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ISSN 1406-894X

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Supply of wood as environmental enrichment material to post-weaning piglets

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Abstract. Slatted flooring is a common system used for post-weaning of piglets. In this condition of breeding, it is very hard to provide materials for environmental enrichment to enable proper investigation and manipulation activities to improve animal welfare.
The research aimed to identify an alternative way to provide natural environmental enrichment during post-weaning on slatted flooring using wood. Core of veneer poplar logs and wood sawdust pressed briquettes were selected among other types of wood thanks to their wide availability and low cost. Moreover, these kinds of wood can be used without compromising the health of the animals, neither by contact nor by ingestion.
The most important step of the research was to design systems to make the wood more attractive for piglets. The developed devices consisted of a fixed structural component to be installed inside the pen to which wood materials could be added and replaced quite effortlessly.
Three devices were developed: a) horizontal system, b) vertical system, c) pendulum system. They were tested in three different pens, each one with 24 post-weaning piglets.
The results confirmed the assumption that there is a relation between the level of activity of the animals and the interaction with the wood proposed in the shape of small logs and briquettes. In particular the device a) can generate a valuable level of interaction of the animals reared inside the pen, especially in the first 10 days post-weaning, which is the most sensitive period for piglets after mixing.

Key words: Slatted flooring, piglets, welfare, environmental enrichment, wood, briquettes, poplar logs.

INTRODUCTION

Since many years, the negative effects of mixing unfamiliar piglets in post-weaning barren environment are well known (Meese & Ewbank, 1973). More recent studies (Li & Wang, 2001; Paratt et al., 2006) confirm that this problem is far from being solved. Merlot et al. (2004) described the behavioural, endocrine and immune consequences on animal welfare, but despite the economic impact, this operation is almost inevitable in modern commercial system (Hillmann et al., 2003).

In the past, the best practices to alleviate the complications of mixing piglets were at the discretion of the individual farmers and local controllers, possibly assisted by instruments for monitoring the pig welfare (Barbari et al., 2008; Gastaldo et al., 2014). With the introduction of the Directive 1991/629/EC, followed by Directives 2001/93/EC and 2008/120/EC (2009) of the European Union, some measures to improve the welfare of pigs have become mandatory. Concerning the environmental enrichment, the law provides that the pigs must have permanent access to a sufficient quantity of material to enable proper investigation and manipulation activities, such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of them, not compromising the health of the animals.

The impact of some of these materials on the behaviour of pigs has already been studied (Jensen & Pedersen, 2008). The involvement of straw has been particularly investigated (Scott et al., 2006; Van de Weerd et al., 2006; Bulens et al., 2016), but also the use of other materials has been object of researches, such as mushrooms (Beattie et al., 2001), roughages (Olsen, 2001) or even wood chips (Jensen & Pedersen, 2010). However, none of the above-said materials offered directly to the animals in the pen is suitable for slatted flooring (Telkänranta et al., 2014), that is a very common solution of farm paving. Straw and other materials tend to slide into the slots and clog the cleaning system. Therefore, in these farms it is necessary to introduce material for environmental enrichment in different form, with large volume and strong texture. Wood is the natural material that is suitable for this employment, versatile and easy to work. Nowicki et al. (2007a) obtained positive results by offering a fixed wooden ball, also in aromatized version, to newly mixed weaner pigs. In a recent study Nannoni et al. (2016), analysing the effectiveness of the enrichments in terms of animal behaviour, cortisol from bristles, hematologic and hematic profiles, cutaneous (skin and tail) lesions, stated that hanging chains can provide a sufficient environmental enrichment for undocked piglets, even when compared to more attractive enrichments (e.g. an edible block).

About the position of the enrichment devices in the pen, if free toys lay on the floor, they can be soiled by faecal material and can be pushed under the trough or into neighbouring pens. Grandin (1989) found that when objects offered to pigs became dirty with excreta, the pigs lost interest in them.

Post-weaning enrichment can also affect behaviour by more indirect ways such as a reduction of stress or by providing distraction (Oostindjer et al., 2011). Piglets may be less motivated to show aggression to establish a rank order directly after weaning if the enrichment is enough interesting, resulting in lower levels and perhaps different types of aggression (Melotti et al., 2011). Enrichment of the post-weaning environment seems important in improving performance and health of newly weaned pigs (Oostindjer et al., 2011).

The research aimed to identify a proper way to provide natural environmental enrichment during post-weaning on slatted flooring using wood. Therefore, in this study systems utilizing wood were designed to be fixed in the pen.

MATERIALS AND METHODS

Development of devices

In order to select the best types of wood for the purpose of research, many available species were catalogued according to their features. Afterwards, the toxic species and those with thorns and spines that can hurt the animals were excluded. In addition, species that require substantial pesticide treatments during their life cycle were kept out. The selection was completed considering also the parameter of the cost. As result, core of veneer poplar logs and wood sawdust pressed briquettes were selected among all possible types (Fig. 1). Moreover, these two materials are the most suitable for chewing.

