents and calorific value

Parameters	Value	Deviation, ± %
Fibre hemp Beniko		
C (carbon) content, %	46.29	1.08
H (hydrogen) content, %	5.94	0.43
N (nitrogen) content, %	0.37	0.31
S (sulphur) content, %	0.11	0.27
O (oxygen) content, %	43.65	-
Ash content, %	3.64	0.02
Moisture content, %	6.88	0.07
Dry biofuel lower calorific value, MJ kg^{-1}	17.21	0.47
Fibre hemp Bialobrzeskie		
C (carbon) content, %	46.74	1.09
H (hydrogen) content, %	5.16	0.43
N (nitrogen) content, %	0.35	0.31
S (sulphur) content, %	0.12	0.27
O (oxygen) content, %	43.82	-
Ash content, %	3.80	0.08
Moisture content, %	7.52	0.07
Dry biofuel lower calorific value, MJ kg^{-1}	17.52	0.35
Fibre hemp Epsilon 68		
C (carbon) content, %	46.61	1.07
H (hydrogen) content, %	5.94	0.43
N (nitrogen) content, %	0.29	0.30
S (sulphur) content, %	0.09	0.26
O (oxygen) content, %	43.52	-
Ash content, %	3.55	0.01
Moisture content, %	6.88	0.07
Dry biofuel lower calorific value, MJ kg^{-1}	17.33	0.39
Fibre nettle		
C (carbon) content, %	45.91	1.09
H (hydrogen) content, %	5.74	0.43
N (nitrogen) content, %	0.73	0.31
S (sulphur) content, %	0.11	0.27
O (oxygen) content, %	41.60	-
Ash content, %	5.91	0.03
Moisture content, %	6.48	0.07
Dry biofuel lower calorific value, MJ kg^{-1}	17.16	0.57

CONCLUSIONS

1. There were investigated three sorts of fibre hemp: Beniko, Bialobrzeskie and Epsilon 68, and one sort of fibre nettle (sown in 60 x 60 cm). These plants were grown in Lithuanian and were investigated the technical means of these plants preparation and usage for energy purposes. It was investigated the technique for plant chopping, milling and pelleting.

2. After evaluating of milling quality of fibre hemp and fibre nettle mill it can be stated that all plants were milled into too small fraction. There were determined, that the biggest mill fraction was on 0.25 mm sieves – from 36.6 ± 1.8% to 38.7 ± 2.6%, and too

big amount of dust was found – from 25.1 ± 0.5% to 27.6 ± 1.9%. There was no fraction on a sieve with 2 mm diameter holes.

3. Determined pellet moisture contents ranged from 6.4 to 8.8%. Bulk density in dry matters (DM) of all investigated fibre plants was sufficiently high, it has exceeded 1 t m^{-3} DM. The density of fibre hemp Epsilon 68 pellets was smallest – 1,082.7 ± 30.2 kg m^{-3} DM, and the density of fibre nettle was the biggest – 1,186.2 ± 36.8 kg m^{-3} DM.

4. Research results of fibre plant pellet elemental composition showed the similar amounts of elements for all sorts of plants: C (carbon) content was the biggest and reached 45.9–46.7%, H (hydrogen) content varied from 5.2 to 5.9%, and other chemicals composition of N (nitrogen) and S (sulphur) was small in volume.

5. The ash content of fibre nettle was the biggest and reached 5.9%, lower ash content was of the hemp, it varied from 3.6 to 3.8% and was about 1.6 times lower than fibre nettle biofuels.

6. The average calorific value when burning of all investigated sorts of fibre hemp and fibre nettle pellets varied from 17.2 to 17.5 MJ kg^{-1} DM. This calorific value of fibre plant pellets was relatively high, close to calorific value of some wood species.

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Transport route segments and stress effect on drivers

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Abstract. Drivers are expected to drive safely whilst carrying out a variety of complex tasks using physical, sensor, cognitive and psychomotor skills. In this paper, the authors examine the influence of road characteristics and microclimate influence in driver's cabin, on different drivers' performance while accomplishing their daily duties. The authors gave prior emphasis on transport route profiles like pedestrian crossing, road junctions, round about; pulling in and out of each bus stop and other unexpected incidences on driver's attention. The research was held on different drivers on the same transport route and segment of articulation. Work experiences, unfamiliarity of the routes were among the key factors for increasing stress and decreasing drivers' attention. This paper analyse stress factors on drivers during the summer period of driving performance. The core data on microclimate situation in the driver's cabin and the heart rate are preserved through careful measurements on all route segments. The drivers' heart rates are carefully recorded at specific parts in the road to examine how the road characteristics affect driver's behaviour. The influence of route characteristics, the microclimate influence in the drivers cabin, and other complications in transport route on heart rate variations of different drivers is the output of the research findings.

Key words: crossroad; downhill drive; roundabout; transport route; uphill drive.

INTRODUCTION

Number of research papers like Philip, (2005), Patel et al. (2011) and Pogotovkina et al. (2013), has shown on their scientific papers as driving to be a complex task which requires good health and a high level of mental and physical coherence. Similarly, Zalcmanis et al. (2014), have concluded that passenger transportation safety is a priority task and should be given maximum attention to the comfort of drivers and their working conditions including the social legislation related to their respective duties. In this paper, the authors examined the thermal comfort, preferable local microclimate conditions and heart rate variation of city bus drivers of Prague. Drivers pull in and out of bus stops, monitor passengers' behaviour, stick to a strict timetable, provide good service to customers and deal with other unexpected events whilst all of the time driving safely is paramount (Zewdie & Kic, 2015). City bus drivers are also expected to change their driving style to meet the safety demands of the driving environment. For example, compensate for a decrease in attention by reducing speed or refraining from performing risky manoeuvres such as overtaking at a crossroads or at a roundabout. These tasks can cause fatigue, stress and overall burn out. Scientific and professional papers, especially by Lawson (2004), show how different parts of the road/road characteristics can play a significant role in influencing drivers' attention and conclude that driving is a complex task which requires the co-ordination of many skills. Similar conclusions were reported from electrocardiographic studies of London's dense fast-moving traffic which could raise a person's heart beat from 70–85 to 100–140 beats per minute (Mehler et al., 2008; Mehler et al., 2010). Other research relating to driver's safety show how both the geometry of a vehicle (the glazed area) and the interior and exterior material properties can heavily influence the microclimate of the driver's cabin (Zewdie & Kic, 2015).

In this paper the authors show how different parts of the road segments affect the heart rate. Measuring the heart rate is a non-invasive tool for analysing the variations in cardiac rhythm (Kaye et al., 2004). These variations are supposed to be of significance mainly on road junctions (crossroads), at traffic lights, in traffic congestion, in different weather conditions (Lukes et al., 2014), internal driver's thermal conditions in cabin and unexpected events on the road. All the operational activities of the drivers were noted on a separate sheet without the knowledge of the driver. The authors recorded data including characteristics of the route, thermal conditions and heart rate of the volunteer bus drivers. This particular paper investigates the driving performance of Prague's bus drivers en route, and how drivers' heart rate affected the results on the bus 107.

MATERIALS AND METHODS

The authors performed the research on three Karosa KbN B941 City Buses of the same model, a Czech brand which is commonly used in the city's transport system. All buses are the property of the district of 'Repy', Prague Urban Public Transport. The authors compared the weight, height, oxygen content of their blood (before and after their drive), the drivers' age and the number of years spent working as a City bus driver. Although, the research was confidential, we took into consideration the background of each and every individual driver. The first driver (A) is twenty-five years old (performed the test in August 2014), had his driving license for five years and drove ten thousand kilometres or more annually. The second driver (B) is forty-nine years old (performed in August 2014) and has fifteen years of working experience as a city bus driver. The third driver (C) is forty-five (performed in July 2015) and has fourteen years' of experience (Table. 1). The drivers' selection was based on the age, weight, and height and work experience in the company they work for. The youngest driver (A) was nearly 50% younger than the other two drivers (B and C). Work experience at the company of driver (A) was nearly a third of the experiences compared to drivers B and C. This selection was made to compare two age categories, i.e. 25 years and nearly 50 years old drivers.

All participants of the research were volunteers with the Prague transport management for two summers (of relatively mild climates – August 2014 and July 2015). Data was collected on each individual driver. The time and route was selected, so that every driver had very similar weather and driving conditions. The measurements were first taken from station 'Za sokolovnou' and ended at the 'Dejvicka' station and then also for the return journey. The measurements were taken on the same route ten round trips by each driver.

Table 1. General information on research conducted drivers

Driver	A	B	C
Age (year)	25	49	45
Weight (kg)	80	130	94
Height (cm)	170	180	185
Work experience (year)	5	15	14
O_2 content in blood (%)*			
-before driving	96	90	92
-after driving	92	86	83
Pulse (min^{-1})*			
-before driving	67	98	85
-after driving	71	99	89
Status (-)	single	divorced	married
Activity (-)	cycling	not willing to tell	musician

* - obtained through measurement

The method of collecting the data was identical for all three drivers. The road numbered 241 was used for the research and is classified as a 2nd category road by EU standards (Fig. 1). It has an average elevation of 5.1 to 5.3% and has a maximum height above sea level of 275 m at the top and 181 m at the lower part of the road (Fig. 2). It is the artery communication route that connects the suburban vicinities adjacent to the capital city transport network and is a main route leading to the city centre and the surrounding areas of the capital. From the metro station Dejvicka, the bus line 107 transports students and employees to the university which makes up to a total of 25,000. Similar bus serves as a transport mode for Suchdol inhabitants and visitors.

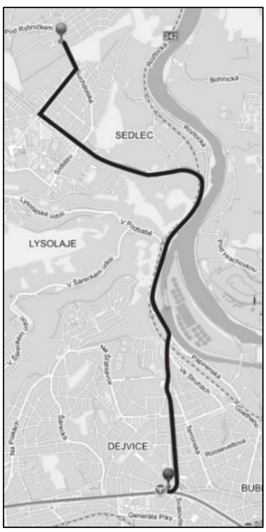

Figure 1. Line 107 road map.

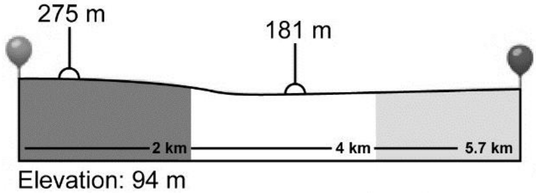

Figure 2. Line 107 road profile.

The route for all three drivers starts at station Za Sokolovnou in Suchdol, Prague 6 and goes to the terminal Vitezne Namesti at the Dejvice metro station, covering a distance of 5.9 km including the return trip the total travelled is 11.78 km. This is performed ten times so the total distance travelled by each driver is 118 km. The route was chosen based on the roads' characteristics. A total of nine data recording points were selected and are shown in more detail on Table 4. At each reference point, the average heart rate has been registered and calculated.