The main characteristics of the materials used in the trials were: cylindrical shape, diameter 8 cm, length 25 cm. The mass of a volume unit (humidity 12%) was 636 kg m^{-3} for core of veneer poplar logs, 360 kg m^{-3} for wood sawdust pressed briquettes.

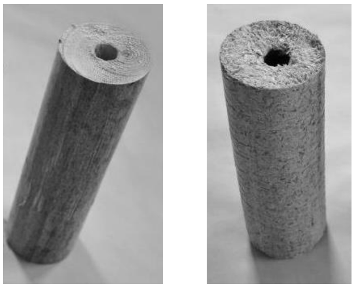

Figure 1. Selected types of wood (left: core of veneer poplar log; right: wood sawdust pressed briquette).

The design process took into account both the point of view of the animal and of the farmer. Therefore, the characteristics of piglets in post-weaning phase were evaluated: weight, height, inclination degree of the head, starting point of the exploration, etc. The devices were designed to allow the animals to manipulate the material with their legs, but especially with the snout. The wood was linked to the device leaving the possibility to move it in one or more directions.

On the other side, the systems were planned to require less labour possible once installed. For that reason, the piece of wood to be inserted in the device had to be standardized (Fig. 1) in order to reduce the effort of replacing it. Three devices were developed. In relation to the position given in the pen, the systems were called: a) horizontal, b) vertical, c) pendulum (Fig. 2).

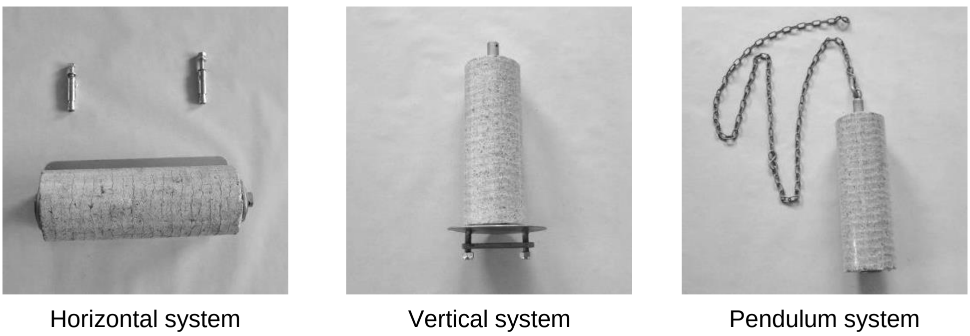

Figure 2. Devices to place in the pens in three different ways.

Test

A trial was arranged to test two hypotheses. The first one was that the three developed devices generate a different level of interaction by the piglets. The second one was that at least one of the system of environmental enrichment causes a clear interaction by animals when active, in order to state that piglets welcome wood proposed in form of small logs or briquettes. An analysis to evaluate a preference between the core of veneer poplar logs and the wood sawdust briquettes did not take place. Thanks to previous experiences, the two kinds of material were considered similar for the animals and were replaced during the test period only for an assessment of their condition at the end of the trial.

The test involved 72 post-weaning piglets divided into 3 pens with hard plastic slatted flooring, as in a typical commercial farm. Only one system of environmental enrichment was installed inside each pen (Fig. 3). The animals were a crossbreed Duroc x Large White. The piglets entered in the pens at the time of mixing after weaning at 28 days of age. Mixing criteria were the same for each group. The animals were fed ad libitum; temperature and light inside the house were automatically regulated.

Figure 3. Devices placed in experimental pens.

Video recordings were made with infrared CCTV cameras. Three cameras were installed on the roof in order to have a detailed vision of each pen. All the 20 days of the trial were considered for the data analysis examining the hours from 05.00.00 to 17.59.59. The behaviour of the pigs was continuously monitored during the entire period of the trials.

In the count, all animals not sleeping were considered active. Among active animals, the ones touching the piece of wood were considered in interaction with it. The average and maximum number of active piglets, and the average and maximum number of piglets busy with the device were detected per each hour and per each device. These values were put into relationship to compute the average and the maximum hourly level of interaction of the animals. Then the daily averages of the two values were derived per each system. One-way ANOVA was performed to assess difference in the level of piglets interaction generated by different devices. Then, a linear regression analysis was performed to study the relationship between the total number of piglets active and the piglets busy with the most attracting device.

RESULTS AND DISCUSSION

Different levels of interaction were recorded for the three devices installed in the pens. In Fig. 4 the comparison between the daily average levels of interaction is reported. The horizontal system caught the highest level of interest among animals ($P < 0.005$). Fig. 5 shows a similar trend for the daily maximum levels of interaction. The study confirms the results obtained by Blackshaw et al. (1997), which found that fixed toys may stimulate more play behaviour than free toys if they are held in one position above the pen floor at weaning pig eye level and swing freely.

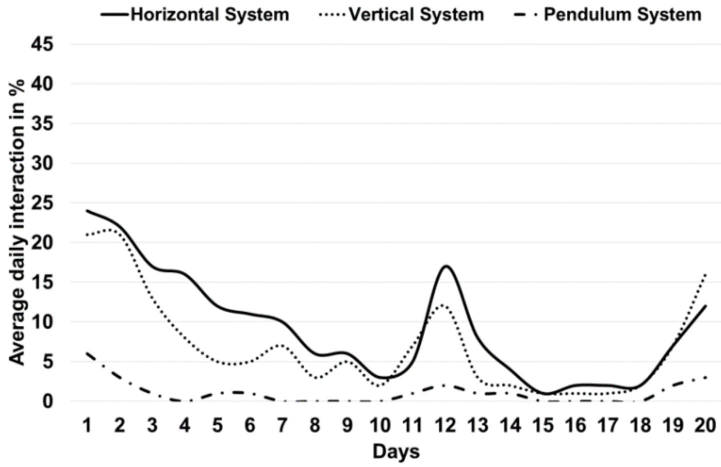

Figure 4. Comparison among systems on average daily interaction.

During some days, more than 40% of active animals played with the system at the same time. It happened in the early days after mixing, which are the most critical because in that period the major cases of aggression occur in order to create a hierarchy. However, there are some other peaks of interaction, particularly evident in Fig. 5. The explanation is that, during those days, the pieces of wood were replaced and piglets were disturbed by human intervention, causing an increase of activity on the animals and also a renewed interest towards the clean materials.

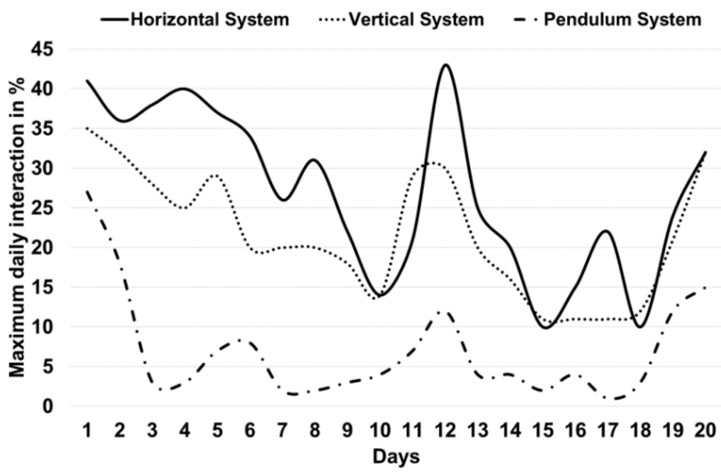

Figure 5. Comparison among systems on maximum daily interaction.

Once established that the device giving the greatest interaction by the piglets was the horizontal one, data related to this system were used to analyse more specifically the correlation between the activity of the animals and the contact with the object. Fig. 6 shows the tendency of interaction in relation to the activity level of the piglets in the pen. The two variables follow a similar trend, most evident in the early days, less in the last ones. The replacement of the material strengthens the interaction, but after that, there are sharp decreases in the lines, stronger than in the initial phase.

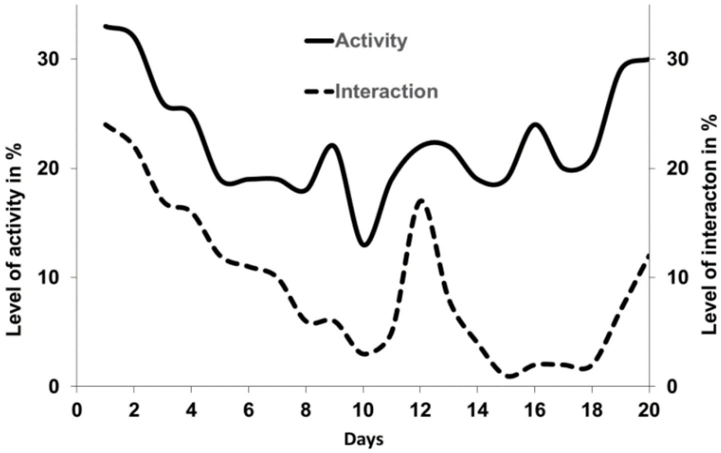

Figure 6. Trend of piglets activity and interaction with horizontal system.

To better analyse the relation, the data of the horizontal system were divided into two groups: the first 10 days and the second 10 days. Fig. 7 concerns the first 10 days and shows the number of animals active during the examined period and the average number of animals using the device at the same time, plotted against each other. In Fig. 8, the data chart of the last 10 days is shown.