MEASURING INSTRUMENTS

For the actual measurement, the driver should put on a sensor (Polar RS800CX) around the body and computer device on the wrist of the driver to record the heart rate variability (HRV). The package of the measurement instrument consists of four parts brand of Polar. The Polar RS800CX is a computer which displays and records the heart rate and other data like position and velocity during driving examination; Polar wear link W.I.N.D. a transmitter, sends the heart rate signal to the computer. It includes connector and strap; CD-ROM which includes software and a complete user manual for the RS800CX computer.

The other accessory to RS800CX computer is Polar s3 stride sensor W.I.N.D. Polar G3 GPS sensor. G3 sensor provides all the data on velocity and distance covered by the vehicle on the basis of income and evaluating GPS satellite signals. The position of the sensor is constantly compared by at least with four visible satellites. The values the sensor G3 transmitted through wireless radio frequency of 2.4 GHz sent out for evaluation in receiver up to a distance of 15 m. Relevant data were collected from measurement devices which are installed on the body and wrist of the performing driver. Data detected (heart rate of the driver, position and velocities of the bus) are stored in Polar RS800CX are transformed through infra port to a personal computer for further processing and analysis.

The Czech government health protection regulation determines the conditions for the protection of health related to light manual work such as driving under normal operating conditions. Under this regulation, for particular metabolic energy output 81–105 W m^{-2}, the recommended operating temperature is 20 ± 2 °C and relative humidity to be 30–70%. Thermal state of the internal environment can be described by applying the index of temperature and humidity (THI). This index is widely used to describe the heat stress, and it is also a key indicator of the environmental conditions of stress.

Data on the microclimate conditions in the bus driver's cabin were collected from measurement devices which are installed on the dashboard of the bus. The thermal comfort in the space was continuously measured by globe temperature (measured by globe thermometer FPA 805 GTS with operative range from –50 to +200 °C with accuracy ± 0.01 K and diameter of 0.15 m) together with temperature and humidity of surrounding air measured by sensor FH A646-21 including the temperature sensor NTC type N with operative range from –30 to +100 °C with accuracy ± 0.01 K, and air humidity by capacitive sensors with operative range from 5 to 98% with accuracy ± 2%. The concentration of CO_2 was measured by the sensor FY A600 with operative range 0–0.5% and accuracy ± 0.01%. All data were measured continuously and stored at intervals of one minute to the measuring instrument ALMEMO 2690–8 during the measurement.

RESULTS AND DISCUSSION

Principal measurement results of heart rates of all three bus drivers, and the conducted vehicles are evaluated and summarized on Figs 3–6. Fig. 6 contains the result the combination (round trip) of three drivers' average heart rates at the monitored reference points, for nine selected variables. The mean values including standard deviation were calculated from the results of measurements for each of parameters. The obtained results of measurements were processed by Excel software and verified by statistical software Statistica 2013. The average values including standard deviation were calculated from the results of measurements for each of external and microclimatic parameters: external temperature t_e, external relative humidity RHe, internal temperature t_i, internal globe temperature t_g, internal relative humidity RHi, THI, BGHI and concentration of CO_2.

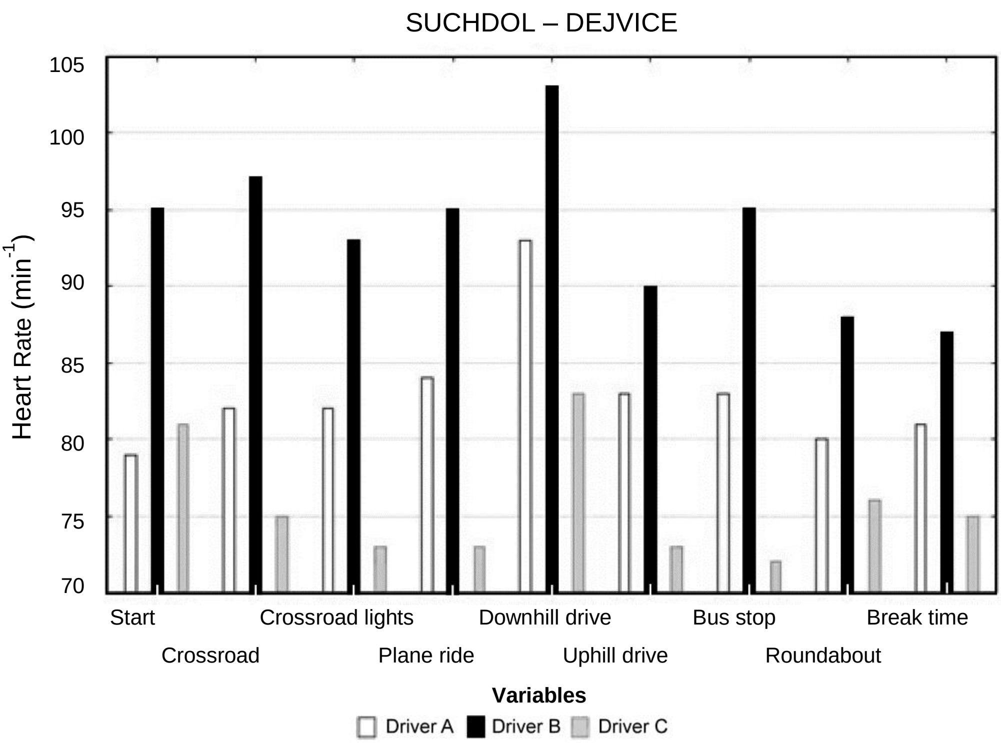

Figure 3. Bar/Column chart of heart rate of different drivers from Suchdol to Dejvice.

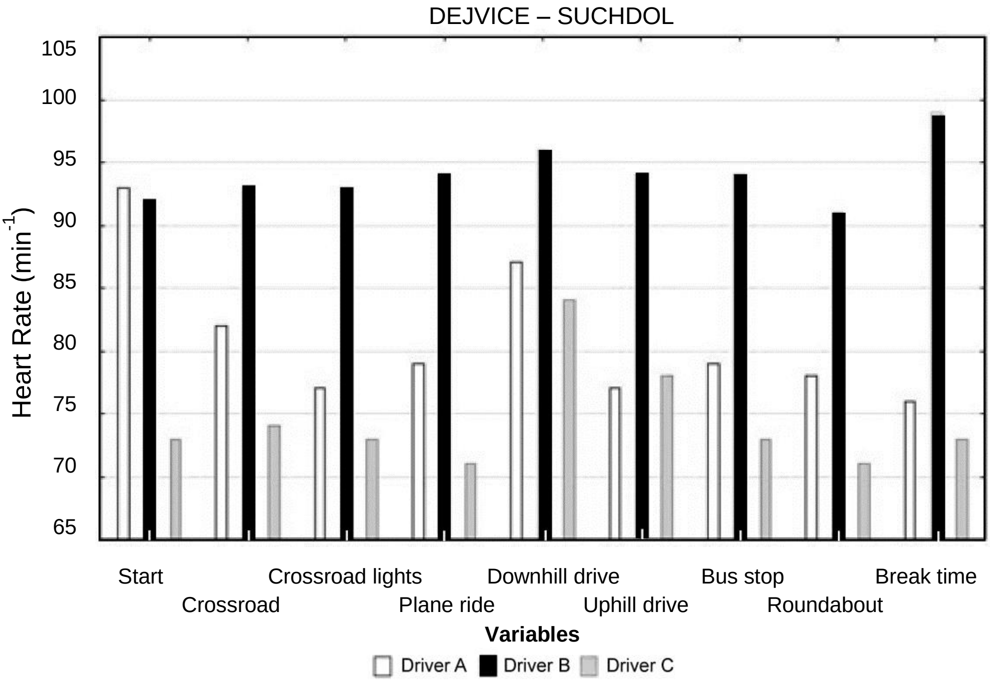

Figure 4. Bar/Column chart of heart rate of different drivers from Dejvice to Suchdol.

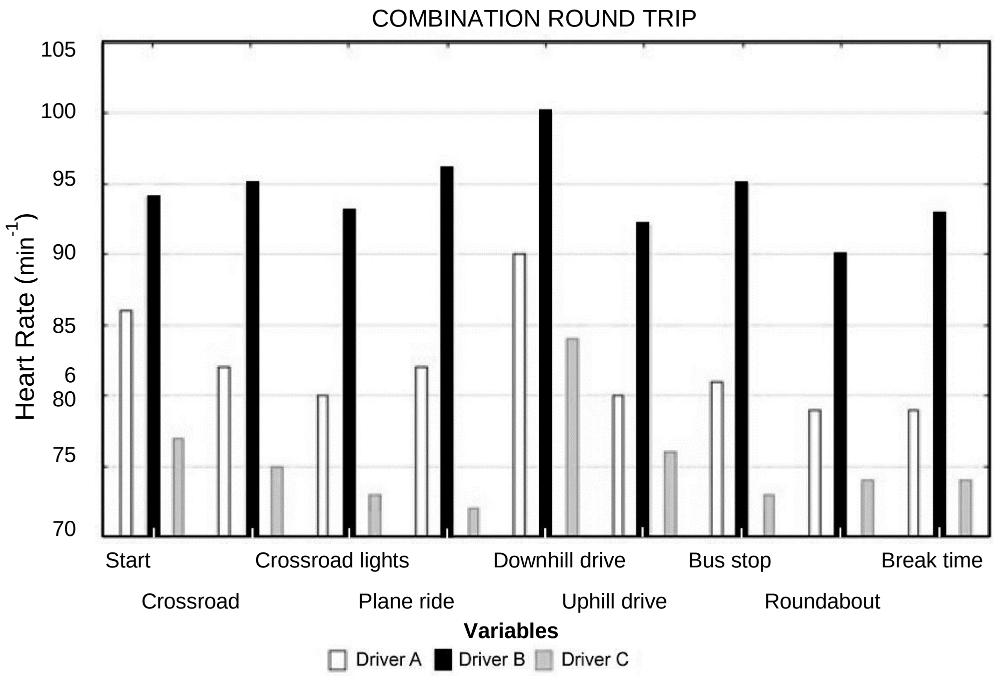

Figure 5. Bar/Column chart of heart rate of different drivers round trip.

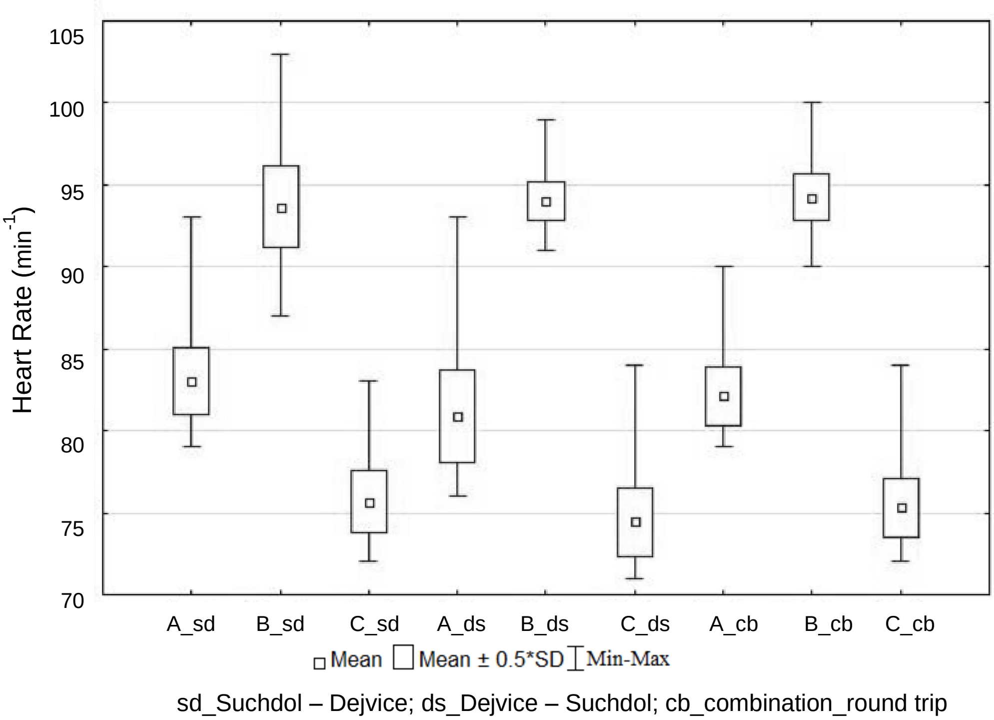

Figure 6. Box and Whisker plot of different drivers heart rate from Suchdol – Dejvice, Dejvice – Suchdol and round trip.

The results of the measurement microclimate in the bus cabin during the morning are presented in Table 2, afternoon measurements are in Table 3. Examples of the course of the THI and BGHI are calculated from the internal parameters measured during the morning and afternoon measurements in the bus cabin.

For the analysis, descriptive statistical values compile number of variables, mean, standard deviation; minimum and maximum heart beats are selected as shown on Table 4. Figs 3–6 compile the results of the final descriptive statistics for all drivers graph representation of results.

Table 2. Indoor parameters in cabin of bus during the morning

Parameter	t_e	RH_e	t_i	t_g	RH_i	THI	BGHI	CO_2
Units	°C	%	°C	°C	%	-	-	%
Mean value	15.4	53.6	22.22	24.19	39.8	67.3	69.7	0.041
Standard devia.	0.5	3.4	0.62	1.25	1.3	0.68	1.5	0.009
Minimum	13.9	48.7	20.65	20.69	36.1	65.54	65.4	0.033
Maximum	16.4	60.8	23.91	26.57	44.5	68.96	72.4	0.075
Median	15.8	51.2	22.14	23.97	39.8	67.18	69.5	0.037

Table 3. Indoor parameters in cabin of bus during the afternoon

Parameter	t_e	RH_e	t_i	t_g	RH_i	THI	BGHI	CO_2
Units	°C	%	°C	°C	%	-	-	%
Mean value	19.5	33.6	29.98	29.88	22.1	73.7	73.7	0.034
Standard devia.	0.4	0.51	2.72	1.30	2.8	2.3	1.5	0.002
Minimum	18.6	32.9	25.95	26.73	14.0	70.1	70.3	0.033
Maximum	20.3	36.0	38.99	33.12	27.3	81.3	77.7	0.050
Median	19.7	33.3	29.0.	29.52	22.5	73.3	73.7	0.033

Table 4. Influence of route segments on drivers heart rate round trip drive

		Drivers HR, min^{-1}		
		A	B	C
Segment	No. of segments	HR ± SD	HR ± SD	HR ± SD
S-D	9	83 ± 4	94 ± 5	76 ± 4
D-S	9	81 ± 6	94 ± 2	74 ± 4
S-D-S	18	82 ± 4	94 ± 3	75 ± 4
Start	2	86 ± 5	94 ± 5	77 ± 4
Crossroad	10	82 ± 4	95 ± 4	75 ± 3
Crossroad with light	8	80 ± 4	93 ± 3	73 ± 3
Plane ride	12	82 ± 5	96 ± 2	72 ± 4
Downhill drive	4	90 ± 4	100 ± 2	84 ± 2
Uphill drive	4	80 ± 5	92 ± 4	76 ± 4
Bus stop	20	81 ± 4	95 ± 3	73 ± 3
Roundabout	4	79 ± 3	90 ± 4	74 ± 2
Drivers break	2	79 ± 3	93 ± 2	74 ± 2

Fig. 3. Represents Suchdol – Dejvice drive. The minimum measured heart rate for driver A was 72 min^{-1}. The downhill drive segment shows the highest 93 min^{-1} or A = 93 ± 5 and the increase demonstrates 129%. Similarly, the lowest heart rate for driver B was 82 min^{-1}. The same segment, downhill drive, indicates the highest heart rate 103 min^{-1} or B = 103 ± 5, which means the highest increase to be 126%. Similar pattern was observed on driver C as the smallest heart rate being 64 min^{-1} and the highest 83 min^{-1} or C = 83 ± 6 at downhill segment and increase in 130%. The heart rates of all three drivers of are showing an increase in the downhill stretch drive probably caused by physiological stress.

Fig. 4. Represents the reverse drive from Dejvice – Suchdol. For subsequent analysis procedures are like the previous drive. The only difference is the bus ride was in the opposite direction, i.e. Dejvicka – Suchdol. Driver A with minimum heart rate 71 min^{-1} was recorded to maximum to be 93 min^{-1} or A = 93 ± 5 right at the beginning of the drives with the increase of 131%. Similarly, driver B with the smallest 82 min^{-1} and maximum 96 min^{-1}, B = 96 ± 4 had the increase of heart rate by 117%. The third driver C had its lowest to be 65 min^{-1} and the highest 84 min^{-1}. C = 84 ± 4 has increased by 129%.

Fig. 5. Shows the result of the combination for both driving directions. The graph is compiled out of ten complete round trips by all three drivers. It is explained by the fact that, it is classified from Suchdol to Dejvice (Fig. 4), and from dejvice to suchdol (Fig. 5) drive. The minimum heart rate for driver A is again 72 min^{-1} and the maximum

90 min^{-1}, or A = 90 ± 5 with the increase of 125% at the downhill segment. It is clearly shown that driver B has the highest heart rate 100 min^{-1} with the increase of 122% at the same downhill segment. Driver C scores the maximum of 84 min^{-1} with the increase of 129%.

Fig. 6. Represents Box and Whisker plot of different drivers heart rate from Suchdol – Dejvice (sd), Dejvice – Suchdol (ds) and round trip as combination (cb). The mean, mean and standard deviation, the mean with minimum and maximum heart rate range graph. From the graph it is clearly seen that the highest positive standard deviation range is at driver A_sd , A_ds and A_cb. This finding probably confirm the age, physical fitness and sports activities of the driver.

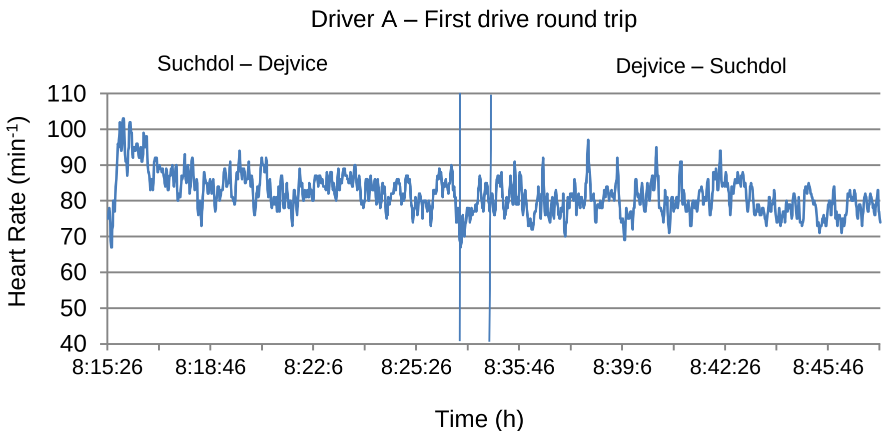

Figure 7. Behaviour of the function of the Heart rate the drivers first drive Suchdol – Dejvice round trip (driver A).

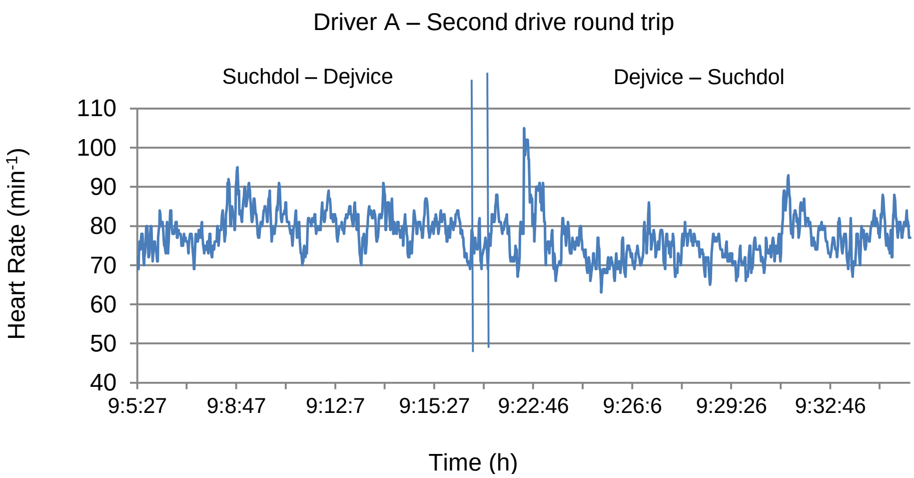

Figure 8. Behaviour of the function of the Heart rate the drivers second drive Suchdol – Dejvice round trip (driver A).

Figs 7, 8. Demonstrate behavioural functions of the heart rate of the driver A. From both figures, it is clearly seen that at every drive the heart rate could differ due to unexpected circumstance like fixing measuring device (Fig. 7) Suchdol – Dejvice drive, radio call from the dispatcher (Fig. 8) Dejvice – Suchdol drive. Driver A had the highest heart beat 103 min^{-1} at the morning drive at 8:15 (Fig. 7), respectively 105 min^{-1} at 9:22 (Fig. 8).

Tables 2, 3 represent the Indoor parameters in cabin of bus during the morning and Indoor parameters in cabin of bus during the afternoon. Thermal state of the internal environment can be described by applying the index of temperature and humidity (THI). This index is widely used to describe the heat stress, and it is also a key indicator of the environmental conditions of stress, temperature.

CONCLUSIONS

This study demonstrates that some drivers exhibit changes in heart rate variability depending on the feature of route segments. Significant influence of the increase of heart beat which was observed on all drivers was a downhill route segment. This could be caused by vehicle breaking leading to stress effect. Radio communication from dispatchers, cell phone calls, and ill-disciplined passengers etc. could be among causes for the increase or heart rate disorders. Physical fitness, social comforts increase the capacity of withstanding variable stress which might be different to each driver. Driver C had low heart rate and factors could be a settled and better social life and may be better health dispositions. Driver B scored the highest heart rate on all variables. Possible factors could be health factors such as age, weight and other social discomfort, etc.