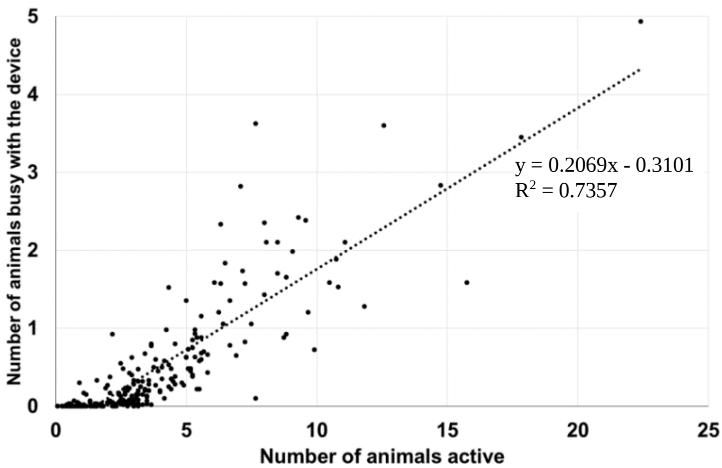

Figure 7. Comparison between hourly average activity and interaction with horizontal system in the first 10 days after weaning.

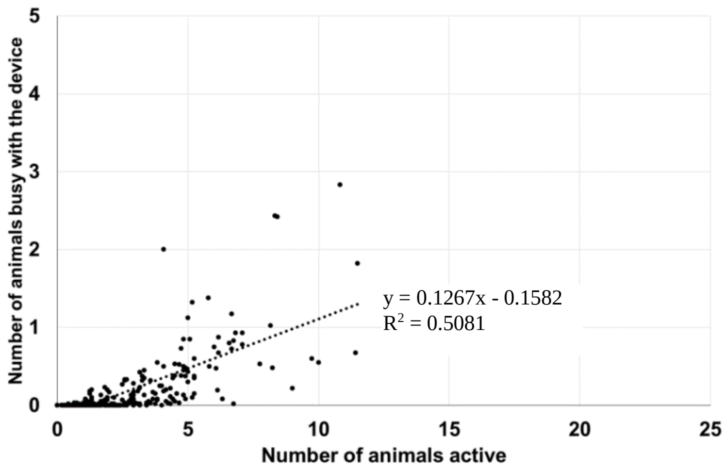

Figure 8. Comparison between hourly average activity and interaction with horizontal system in the last 10 days of weaning phase.

The linear regression lines of the two groups of data are very different. In the first 10 days, y = 0.20x (R^2 = 0.73), which means that in this period on average 20% of the active animals play with the horizontal system and there is a good correlation between the level of activity and the level of interaction. In the second 10 days, y = 0.12 (R^2 = 0.50), which means there is a fall to 12% in the average use of the device with a poorer correlation between the activity and the interaction.

As far as the other systems, vertical one showed to be a valuable device of environmental enrichment. Notwithstanding, there were some problems, especially during the first days. The presence of a stationary object in the middle of the pen with a large number of animals moving provoked some injuries. The pendulum system, instead, despite its poor performance could be considered a suitable system, but it needs to be improved in order to generate higher interest in piglets.

A last consideration concerns the difference between the two materials used during the test. In previous experiment with older animals, the wood sawdust pressed briquettes did not survive the first day because pigs ate them. Vice versa, during the trials in the post-weaning phase, the sawdust pressed briquettes proved to be durable as the poplar logs.

In conclusion, the results of the trials confirm the statements of Nowicki et al. (2007b). The possibility of chewing the material, till destruction, makes a device for pigs more attractive, shortening the time of agonistic behaviour and helping to establish the social hierarchy earlier.

CONCLUSIONS

The study confirms that wood in form of small logs and briquettes can generate an exploratory behaviour in post-weaning piglets. A reasonable level of proper investigation and manipulation activities has reached in the pen with slatted floor. However, the result greatly depends on how the materiel is proposed.

The horizontal system seems to be the most efficient way to stimulate the willingness to play of the piglets. In spite of this, the exploratory behaviour is decreasing, especially after 10 days, and the trend cannot be changed even replacing the consumed material with a new one.

Further studies can be useful to confirm if wood proposed in such form has a direct impact in reducing aggression after mixing. Besides, it would be interesting to compare pig behaviour and preferences for the device placed in different positions of the pen. In the meantime, the level of interaction reached by these systems can be considered a good indicator of the capacity of the devices to be a suitable way to propose wood as environmental enrichment for post-weaning pigs in farms with slatted flooring.

ACKNOWLEDGEMENTS. This work was supported by Progetto AGER, grant n. 2011–0280.

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Agronomy Research **15**(2), 322–328, 2017

Agricultural vs forest biomass: production efficiency and future trends in Polish conditions

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Abstract. Biomass is one of the main sources of renewable energy with rapidly growing trend in the European Union countries. The technical potential of biomass energy in Poland is one of the highest in Europe, estimated at approximately 900 PJ/year. Solid biomass is the primary Polish RES and the share in the structure of production in Poland amounted to almost 77% in 2015. The most common types of biomass are waste raw materials from crop fields and forests.
The paper presents current potential of the biomass of two basic types, i.e. agricultural and forest material, based on the analyses developed with the scenario forecast of future use in Poland. Detailed considerations include differences in efficiency of agricultural and forest biomass production. To develop the efficiency aspects some indices were proposed to compare potential of energy production basing on different kind of biological material.

Key words: solid biomass, renewable energy, energy efficiency.

INTRODUCTION

The objective of this article is to show future potential of energy usage of the most common types of biomass available in Poland: agricultural and forestry wood wastes.

According to statistic data, energetic potential of agricultural waste in Poland is 10^7 tons annually[1] only from straw (cereal straw understand as stalks of threshed grain, especially of wheat, rye, oats, or barley) which could covers approximately 4% of country primary energy demand.

Apart from straw, wood wastes coming from the forestry production[2] and the wood industry determined types of energy sources that comprise woodchip and the smallest fractions of wood that usually being used in the form of briquettes or pellets.

On account of the minimum price and the greater availability, the most common used biomass in energy power plants in Poland is the one of forest origin. Taking into consideration the contribution of forestry biomass and remaining types of biomass, consuming wood wastes constitutes about 70% of the total volume. Consumption per input of energy transformations in 2015 accounted for 34.29% of national consumption,

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[1] Total mass after harvesting.

[2] Defined as any material wastes from forestry, logging, timber trade, and the production of forest products, timber/lumber and primary forest.

with 86.77% of the consumption falls on power plants and power generation plants (ARE, 2015).

The pie chart (Fig. 1) compares the share of biomass consumption in Polish energy sector. The largest share occurs to forest biomass which increases to over 49%. The smallest part, has a biomass energy crops, which results from a small area of plantations in Poland. In the coming years, there may be an increase in the consumption of this type of biomass, but it will be up to a few percent.

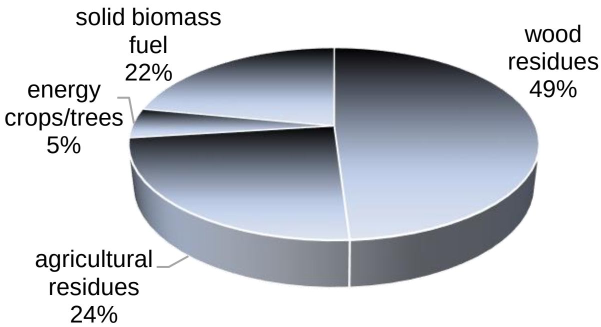

Figure 1. The structure of average biomass consumption in Polish energy sector (ARE, 2015).

The main features of biomass are as following (Strzelczyk & Wawszczak, 2008):

– modulus and respective deformations;
– the low calorific value – ranges: 6 MJ kg^{-1} (waste), 15–16 MJ kg^{-1} (wood chips, straw), 18 MJ kg^{-1} (pellet);
– high moisture content in the raw biomass (45–60%) strongly reduces its calorific value, and negatively affects the efficiency of the combustion process.

The main determinant of calorific value for every types of biomass is humidity which in case of fresh straw varies between 12–22% and for fresh woodchips 50–60% (Table 1).

Table 1. Selected properties comparison – straw and woodchips

Parameter	Unit	Straw	Woodchips
Humidity contain	wt%	20	40
Ash contain	DM	3–4	0.6–1.5
Carbon contain	wt%	42–43	50
Flue dust	wt%	70–73	70
Gross calorific value	MJ kg^{-1}	15.4–16	10.4
Net calorific value		18.2–18.7	19.4

Source: Hołubowicz-Kliza, 2007.

Recent changes in national legislation, which could serve was observed in the years 2014–2015 in the field of renewable energy sources (RES), environmental protection and waste management, provide problem of new opportunities of biomass management and possibilities for energy plant development. Responsibilities of the state to maintain the growth of the share in use of energy from renewable sources in the primary energy consumption does not allow only the actions of market mechanisms.

MATERIALS AND METHODS

The base for all calculation was data about annual crop production in Poland since 2009, for basic types of crops: wheat, rye, barley and triticale (Fig. 2). As it can have been seen below (Fig. 2) accumulated value of production fluctuates in time, which generates difficulties in estimation method selection.

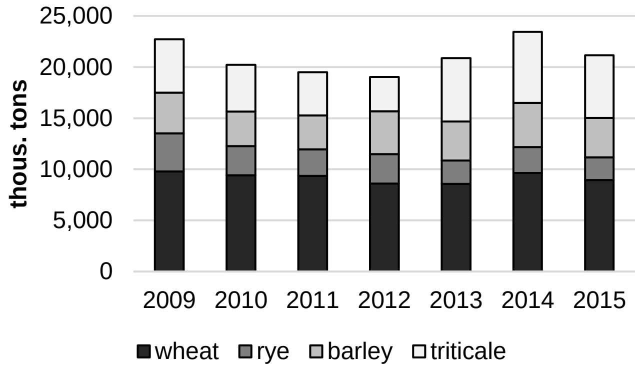

Figure 2. Annual crops production in Poland. (*Source: own elaboration based on (GUS, 2015–2009)*).