All drivers had different heart rate increases at different segments. Driver A scored the highest increase in percentage at the downhill drive (125%) and the start point (119%). On driver B, it was observed the increase at five segments; plane ride (117%), crossroad (116%), bus stop (116%), crossroad with light (113%), and the heights were the downhill drive (122%). Driver C also features the increase in percentage on four segments; downhill drive (129%), start position (118%) and uphill drive (117%).

The internal conditions in the cabin of bus are strongly influenced by solar radiation, especially at a larger proportion of cabin glazing. Based on the result of the morning measurements in the bus, higher temperatures have occurred, for example global temperature t_g from 20.7 °C to 26.6 °C. The internal temperature t_i rose from 20.7 °C to 23.9 °C. This indicates that the influence of solar radiation has increased rapidly compared to the internal temperature, which is against regulation in relation to the directive on health supervisor (Government Regulation 361/2007 of Czech Republic, 2007).

Measurement evaluation applying the THI and BGHI indexes also reveals the major influence of radiation. E.g., the mean value of the THI is 67.3 and the BGHI mean value 69.7. In the lower outside air, temperatures can reduce the influence of solar radiation by adequate ventilation of the cabin. In the higher outside air, temperatures can maintain the recommended air temperature inside only using the cooling (air conditioning) of air. Drivers are recommended to ventilate sufficiently even in colder outdoor conditions to let in the fresh air (O_2) and exhaust the polluted air (CO_2 and odours). Based on the results of the measurement, a slightly higher concentration of CO_2 (0.075%) has occurred.

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Impact of cultivation method on the soil properties in cereal production

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Abstract. The aim of present paper is to give an overview about results collected in 2012–2014 related to impact of cultivation method on the cereal field soil properties. Experiments were conducted on Estonian farmers' production fields to compare no-till and plough-based tillage practices. Studied properties were among others soil bulk density, structure, water content, microbial activity and weeds seeds content.
The bulk density, gravimetric moisture content and structure of soil from 0–10, 10–20 and 20–30 cm layers were evaluated. For microbial activity an enzyme dehydrogenase, which occurs in all viable microbial cells, was determined in soil layers 0–10 and 10–20 cm. Soil samples were taken from 0–25 cm layer to determine weed seeds content. Seeds were extracted from the soil using a flotation-method. The seeds were counted and species identified under the microscope.
The cultivation method has significant impact on some soil properties and insignificant to other. Cultivation method had no significant impact on ratio of agronomically preferred soil particles (2–4.75 mm). No-tilled fields soil bulk density had no differences between layers except 0–10 layer in Pärnumaa ($p < 0.05$). Soil bulk density differences ($p < 0.05$) between layers occurred in Soth-Viljandimaa and Pärnumaa tilled soils, in which plough pan in layer 20–30 cm was noticeable.
In average the abundance of weeds seeds was higher on no-tilled fields, compared to tillage accordingly 60,975 and 29,250 weed seeds m^{-2} ($p < 0.003$).
Results showed higher soil dehydrogenase activity in the no-tilled soils layer 0–10 cm than in 10–20 cm layer ($p < 0.05$). In the tillage the dehydrogenase activity had no significant difference between soil layers.

Key words: no-till, tillage, soil physical properties, soil dehydrogenase activity, weed seeds.

INTRODUCTION

In Estonia 9% of arable land was cultivated with direct drilling method by inquiry made in 2010 (PMS602, 2010) and the interest to use that technology is increasing because of farmers hope to reduce production costs and work time with that. However, farmers suffer under lack of sufficient information related with possibilities to use direct drilling in Estonian agroclimatic and soil conditions, which are very heterogeneous despite of small area of country. There is no comprehensive research made in Estonia to study different aspects of no-till technology and which can be used as support for decisions related to selection and usage of tillage method and machines; and taking into account agroclimatic, economic, ecologic, technical and soil-derived aspects.

In Europe the no-till and tillage studies have been carried out for a long period (Soane et al., 2012). The results have pointed out some disadvantages for both cultivation methods. Kassam et al. (2009) found that the ploughing may result loss of soil structure, while Munkholm et al. (2003) found the no-till tend to increase soil bulk density. In northern Europe no-till raised up a problem in delay of spring-sowing due to the fact that in spring the soil surface of no-tilled fields is covered with plant residues, which slow down the warming up of the soil (Mikkola et al., 2005; Soane et al., 2012).

Through the changes of soil physical property and plant residues distribution the biological processes in soil depend on the tillage practices (Bogužas et al., 2010; Janušauskaite et al., 2013). The measurement of soil enzymatic activity could be used as an indicator of tillage management induced changes on soil microorganisms (Watts et al., 2010). Dehydrogenase is an enzyme that occurs in all viable microbial cells (Nannipieri, 1994) and therefore soil dehydrogenase activity (DHA) is widely used to describe overall soil microbial activity (Wolinska & Stepniewska, 2012).

Soil weed seed bank is the main source of weed infestation in any crop. Tillage affects the vertical weed seed distribution in a soil profile (Chauhan & Johnson, 2009). Moving the soil on field encourages germination of weeds seeds stored in the soil. Tillage systems cause changes in the density and composition of soil weed seedbank (José-Mariá & Sans, 2011), especially in weed seed composition in the upper 0–15 cm soil layer (Barberi and Lo Cascio, 2001). Feldman et al. (1997) and Tørresen et al. (2003) reported that weed seed densities in the upper soil surface in no-till and reduced tillage systems were higher than in ploughed systems. In contrast, Unger et al. (1999) concluded, that tillage method does not affect seed density. Similar results were found by Ruisi et al. (2015) who noted that tillage system had no effect on the size of the weed seedbank, but altered both its composition and the distribution of seeds within the soil profile.

The aim of this study was to evaluate the response of soil physical properties, microbiological activity and weed seed content to no-till and tillage practices in different Estonian agroclimatic and soil conditions.

MATERIALS AND METHODS

The field experiment was carried out in 2012–2014 on the commercial fields in Estonia. The trial plots were located on seven location, different farmers' fields. The fields were selected on the principle that in all sites the comparison pairs of tillage and no-till fields locate closely (under the similar weather conditions) and have similar soil characteristics (Table 1). For observations a study area with size 1 ha was selected from each field. Crops grown on the fields are presented in Table 2. During 2012–2014 the average use of pesticides in no-till and tillage fields were in correspondingly as follows (active ingredient kg ha^{-1}): pesticides 1.1 and 0.9, of them glyphosate 0.53 and 0.26. In investigated fields different mineral fertilizers were used during study, only in 2013 spring in Tartumaa the liquid cattle manure at the rate 30 t ha^{-1} was used. The fertilisation and plant protection strategy were decided by farmers managing the fields and it depended from farm production plan. Same strategies were used in Soth-Viljandima comparison pair and in Jõgevamaa comaprision pair, but different by region.

Tillage based on mouldboard ploughing to a depth of 20 cm. The no-till fields in North- and South-Viljandimaa, Valgamaa and Põlvamaa have not been ploughed over ten years and in Pärnumaa and Tartumaa during two and in Jõgevamaa one year.

Table 1. Soil characteristics on experimental territories

Location	No-till					Tillage			
	Depth, cm	C_{org} %	Sand %	Clay %	Silt %	C_{org} %	Sand %	Clay %	Silt %
North-Viljandi	0–10	1.6	53	13	34	2.8	47	12	41
	10–20	1.5	44	13	43	2.8	50	11	39
South-Viljandi	0–10	1.6	60	9	31	1.5	66	7	27
	10–20	1.4	60	8	32	1.4	77	4	19
Valgamaa	0–10	1.4	69	8	23	1.5	84	4	12
	10–20	1.6	66	7	27	1.5	75	5	20
Põlvamaa	0–10	1.7	56	7	37	1.0	69	8	23
	10–20	1.4	57	7	36	1.2	68	8	24
Tartumaa	0–10	1.8	47	9	44	1.8	48	9	43
	10–20	1.4	51	10	39	1.9	49	10	41
Jõgevamaa	0–10	1.9	35	11	54	1.9	35	11	54
	10–20	2.0	37	11	52	2.0	37	11	52
Pärnumaa	0–10	4.0	67	23	10	3.1	68	23	9
	10–20	3.1	71	20	9	2.8	72	21	8

Notes. One composite sample was collected from every experimental territory. Organic carbon (C_{org}) content in soils was measured by NIRS method. Soil texture was measured in the soil science and agrochemistry laboratory of Estonian University of Life Science.

Table 2. Cultivated crops in no-till (NT) and conventionally tilled (CT) fields in 2012–2014

Location	Treatment	2012	2013	2014
North-Viljandi	NT	spring barley	spring rape	spring wheat
	CT	spring barley	spring rape	spring wheat
South-Viljandi	NT	spring rape	winter wheat	spring barley
	CT	spring rape	winter wheat	spring barley
Valgamaa	NT	winter wheat	oats	winter wheat
	CT	winter wheat	oats	spring rape
Põlvamaa	NT	–	winter wheat	spring barley
	CT	–	winter wheat	spring barley
Tartumaa	NT	–	spring wheat	spring wheat
	CT	–	oats	clover
Jõgevamaa	NT	–	oats	winter wheat
	CT	–	oats	winter wheat
Pärnumaa	NT	–	spring barley	spring rape
	CT	–	spring barley	spring rape

Soil bulk density, moisture content and structure

The soil physical properties, i.e. bulk density (Mg m^{-3}), soil gravimetric water content (kg kg^{-1}), soil structure and water stable aggregates (%) in the 5 points of the Z-scheme were observed at fields. Each measurement point was established by GPS equipment. The measurements were made in soil layers 0–10, 10–20 and 20–30 cm.

The soil bulk density and gravimetric soil moisture content are evaluated by cylinder (100 cm^3). The soil structure K_{str} (Nugis, 2010; Nugis et al., 2014) is evaluated by USA Standard Testing Sieve and also by method of Swedish University of Agricultural Sciences (Hakansson, 1983; Kritz, 1983) by which the soil has been sieved in the moist conditions. For this the soil samples were collected from above mentioned fields. The soil has been sieved also in the dry conditions by full set of abovementioned sieve's equipment with corresponding sieves with diameter of bores (9.5; 4.5; 2.0; 1.0; 0.425; 0.250; 0.150 and 0.075 mm). The ratio of water stable aggregates (%) from soil aggregates with diameter of particles between 0.250–1.0 mm were evaluated from same samples. The ratio (soil dry sieving) of soil water stable aggregates (%) is calculated with equation:

$$W_r = \frac{m_a}{100M} \quad (1)$$

where: m_a – total mass of soil upon sieves with diameter of bores 0.425 mm and 0.250 mm, in which the aggregates of soil have been remaining on these sieves; M – total mass of the soil upon full set of abovementioned sieves.