Estimation of wheat production was prepared according to crops purchase (Table 2) with three year move using linear regression:

$$Y \approx f(X, \beta) \tag{1}$$

Linear regression calculates an equation that minimizes the distance between the fitted line and all of the data points. The statistical measure of fitted the data to regression line – coefficient of determination R^2 was relatively high amounted to 0.82.

Table 2. Annual value of crops purchase

Year	Wheat	Rye	Barley	Triticale	Total
	Thousand tons				
2009	5,614.1	1,295.4	785.6	705.2	8,400.3
2010	5,603.2	940.6	850.9	777.7	8,172.4
2011	5,674.7	661.7	756.9	516.3	7,609.6
2012	5,689.6	1,004.9	1,046.0	610.5	8,351.0
2013	5,040.0	1,280.3	948.3	681.1	7,949.7
2014	6,805.5	1,101.6	811.6	1,007,2	9,725.9

Source: own elaboration based on (GUS, 2015–2010).

Next step was to carry out the multiple regression with independent variables (Eq. 2), i.e. rye (x_1), barley (x_2), and triticale (x_3) annual production volumes and dependant variable – wheat annual production what give R^2 = 0.80 and equation like below:

$$y = 0.974x_1 + 0.059x_2 + 0.497x_3 \tag{2}$$

Independence of observation was checked using Durbin-Watson statistic test.

All parameters in the study were distributed normally. Data were expressed as mean ± standard deviation. Differences were tested by two-tailed t-test. Pearson's correlation was used to analyse the association between all studied parameters. The values $P < 0.05$ were considered statistically significant.

To evaluate the potential of straw for energy purposes the total amount of harvest straw has to be reduced by its consumption in agriculture (firstly, straw must cover the needs of animal production (litter and feed) and maintain a sustainable balance of soil organic matter (fertilization).

Following formula was used for calculation:

$$N = P - \left(Z_s + Z_p + Z_n\right)[t] \quad (3)$$

where: N – straw surplus for energetic use; P – straw total production; Z_s – demand for bedding; Z_p – demand for litter; Z_n – demand for mulch.

Results of the calculation is shown on Fig. 3 and as it can be seen its quantity varies in the time in relation to total volume as well as single crop's straw type.

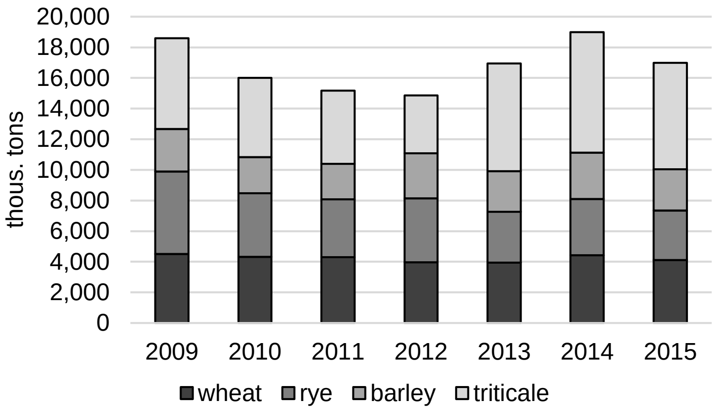

Figure 3. Annual production of crop's straw. (*Source: own elaboration*).

Results of prognosis for forestry biomass was assumed in accordance with (Gołos & Kaliszewski, 2013). To estimate potential amount of wood for energy purposes, data on the share of wood assortments, which formally can be used to produce energy from renewable sources were used by authors. According to the Regulation of the Ministry of Economy of 18 October 2012. (Dz. U. of 2012., Pos. 1229) as a defective wood can be treated as firewood.

To sum up the matter of wood and agricultural wastes energy potential comparison the forecasted volumes was multiply by average calorific value of selected types of biomass used in Polish energy sector (Table 3).

Table 3. Average calorific value of selected types of biomass used in energy sector in 2015

Biomass types	Average calorific value, MJ kg^{-1}
Forestry wastes	9.99
Agricultural wastes	14.51

Source: own elaboration based on (ARE, 2015).

In spite of fact that wood production is less energy intensive than agricultural unitary energy potential cumulated in the first type of biomass is minor.

RESULTS AND DISCUSSION

Results of all calculation are presented below in accordance with the methods presentation.

The outcomes of agricultural wastes forecast are highly possible which confirmation is presented on Fig. 4 that shows coverage of predictions and real values – example for wheat.