The ratio of soil structure K_{str} (soil moist sieving) was calculated with equation:

$$\mathrm{K}_{\mathrm{str}} = \frac{s_{ad}}{s_{un1} + s_{un2}}, \quad (2)$$

where: s_{ad} – percentage of soil particles with diameter between 2–4.75 mm (agronomically preferred soil structure); s_{n1} – percentage of soil particles with diameter < 2 mm (agronomically not-preferred soil structure); s_{n2} – percentage of soil particles with diameter > 4.75 mm (also agronomically not-preferred soil structure).

Weed seed bank in the soil

The weed seed bank was sampled at the end of August after crop harvest. From each plot 10 soil samples were taken from 0–25 cm soil layer. Samples of each plot were mixed together in a bucket and bagged. For analysis, the samples were sieved to remove stones and air-dried. Seeds were extracted from a 300 g portion of the soil sample using a flotation-based method (Gross & Renner, 1989). 53% solution of K_2CO_3 was used as the flotation solution (specific gravity 1.56 g ml^{-1}). Weed seeds were counted and species identified under the microscope.

Soil dehydrogenase activity

Soil samples from Valgamaa and South-Viljandimaa no-till and tillage fields were taken in 2012–2014 and from North-Viljandimaa, Põlvamaa and Tartumaa in 2013–2014 of April, before cultivation. Soil samples (0.5 kg) from each treatment in six or nine replications (three in each year) were taken by a random method from the 0–10 and 10–20 cm soil layers with a 1 cm ∅ auger. Each soil sample was composite of 20 sub-samples. Samples were sieved (2 mm) and stored at 4 °C until they were analysed in laboratory.

Dehydrogenase activity (DHA) was measured in accordance to Tabatabai (1982). Soil samples (5 g) incubated at 30 °C for 24 h in the presence of an alternative electron acceptor (triphenyltetrazoliumchloride). The red-tinted product triphenylformazan (TPF) was extracted with acetone and measured in a spectrophotometer at 546 nm.

Data analyses

Soil physical parameter results were based on five (structure K_{str} and water stable soil aggregates) or fifteen (soil bulk density and gravimetric water content) sample replicates. All soil dehydrogenase activity results were based on six (North-Viljandimaa, Põlvamaa and Tartumaa) or nine (Valgamaa and South-Viljandimaa) soil sample replicates. The data were analyzed by ANOVA. For the soil physical parameters and dehydrogenase activity the Tukey-Kramer Honest Significant Difference (HSD) test was used via the software *JMP 5.0.1.2* (SAS, 2002).

RESULTS AND DISCUSSION

Soil bulk density, gravimetric moisture content and structure

The soil bulk density is important parameter to describe the soil physical status. The moderate bulk density which enhances root growth is 1.3–1.5 Mg m^{-3} (Tracy et al., 2012), but its depends also on the soil texture and the content of organic matter (Guimarães et al., 2002). In this study the average soil bulk density for all years, sites and depths was similar to both tillage systems (no-till – 1.54 and tillage – 1.52 Mg m^{-3}) (Table 3). The highest soil bulk density in all three investigated soil layers (Table 1) were measured on Valgamaa conventionally tilled field (0–10 cm – 1.65, 10–20 cm – 1.65, 20–30 cm – 1.75 Mg m^{-3}) (Table 3) which soil has high sand and low silt and clay content.

In 0–10 cm soil layer occurred lower soil bulk density in South-Viljandimaa and Pärnumaa tilled fields compared to no-till fields, which were not ploughed over ten and two years (Table 3). The lower soil bulk density in tillage than no-till fields soil was also found by Munkholm et al (2003) and Saoirse et al (2013). In South-Viljandimaa and Pärnumaa 20–30 cm layer was soil bulk density in no-tilled field similar to the conventionally tilled field or remained even lower. The higher bulk density in conventionally tilled soils 20–30 cm layer could be explained with formation of plough pan. The plough pan can create impenetrable layer to growing roots of cultured plant (Soane et al., 2012).

During study the average soil gravimetric water content for all treatments, depths and years was 0.209 kg kg^{-1} (Table 3). Considerably lower soil gravimetric water content in 0–30 cm soil layer (0.199 kg kg^{-1}) was measured in tilled soils compared to no-till (0.220 kg kg^{-1}). Higher soil moisture content in no-till soils cold be due to the plant residues covering soil surface and therefore hindering the solar radiation access and soil evaporation. This effect may cause serious delay of the spring-sowing and thus decrease of yield in no-till systems (Mikkola et al., 2005; Soane et al., 2012).

Table 3. Mean values of soil bulk density, gravimetric water content, structure and water stable aggregates in no-till (NT) and conventionally tilled (CT) fields (n = 15)

Location	Depth cm	Bulk density, Mg m^{-3}		Gravimetric moisture content, kg kg^{-1}		Structure, K_{str} 0–20 cm (n = 5)		Water stable aggregates, % 0–20 cm (n = 5)	
		NT	CT	NT	CT	NT	CT	NT	CT
N-Viljandi	0–10	–	–	–	–	0.72^{abc}	$0.71^{a–d}$	8.4^{cd}	$10.7^{a–d}$
	10–20	–	–	–	–				
	20–30	–	–	–	–				
S-Viljandi	0–10	1.44^{cd}	1.29^{e}	$0.236^{a–e}$	$0.220^{b–f}$	0.33^{cde}	$0.47^{a–e}$	8.4^{cd}	15.1^{ab}
	10–20	1.45^{cd}	1.40^{d}	$0.212^{c–g}$	$0.206^{e–h}$				
	20–30	1.49^{cd}	1.58^{b}	$0.208^{d–h}$	$0.183^{f–i}$				
Valga-maa	0–10	1.54^{bc}	1.65^{ab}	$0.217^{c–f}$	$0.172^{g–j}$	0.16^{e}	0.23^{e}	9.9^{cd}	$13.7^{a–d}$
	10–20	1.56^{bc}	1.65^{ab}	$0.193^{e–i}$	0.150^{ij}				
	20–30	1.64^{ab}	1.75^{a}	0.167^{hij}	0.131^{j}				
Põlva-maa	0–10	–	–	–	–	0.86^{a}	$0.66^{a–d}$	17.5^{a}	16.7^{ab}
	10–20	–	–	–	–				
	20–30	–	–	–	–				
Tartu-maa	0–10	–	–	–	–	$0.42^{b–e}$	$0.60^{a–e}$	4.0^{e}	7.4^{de}
	10–20	–	–	–	–				
	20–30	–	–	–	–				
Jõgeva-maa	0–10	–	–	–	–	0.81^{ab}	0.79^{ab}	7.5^{de}	9.1^{cd}
	10–20	–	–	–	–				
	20–30	–	–	–	–				
Pärnu-maa	0–10	1.40^{d}	1.31^{e}	0.265^{a}	$0.253^{a–d}$	0.31^{de}	0.38^{cde}	4.0^{e}	8.0^{cd}
	10–20	1.65^{ab}	1.41^{d}	$0.252^{a–d}$	0.262^{ab}				
	20–30	1.65^{ab}	1.65^{ab}	$0.228^{a–e}$	$0.215^{c–g}$				
Prob > F		< 0.0001		< 0.0001		0.012		< 0.0001	

Note. Different letters behind the mean values indicate significant differences ($p < 0.05$). Significances of model effects ($p > F$) are indicated. In the case of significant model effects, a Tukey-Kramer HSD test was performed in order to compare mean values.

Soil structure is based on soil aggregate dynamics. Soil agregates play an essential role in water availability, movement in soil and thus they are very important in crop production (Bronick & Lal, 2005). Results showed a best soil structure K_{str} in Põlvamaa no-till field (0.86), the lowest value (0.16) was found in Valgama no-till field. Significant differences between tilled and no-till fields soil structure K_{str} was not found.

The more soil consists particles resistant to precipitations, the bigger is ratio of water stable soil aggregates W_r (%). In South-Viljandimaa and Pärnumaa the ratio of water stable soil aggregates W_r (%) was significantly bigger in tilled than in no-tilled soils. However, according to Bogužas et al. (2010) no-till increases the amount of water stable soil aggregates because tillage influences changes in the natural soil features and the organic matter decomposition is enhanced.

Weed seed bank in the soil

In average the abundance of weeds seeds was higher on the test fields with no-till, compared to tillage – accordingly 60,975 and 29,250 weed seeds m^{-2} in 25 cm soil layer ($p < 0.003$) which is in accordance to Carter and Ivany (2006), Chauhan et al. (2006), Auškalnienė & Auškalnis (2009). Our research also supported findings by Tørresen et al. (2003) who found that weed seed densities in the upper soil surface in no-till soils were higher than in ploughed soils. On the fields with tillage the soil in the tillage depth is moved over whole field area, thus the weed seeds were distributed more evenly in the tillage depth. Soil weed seed bank consisted largely of annual weed seeds. *Chenopodium album* was the most abundant weed species in both tillage systems. A lesser extent of the seeds of *Viola arvensis, Thlaspi arvense, Polygonum convolvulus* and *Galium aparine* were present. The highest number of weed species were found from the South-Viljandi no-till field (weed seeds from 15 different species) and smallest number from North-Viljandi no-till field (8 species). Also, Murphy et al. (2006) found that no-till promoted higher weed species diversity compared to the ploughed fields. Tørresen et al. (2003) observed an increase in annual grasses and perennial weeds species under no-till. Only in South-Viljandi no-till field we found that number of perennial weeds species were higher than in ploughed field.

***S*oil dehydrogenase activity (DHA)**

Results showed that no-till fields had higher soil DHA in the 0–10 cm layer compared to 10–20 cm layer (Table 4). In tillage occurred no significant difference between soil layers DHA. Similar results were found by Gajda et al. (2013) and Janušauskaite et al. (2013). This could be caused by the fact that in the no-tilled soils the content of organic carbon (C_{org}) (Table 1) in the upper layer was higher than in lower layer, but in tilled soils the C_{org} content in both layers was similar between each other or opposite to no-till. The positive relationship between soil C_{org} content and DHA was observed in North-Viljandimaa and Põlvamaa where the soil DHA was remarkably higher in the comparison pair soil with higher content of C_{org} (Table 1, Table 4).

Table 4. Impact of different tillage systems on soil DHA (µg TPF g^{-1} soil h^{-1}) in 2012–2014 (North-Viljandimaa, Põlvamaa, Tartumaa n = 6; Valgamaa and South-Viljandimaa n = 9)

	No-till		Tillage	
Location	0–10 cm	10–20 cm	0–10 cm	10–20 cm
North-Viljandimaa	7.9^{b}	4.8^{d}	9.8^{a}	8.5^{ab}
South-Viljandimaa	3.7^{ef}	1.7^{i}	2.8^{fgh}	2.2^{ghi}
Valgamaa	3.7^{ef}	2.3^{fghi}	2,2^{ghi}	1.8^{hi}
Põlvamaa	4.6^{de}	2.4^{ghi}	3.1^{fg}	2.9^{fgh}
Tartumaa	10.2^{a}	5.6^{cd}	6.0^{c}	6.0^{c}
Prob > F	< 0.0001			

Note. Different letters behind the mean values indicate significant differences ($p < 0.05$). Significances of model effects ($p > F$) are indicated. In the case of significant model effects, a Tukey-Kramer HSD test was performed in order to compare mean values.

Compared to tillage, the 0–10 cm layer DHA activity was higher in no-till in Valgamaa (Table 4). The main reason could be that the content of sand (75–84%, Table 1) in the tilled field was higher than in no-till (66–69%). The negative relationship between soil microorganisms and sand contents was also noticed by Najmadeen et al. (2010).

The soil microorganisms are directly affected by fertilization. The application of organic fertilizers, due to supply of organic compounds to the carbon-limited microbial communities generally results in increased microbial activity (Knapp et al., 2010).

Therefore, the liquid manure at the rate 30 t ha^{-1} used in Tartumaa no-till field in 2013 could be the main reason why soil DHA in 0–10 cm soil layer was higher than in tillage.

CONCLUSIONS

The trial period 2012–2014 is too short to make general conclusions about response of soil bulk density and gravimetric moisture content to contrasting tillage methods. However, soil bulk density differences between layers occurred in South-Viljandimaa and Pärnumaa tilled soils, in which plough pan in layer 20–30 cm was noticeable.

Smaller numbers of weed seeds in tilled soils shows that tillage encourages weed seeds to germinate which is resulting with termination of weed seeds and plants after treatments. No-till preserves weed seeds better in soil compared to tillage. Thus, any soil movement on no-tilled field may lead to much larger number of emerging weeds compared to tilled soils.

Soil dehydrogenase activity is higher in the upper 0–10 cm and lower in the 10–20 cm layer in no-till systems. In tillage, no significant difference occurred between dehydrogenase activity of soil layers.

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Realtime soil moisture measurement during field work

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Abstract. Soil moisture affects grain germination. If the seeds are sown in dry soil the germination is poor and the emergence is uneven. In Finland, the fieldwork during the spring sowing season takes a couple of weeks and during this period the soil is drying or it is wetting if there are rains. If the seeds can be sown to optimal soil moisture content this enhances germination and increases the yield.
Soil moisture content and temperature was measured before spring tillage. By utilizing these results a prototype of soil moisture measurement system was built utilizing commercial NIR-technology moisture sensor. This system could be used in harrows and drills so that the work is done to proper soil moisture content. The principle functioned reliably when properly calibrated and mounted. The measuring system could be further improved with narrower light beam so that the falling soil aggregates would not have interference to the results. This kind of instrumentation could be used in implements.
Harrowing and sowing season could be prolonged with a small impact on yield if the seeds could be sown to advantageous moisture content. This would be also economical because the work capacity and machine sizes could be reduced. Also risk of soil compaction would be less.

Keywords: moisture, precision farming, tillage, NIR-technology.

INTRODUCTON

Seed germination depends mainly on three soil factors, water availability, temperature and gases (porosity). When the seeds are sown they uptake moisture from the soil and their moisture content increases. For germination it is essential that there is water available for uptake and the seeds have a good contact with the soil. Seeds have critical moisture content for germination. For instance for corn the critical moisture content in seed is 30% and in wheat 40% (McDonald 2015).

According to Haller (1984) the moisture content and porosity of the soil during sowing has a strong effect on yield, germination and number of grains in the ear. Soil moisture content and porosity around seeds affects germination. Poor porosity, which is due to compaction or moisture content and shortage of moisture in the beginning of germination decrease the yield

Alakukku (2006) studied germination in laboratory in different soil moisture contents and in two different soils. During ten days incubation time, the optimum soil moisture content for germination was in clay soil 45–80 % of field capacity and in sandy soil 20–70%. At this moisture content, germination was nearby 100%.

The optimum temperature for germination of barley and oats is 20 °C (Isleib 2012). Germination happens also in lower temperatures but it is slower. Minimum germination temperatures are hard to determinate. Isleib (2012) gives minimum temperatures for barley 4 °C, oats 6 °C and potato 7 °C. Temperature response depends on species, variety, growing region and quality of seeds.

The soil porosity and water content accomplishes air supply of the seed. Seeds need oxygen for germination and the carbon dioxide content must be low enough, under 0.03% (McDonald 2015).

Under Nordic countries conditions the traditional seedbed preparation is 2–3 harrowing followed by sowing. This implies a major risk of soil compaction because the soil is still around the field capacity after winter. One must wait for the soil to dry before seedbed preparation can be started. Late sowing implies risk on seed germination because of delays, so the early sowing of spring cereals without or limited harrowing should be more useful if done by a new types of sowing machines Arvidsson (1997) and Arvidsson et al. (2000).

Tamm (2009) examined the yield decrease compared to best sowing day. He found out that yield decreased in average 1.4% day^{-1}. Recommendation for field work in borealis condition during spring time is one week time. If the spring works starts in optimum condition, then after one week the last fields will produce about 10% less yield. Part of this decrease could be avoided by sowing the seeds into correct moisture content.

Tillage methods also have an influence how the soil is dried and warmed. A five year study of zero versus conventional tillage was conducted under central Alberta conditions to determine soil temperature and percent moisture in soil by Malhi & OSullivan (1990). The result was that soil temperatures in the spring at 2.5 or 5.0 cm depths were generally lower under zero tillage than conventional tillage. On the average of 10 recording dates over 3 years, soil temperature at a depth of 2.5 cm. under zero tillage was 2.8 °C lower than under conventional tillage. Percent soil moisture in the top layer (0–15 cm.) on the average of 5 years was 7.2% greater on zero tillage plots than on conventional tillage plots.

Soil moisture content during harrowing or sowing can be determined with Time Domain reflectometry (TDR), capacitive method, impedance method or with spectroscopic methods. The main problem with these methods is that soil density, temperature and electrical conductivity can have an influence on the results (Drücker et al., 2009). The spectroscopic methods are least influenced by these but it measures only surface moisture content. Drücker et al. (2009) used a dielectric measurement system with high frequency (100 MHz), which eliminated the influence of soil density. The sensor was mounted on a cultivator so that it operated in untreated soil. To exclude soil texture and conductivity they sorted the data according to the soil conductivity. Also Andrade-Sanches et al. (2004) studied a dielectric sensor for moisture measurement. They found out that the sensor was insensitive to soil texture but sensitive to soil salinity. Price & Gaultney (1993) used a near infrared sensor (NIR) in measuring soil moisture content. They used a multiple wavelength sensor technology so that measurements would operate on all soils with one calibration. NIR principle measures only the surface moisture content. For this reason the sensor was built on shank which was travelling in the soil and measured the moisture content at that depth. In field tests the sensor detected with 82% accuracy the optimum sowing depth.

Besides the plants we have also to see what the tractability of the soil is. In soft soils also the machinery will have problems to move which can cause a compaction problem. Rotz et al. (2008) give for spring tillage values from 92% to 100% of field capacity as limits for workability. Clay soils have lower values and sandy soils higher. For fall tillage the values are from 99% to 104%. Toro & Hansson (2004) give thresholds for soil workability for secondary tillage in top layer 85% of field capacity and in 3–7 cm depth 107%. For ploughing the threshold is 110%.

Harrowing and sowing season could be prolonged with a small impact on yield if the seeds could be sown to advantageous moisture content. This would also be economical because the work capacity and machine sizes could be reduced. Also risk of soil compaction would be less.

The aim of the study was to find out what kind of moisture profile soils have before spring work and if moisture sensors functions in these circumstances when mounted on an implement.

MATERIALS AND METHODS

Soil moisture and temperature in spring before the tillage work started was measured in Viikki (E025°00', N60° 13'). The soil texture was silty clay. The moisture content was measured with Decagon ECH2O EA-10 capacitive meter and the temperature was measured with Fluke TM 1300 meter. The moisture and temperature profiles were measured in 5 cm thick layers from the top to 30 cm depth and from ten different spots and average value for each layer was calculated from these values.

Spectroscopic method was chosen for the implement soil moisture measurement prototype because it is contactless and it is least influenced by soil properties. Water absorbs NIR (Near Infra Red) light especially at the wavelengths of 1,450, 1,950 and 2,950 nm wavelengths (Plamer & Williams, 1974). In reflecting measurements 1,930 nm wavelength is often used because of higher sensitivity (Järvinen et al., 2007). Commercial NIR sensor IRMA 7 D was used in the experiments (www.visilab.fi). It is operated in 1,950 nm wave length and its measuring frequency is 400 Hz. The sensor is mainly used in measuring paper moisture content in paper machines. It measures the moisture content to 150 μm depth from the top (Launonen & Stenlund, 2007). The equipment was assembled to a three point hitch frame and it had a coulter in front of it, Fig. 1. This made possible to use it in different working depths and the coulter made an even surface for the sensor. The NIR beam of light at 225 mm distance was 190 x 105 mm and the measurement result was the average from this area. If the travelling speed is 3 m s^{-1} and the length of the beam is 190 mm, measuring frequency of 16 Hz is enough for almost continuous moisture measurement.

The sensor was calibrated with gravimetric method in the laboratory. Also the effect of inclination and step response were measured in the laboratory. Inclination can happen during measurement if the furrow done by the coulter is V-shaped. Step response was measured to see how quickly the instrumentation reacted to a change.

Figure 1. IRMA 7 D sensor mounted to a three point hitch frame.

RESULTS AND DISCUSSION

Fig. 2 shows the results of layered moisture and temperature measurements before spring work. The top layer of the field was already quite dry (34% of field capacity) but in the lower layers the moisture content was clearly higher. In 5–10 cm layer the moisture content is 50 % of field capacity, which means that in this layer the moisture content is in optimum range concerning germination but in the top layer it is already too dry. The temperature of the soil does not however change much in deeper depths. According to Fig. 2 the soil temperature in 5–10 cm layer is almost the same as in top layer, so it does not have much effect on germination. This means that it would be favorable to have sowing depth in the 5–10 cm layer.