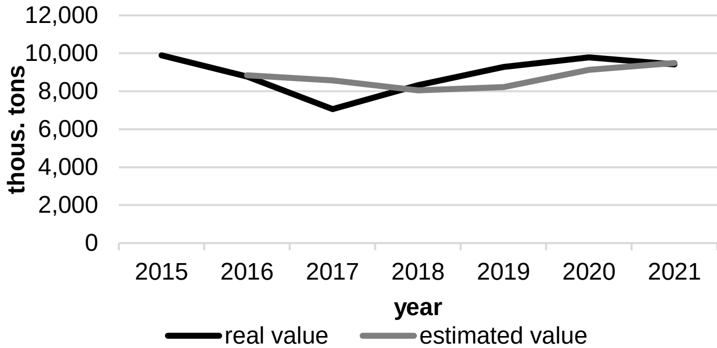

Figure 4. Wheat – results of forecast. (*Source: own elaboration).*

Rotary changes in historic crop production affects results of forecast (Fig. 5). The amount of energy straw production varies between 6,969 thousand tons in 2018 and maximum value 8,035 in 2021.

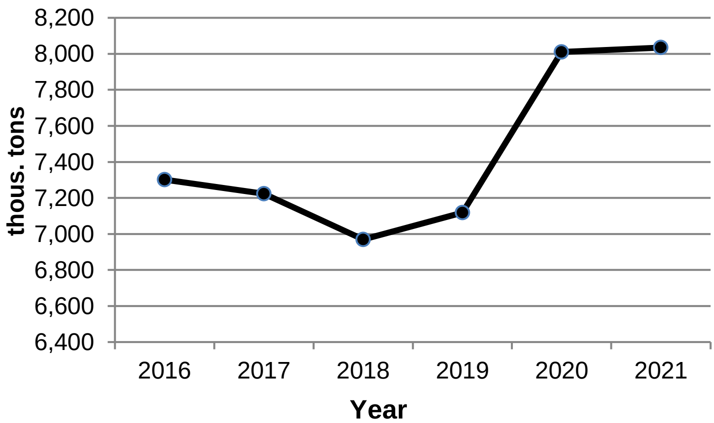

Figure 5. Estimation of energetic straw production. (*Source: own elaboration).*

Presented result of wood wastes forecast (Table 4), which was covered by (Gołos & Kaliszewski, 2013), shows that in 2021 total expected amount of small timber and woodchips is 4.53 million cubic meters.

Table 4. Selected types of forestry biomass used in energy sector in Poland – historic and estimated volumes

Assortment	2011	2021
	m m^3	
Small timber	2.14	2.45
Woodchips	1.82	2.08
Total	3.96	4.53

Source: Gołos & Kaliszewski, 2013.

Comparison of total energy potential calculated for 2021 for wood and agricultural wastes exhibits:
large possibilities for agricultural wastes usage in energy sector because estimated amount is 116.583 PJ,
– poor potential of wood wastes – 27.393 PJ in 2021.

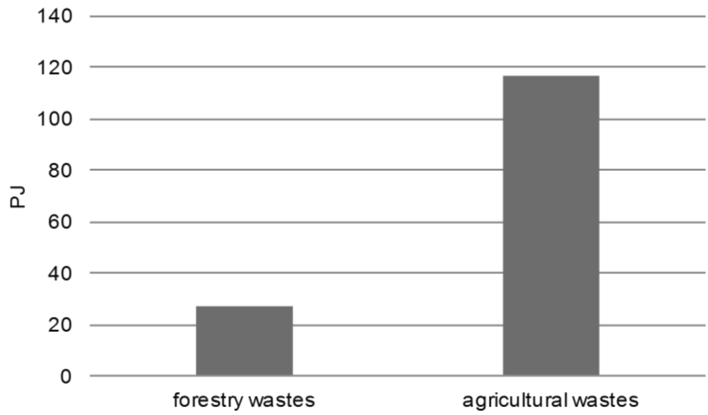

Figure 6. Energetic potential of forestry and agricultural biomass in 2021. (*Source: own elaboration*).

The calculations concerning biomass production as well as energy production coming from the straw show expected values to compare them with energetic potential of forestry biomass. On the other hand, the expected values can be verified in practice by many factors deciding about effectiveness of energy production (Komorowicz et al., 2009). There can be relation of energy content variations of straw to the fraction size, humidity, composition and environmental impact (Kalinauskaitė et al., 2013). Importance of humidity is considered in comparisons on agricultural and forestry biomass in the process of pellets and agri-pellets production (Vlădut et al., 2010). Basing on the results of detailed data it is possible to compare energetic value of many agricultural biomass sources (Niedziółka & Zuchniarz, 2006).

CONCLUSIONS

Comparison of energetic potential of forestry and agricultural biomass show considerable differences in amount of accessible biomass for energy production, so it can be important information concerning future needs in the field of technical operation and management of particular kind of biomass.