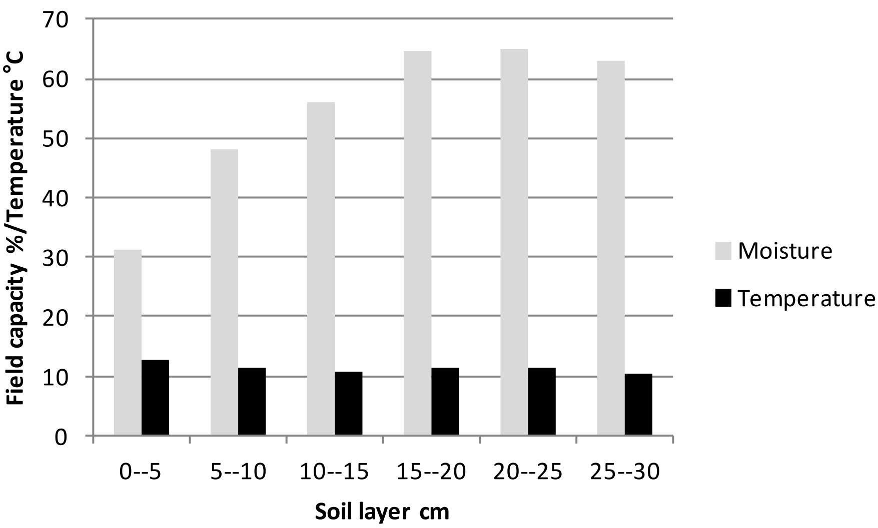

Figure 2. Temperature and moisture profiles of a field before spring tillage.

The soil moisture measurement prototype sensor was calibrated in laboratory with four different soil types and six different moisture contents. It was noticed during the calibration that light soil color (heavy clay) gave a little bit different calibration curve. When compared to gravimetric moisture measurement the sensor had an inaccuracy of 0.1–0.6 percentage point depending on the soil type. For soil moisture measurement during work this is accurate enough to determine the optimum working depth.

The sensor sensitivity to inclined surface and internal deviation were measured before the field tests. The sensitivity tests indicated that the sensor gave higher moisture values for the same sample as the angle of the measured surface increased in relation to the horizon. Measures of dispersion were also affected by the increasing angle; the greater the angle, the greater the variance and standard deviation of the average soil moisture.

The internal deviation of the sensor was determined with three different soil samples by measuring the same sample a longer time. The standard deviation of the sensor reading was depending on the soil type from 0.1 to 0.6 percentage point.

Fig. 3 shows a field measurement with the protoype. At 10 second the sensor is lowered down and the moisture measurement starts. At 50 seconds the fastening of the coulter has loosened and the coulter has turned to a new position and soil aggregates have started to fall in to the furrow causing errors in the reading. The sensor worked reliably during the testing. It gave the soil moisture content in sufficient accuracy for harrowing and drilling. This was controlled on the field with comparative moisture measurements.

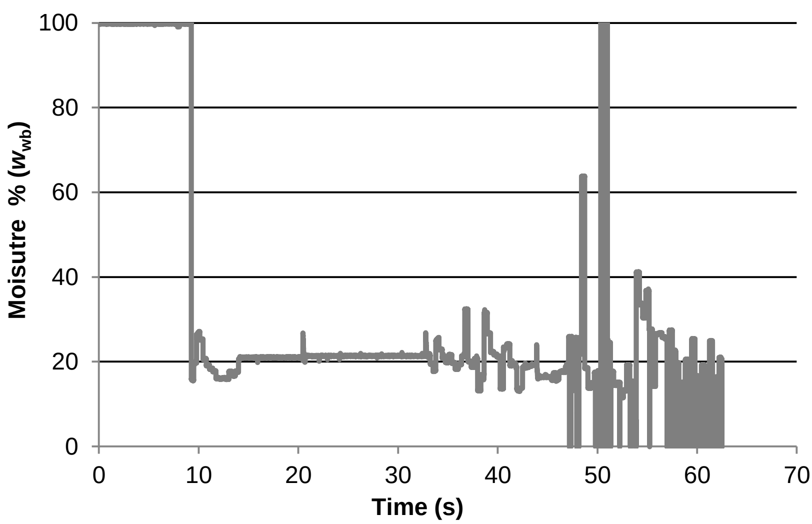

Figure 3. Soil moisture measurement with IRMA sensor.

The prototype was meant for only to study the suitability of the measurement principle. For harrowing and drilling work a smaller sensor with proper coulter and attachment is needed.

CONCLUSION

The top layer of the field during spring work can be too dry for proper germination. It is then profitable to use a deeper harrowing or sowing depth in these cases. The study showed that before spring work the soil moisture profile of the soil was clearly observable and suitable moisture content for germination can be found in deeper layers.

Real time soil moisture measurement could make possible automatic work depth control. The NIR spectroscopy used in this study could be one solution because it is contactless and the sensor is easy to assemble on an implement and it could be easily changed from one implement to another. The sensor used was reliable enough for real time soil moisture measurement. The measurement is however affected by the inclination of the reflecting surface and therefore needs an even surface and for this reason a coulter is needed in front of the sensor. The sensor properties could be improved with a narrower light beam so that the falling soil aggregates would not have interference to the results. The commercial sensor used in the study is mainly used in paper machines. The construction of the sensor should be minimized and improved for implement use.

Different soils types (clay, sandy, organic) have different reflecting properties and the device should be further tested. For instance the reflecting of light is different in dark and light soils.

Harrowing and sowing season could be prolonged with a small impact on yield if the seeds could be sown to advantageous moisture content. This would be also economical because the work capacity and machine sizes could be reduced. Also risk of soil compaction would be less.

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The water content in the engine oil by using E85

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Abstract. The European Union adopted a decision to achieve by 2020 at least 20% reduction in greenhouse gas emissions. To fulfill this task, the EU proposed in 2020 binding targets - further improve energy efficiency by 20%, achieving a 20% share of renewable energy and a 10% share of biofuels in the fuel market. One of the most widely used biofuel in the automotive industry is bioethanol. Bioethanol can be used on low-percentage blending into petrol, which is governed by European Directive 2003/30/EC, and on high-blend bioethanol mixture, particularly E85 consists of 85% bioethanol and 15% petrol BA95. But in recent years, increasingly demonstrating opinions, that biofuels do not produce nearly as much effect as was propagated. This paper deals with the concentration of water in the engine oil with using biofuel E85. The water in the engine oil significantly affects its parameters (especially viscosity). How measurement results demonstrated the use of bioethanol in the fuel increases the concentration of water in the engine oil.

Key words: biofuel, oil, concentration, water.

INTRODUCTION

In recent years the European Union has devoted increasing attention to the possibility of the use of biofuels as an energy source for transportation. The main requirements for biofuel include a requirement to its similarity of chemical and physical properties with conventional fuels.

As the most widely used the reimbursement of fossil fuels, which covers most of the energy consumption in the transport sector, particularly in the automotive industry, is currently biofuel E85.

Fuel E85 is a type of biofuel which has a characteristic mixture. E85 consists of 85% ethanol and 15% BA95. This ratio is possible under various seasonal of conditions to change, but a minimum proportion of ethanol have to be 70% (G7–pohonné hmoty, 2014).

Several studies have examined the effects and emissions of different concentrations of ethanol in the fuel mixture FFV (Flexi Fuel Vehicle) gasoline engines, which significantly differed. Concentrations were mixed in proportions under the names E5 (5% ethanol–i.e. winter mixture), E85 (85% ethanol–called. summer mixture), E75 (75% ethanol–i.e. winter mixture), (Graham et al., 2008; De Melo et al., 2011; Cordeilo de Melo et al., 2012; Karavalakis et al., 2012; Clairotte et al., 2013; Environmental Protection Agency, 2014).

Biofuel E85 is most used In Europe, concretely in Sweden, where it operates more than 16,000 vehicles FFV (Flexi Fuel Vehicle–Motor to which it is possible to refuel BA95 and also biofuel E85). Automobiles brand The Saab with FFV engines are manufactured since 2000 and the number of filling stations with E85 is higher than 250th (West et al., 2007; Flexcar, 2008–2012).

The raw material for the production of E85 may be any biomass lignocellulose–containing e.g. wood, sawdust or waste in the production of pulp and paper (IP Dsignation).

The target of this paper is detection of water concentration in engine oil with using biofuel E85. The values E85 were compared with values of engine oil with using fossil fuel BA95. Measurements were performed on the cars of brand Saab 95, concretely the engines B235, 2.3 liter Turbo. From each car were taken a total of 7 samples of oil. The first part of the samples was from a car driven by biofuel E85 and the second part from engine operating on fossil fuel BA95. The cars rode in urban traffic with the few days to week parking.

MATERIALS AND METHODS

One of the basic parameters of quality oils in terms of tribotechnology is water content. For water determination was proposed many physical, chemical and physic-chemical methods. In the area of tribotechnical diagnostics but most commonly used method of coulometric titration (IP Dsignation) shown in (Fig. 1).

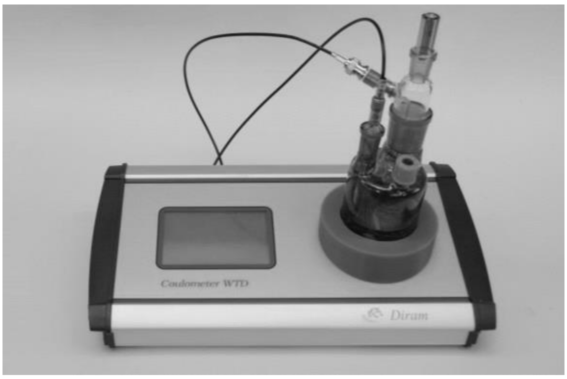

Figure 1. Coulometer WDT (Diram).

This is a design of fully automated apparatus with using coulometry. The passage of flow of electrochemical container on the platinum anode is formed from present iodine the elemental iodide which is the titrant agent. Its amount is proportional pass charge, i.e. the integral of current over time. The unit charge is the coulomb, which is formed a current of one ampere for one second. A simple relationship according to Faraday's law of electrolysis can be express amount of substance analyzing of compound, in this case water (Podhajecky, 2011).

Basic parameters of measurements such as the current of indicator circuit, end point of titration, timing of start, time of extraction or times of distillation, the stirring speed and others, can be set through a touch screen or with help of computer connected via a USB interface. On the display and on the computer is then depicted the progress of the titration and results measuring of water concentration (Diram), as shown on (Fig. 2).

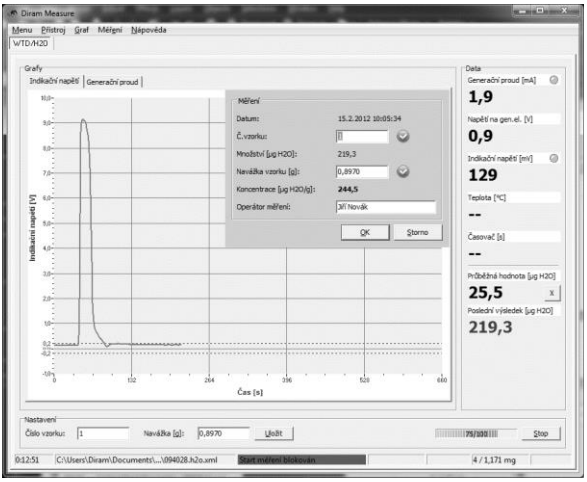

Figure 2. The course of titration (Diram).

Into titration flask of coulometric apparatus Karl Fischer is injected weighed sample. In the collecting flask is formed on the anode the coulometric iodine for the reaction Karl Fischer. After titration of the all water is detected the excess of iodine with electromotive detector of ends of titrations and the titration is terminated. On the base of stoichiometry one mole of iodine reacts with one mol of water, and therefore Faraday's law says that the amount of water is directly proportional to the total integrated current. The result of measurement is always the total quantity of water in the sample in micrograms (Torbacke et al., 2014).

The calculation of the water content using a coulometer WTD is represented of relationship (1).

$$C_s = \frac{m_2}{m_1 \cdot 10^4} \qquad (1)$$

where: C_s – water content of the sample (μg g^{-1}); m_1 – mass of the test sample in grams (g); m_2 – water weight, expressed on a titrator apparatus, expressed in micrograms (μ g) (CSN EN ISO 15489, 2008).

RESULTS AND DISCUSSION

To monitor of state the oil was selected vehicles which have a similar mode of ride. Especially such vehicles, where time is often interspersed with longer driving time without traffic load, which is a standard family vehicle with weekend traffic. Due to the function of the internal combustion engine it is not possible to completely prevent contact of engine oil with air humidity. The humidity then may cause a number of problems under unfavorable operating modes of the internal combustion engine, between which the faster impairment of the properties of motor oil. Current values of the water in the engine oil varies at internal combustion engines of road vehicles in to 0.2%, and do not cause major problems. When the amount of water in the oil approaching 0.5%, so it no longer indicates improper operation, and when the value of 1–2% is already a defect, especially leak in the cooling system of the internal combustion engine. Measured values of water concentration when using fossil fuels BA95 and biofuels E85, the percentage differences in the concentration of water of new oil are listed in (Table 1). From the values it is clear that when using fuel BA95 concentration of water in the engine oil is below 0.2%, whereas E85 is already approaching 0.5%, which corresponds to the improper operation of the combustion engine. Water content of new oil was needed to be measured only one time, before adding it to engine.

Table 1. The concentration of water in use of fossil fuel BA95, biofuel E85 compared with the concentration of water of new oil

Time of operating	Water concentration BA95	Water concentration E85	% difference BA95 to new oil	% difference E85 to new oil
Concentration before adding oil to engine	1,357 $\mu g\ g^{-1}$		0%	
34 km	1,295 $\mu g\ g^{-1}$	1,449 $\mu g\ g^{-1}$	4.6%	**6.8%**
2,000 km	1,314 $\mu g\ g^{-1}$	2,334 $\mu g\ g^{-1}$	3.2%	**72.0%**
4,000 km	1,336 $\mu g\ g^{-1}$	1,503 $\mu g\ g^{-1}$	1.5%	**10.8%**
6,000 km	1,373 $\mu g\ g^{-1}$	2,028 $\mu g\ g^{-1}$	**1.2%**	**49.4%**
8,000 km	1,363 $\mu g\ g^{-1}$	3,241 $\mu g\ g^{-1}$	**0.4%**	**138.8%**
10,000 km	1,379 $\mu g\ g^{-1}$	2,419 $\mu g\ g^{-1}$	**1.6%**	**78.3%**
12,000 km	1,397 $\mu g\ g^{-1}$	3,601 $\mu g\ g^{-1}$	**2.9%**	**165.4%**

From (Table 1) it is evident that when using fossil fuel BA95 the concentration of water was in the engine oil in order to comparing the concentration of the new engine oil. In three instances during the time of operation 34, 2,000, and 4,000 km was measured at lower water concentrations as compared to the new engine oil. In other times of operation, traffic concentration was approximately at the same level as the new engine oil, level concentrate was not changed by more than 3%. The values of the concentration of water using fossil fuels BA95, it is possible to say that reaching a normal level, which does not affect the trouble-free operation of this petrol engine. A different situation occurred when using biofuel E85. The water concentration in this biofuel was at time of operation 12,000 km about 2.5 times higher than the concentration of water with new engine oil. Higher water concentrations above 30% was noted already at the time of operation of 2,000 km, where the difference in water concentration E85 and new oil was 72%. This jump occurred due to a 14–day break between journeys. Another value of the concentration of water decreased as it was partially evaporated, then the car again stood for several weeks and the concentration of the water continues to increase.

The cause high concentrations of water for biofuel E85 is its hygroscopicity in combination with prolonged standing of petrol engine. The longer stall of the engine was, the higher the concentration of water which due to its mode of operation already wasn't evaporated. Liquid water is then accumulated in the engine oil, which was vigorously stirred, and created the emulsions of water in oil, which is deposited on the cap of the oil pan. The concentration of water depending on the time of operating of the engine oil, using fossil fuel BA95 and biofuel E85 is shown in (Fig. 3).

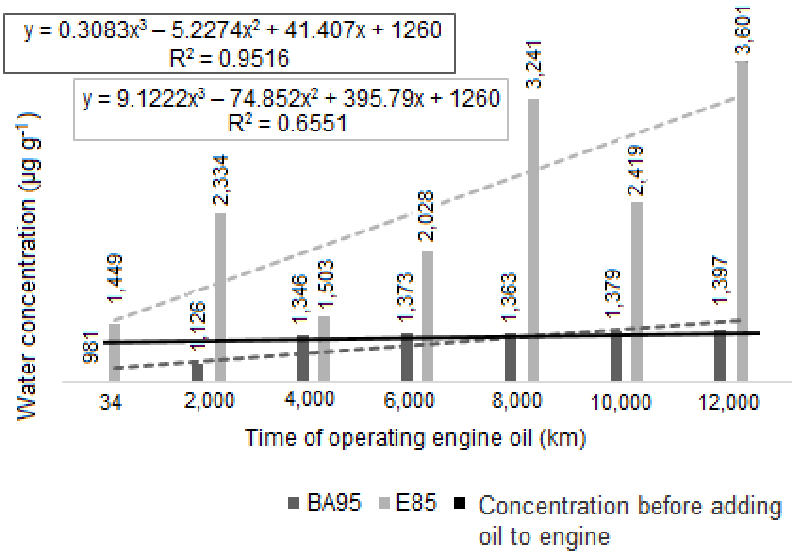

Figure 3. The concentration of water in the engine oil when using fossil fuels BA 95 and biofuels E85.

CONCLUSIONS

The presence of water in the oil is a reversible phenomenon. Water can, if it is not too much in the oil due to a malfunction, re-evaporate in the longer run the warmed up engine. Nevertheless, water in oil and after evaporation leaves traces. At a time when the oil was in contact with excess water, there may be some reactions that may change additivities oil. Water may cause e.g. precipitation of certain additives in the form of sediments or sludge or hydrolysis and impairment of other additives (typical of detergents).

From Analyses of water concentration when using biofuels implies that the engine oil is constantly exposed of effect water. This phenomenon is due to hygroscopicity biofuel E85 and irregular operation with long parking time.

In comparison to commonly using of fuel BA95 with biofuel E85 occurred in engine oil of ignition internal combustion after driving 12,000 km an increase in water concentration. The amount of water in the motor oil was up to 2.5 times higher when using E85 than when using fuel BA95 and the same driving mode.

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Papers must be in English (British spelling). English will be revised by a proofreader, but authors are strongly urged to have their manuscripts reviewed linguistically prior to submission. Contributions should be sent electronically. Papers are considered by referees before acceptance. The manuscript should follow the instructions below.

Structure: Title, Authors (initials & surname; an asterisk indicates the corresponding author), Authors' affiliation with postal address (each on a separate line) and e-mail of the corresponding author, Abstract (up to 250 words), Key words (not repeating words in the title), Introduction, Materials and methods, Results and discussion, Conclusions, Acknowledgements (optional), References.

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- Use preferably the latest version of **Microsoft Word**, doc., docx. format.
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- Use single line spacing and justify the text. Do not use page numbering. Use indent 0.8 cm (do not use tab or spaces instead).
- Use font Times New Roman, point size for the title of article **14 (Bold)**, author's names 12, core text 11; Abstract, Key words, Acknowledgements, References, tables and figure captions 10.
- Use *italics* for Latin biological names, mathematical variables and statistical terms.
- Use single ('…') instead of double quotation marks ("…").

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- All tables must be referred to in the text (Table 1; Tables 1, 3; Tables 2–3).
- Use font Times New Roman, regular, 10 pt. Insert tables by Word's 'Insert' menu.
- Do not use vertical lines as dividers; only horizontal lines (1/2 pt) are allowed. Primary column and row headings should start with an initial capital.

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- All figures must be referred to in the text (Fig. 1; Fig. 1 A; Figs 1, 3; Figs 1–3). Use only black and white or greyscale for figures. Avoid 3D charts, background shading, gridlines and excessive symbols. Use font **Arial** within the figures. Make sure that thickness of the lines is greater than 0.3 pt.
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References

- **Within the text**

In case of two authors, use '&', if more than two authors, provide first author 'et al.':

Smith & Jones (1996); (Smith & Jones, 1996);
Brown et al. (1997); (Brown et al., 1997)

When referring to more than one publication, arrange them by following keys: 1. year of publication (ascending), 2. alphabetical order for the same year of publication:

(Smith & Jones, 1996; Brown et al., 1997; Adams, 1998; Smith, 1998)

- **For whole books**

Name(s) and initials of the author(s). Year of publication. *Title of the book* (*in italics*). Publisher, place of publication, number of pages.

Shiyatov, S.G. 1986. *Dendrochronology of the upper timberline in the Urals*. Nauka, Moscow, 350 pp. (in Russian).

- **For articles in a journal**

Name(s) and initials of the author(s). Year of publication. Title of the article. *Abbreviated journal title* (*in italic*) volume (in bold), page numbers.

Titles of papers published in languages other than English, German, French, Italian, Spanish, and Portuguese should be replaced by an English translation, with an explanatory note at the end, e.g., (in Russian, English abstr.).

Karube, I. & Tamiyra, M.Y. 1987. Biosensors for environmental control. *Pure Appl. Chem.* **59**, 545–554.

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- **For articles in collections:**

Name(s) and initials of the author(s). Year of publication. Title of the article. Name(s) and initials of the editor(s) (preceded by In:) *Title of the collection (in italics)*, publisher, place of publication, page numbers.

Yurtsev, B.A., Tolmachev, A.I. & Rebristaya, O.V. 1978. The floristic delimitation and subdivisions of the Arctic. In: Yurtsev, B. A. (ed.) *The Arctic Floristic Region*. Nauka, Leningrad, pp. 9–104 (in Russian).

- **For conference proceedings:**

Name(s) and initials of the author(s). Year of publication. Name(s) and initials of the editor(s) (preceded by In:) *Proceedings name (in italics)*, publisher, place of publishing, page numbers.

Ritchie, M.E. & Olff, H. 1999. Herbivore diversity and plant dynamics: compensatory and additive effects. In: Olff, H., Brown, V.K. & Drent R.H. (eds) *Herbivores between plants and predators. Proc. Int. Conf. The 38th Symposium of the British Ecological Society*, Blackwell Science, Oxford, UK, pp. 175–204.

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- Use '.' (not ',') for decimal point: 0.6 ± 0.2; Use ',' for thousands – 1,230.4;
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