Differences in annual amount of produced straw constitute significant data to expect and balance demand and supply in the energy market including some additional sources of energy.

Authors own experience and agriculture market observation allow to draw the conclusion about annual fluctuation in cereal crops production. All the changes in total end-volumes ground on complex agri-economic factors that indicate Polish market.

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Classification of the soils formed in toposequence Kayi and Aydinpinar streams (Tekirdag) and classes of suitability to agricultural uses

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Abstract. The soils formed in the vicinity of Kayı and Aydınpınar streams were investigated in transects formed toposequence splitting vertically towards the coastal line of Thrace region. On the characteristic points of topography formed by the Kayı and Aydınpınar streams, five soil profiles were described, the two on the Oligocene marine deposits, the two on side stream creeks and the one on the alluvial bed representing low land. The morphological, physical and chemical properties of the samples taken from these profiles according to the genetic horizon principle were determined. The classification of these soils formed in the toposequence relationship and their suitability to various plants varieties were determined. The 4th profile in subgroup of Typic Xerofluvent were formed in alluvial land, The 2nd profile in subgroup of Calcic Haploxerept, 1st, 3rd and 5th profiles in subgroup of Typic Haploxerept were classified.
The soil formed in a toposequence is different for suitability of plant cultivation varies. KA1, KA2 and KA5 soils are highly suitable for grass families expect maize and sudan grass while KA3 soil is medium suitable for grass families. KA1 and KA2 soils (expect soybean) are highly suitable, KA3 (expect alfalfa and sainfoin) and KA5 (expect alfalfa) soils are medium suitable and KA4 soil is marginal suitable for legume plants.

Key words: Soil genesis, toposequence, entisols, inceptisols.

INTRODUCTION

One of the prerequisites for the management and planning of agriculture is the use of agricultural lands in accordance with the nature and ability of the land with the sustainable land management theories that must be applied. In this, the definition of the characteristics of the soil, the conditions of soil formation and soil genesis events and the position in the nature should be examined well.

Sharma et al. (1994) studied the physicochemical properties of soil formation on a toposequence in the Indore Region of Malwa Plateau. In the study, the profiles of four soil series named Dakachya, Saral, Baloda and Malikhedi were examined and the effects on morphological characteristics were observed. According to the texture analysis, no definite change was detected by the reduction of the slope or depth. The rate of $CaCO_3$ content increased with decreasing inclination of all profiles. The proportion of organic content was low on the surface, and it decreased with depth.

Integrated Toposequence Analysis (ITA) was used to integrate scientific and local knowledge on land resources and land use systems and to identify factors determining land use and land resource management (Gobin et al., 2000). The application of ITA at different toposequence types resulted in a nested, geo-referenced information system relevant to different decision-making levels, and demonstrated the variation in soils, land cover use and cropping systems between landform complexes macro, unit landforms meso and facets micro at the Nsukka Agricultural Zone southeastern Nigeria by Gobin et al. (2000). The local soil classification was coupled to the World Reference Base for Soil Resources using the results of three toposequences and eight soil profile pits. Despite the overall low soil fertility, distinct differences in cropping systems and cultivation techniques were practiced. Local land use and management decisions were guided by the local soil classification and depended on the position in the landscape, the soil texture, occurrence of ironstone and soil color to tillage depth. The local knowledge provided insights in present management strategies, whereas the scientific information demonstrated the constraints on present land use systems.

In a large stream network system in Thrace Region, a partially flattened peneplain (flattened plain) formed the most important macro-topographic structure. This plain joins the Marmara Sea with its final boundary in the Tekirdag Region, and thus in the study area, with the Oligocene marine sediments forming sea forms. In the meantime, it ensured that the tectonic events take place in a fluctuating position. Kayı and Aydınpınar cores formed their own beds and formed low land with alluvial sedimentary environment in the lower and inclined regions of the wavy land.Different soils are formed as a result of topography in soil formation. The purpose of this study is to identify plants that can be grown in these different soils under the same climatic conditions.

MATERIALS AND METHODS

The toposequence that was formed by Kayi and Aydınpinar in the central district of Tekirdag province was examined. On the toposequence formed by the Kayi and Aydınpinar ridges, five soil profiles were described, two on the Oligocene marine sediments, two on the two side stream mouths and one on the alluvial bed representing low land (Boyraz 2003). Alluvial deposits in the Quaternary split the slopes of the marine forms, especially with the new alluvium sediments in Holocene, the material of KA2 and KA3 in the Aydınpinar side and the material of KA4 in the Kayi side and the tin and the clayey textured material in the side of Kayi. The KA1 and KA5 profiles representing high land were opened around the Oligocene marine formations. The KA1 profile, which is surveyed 130 m high from the sea, represents the highest level of profile. The KA5 profile was examined at a height of 80 m above sea level and at low peneplain level of the sea. The cross-section of the physiographic units with the topographic location of the orientation is clearly visible in Fig. 1.

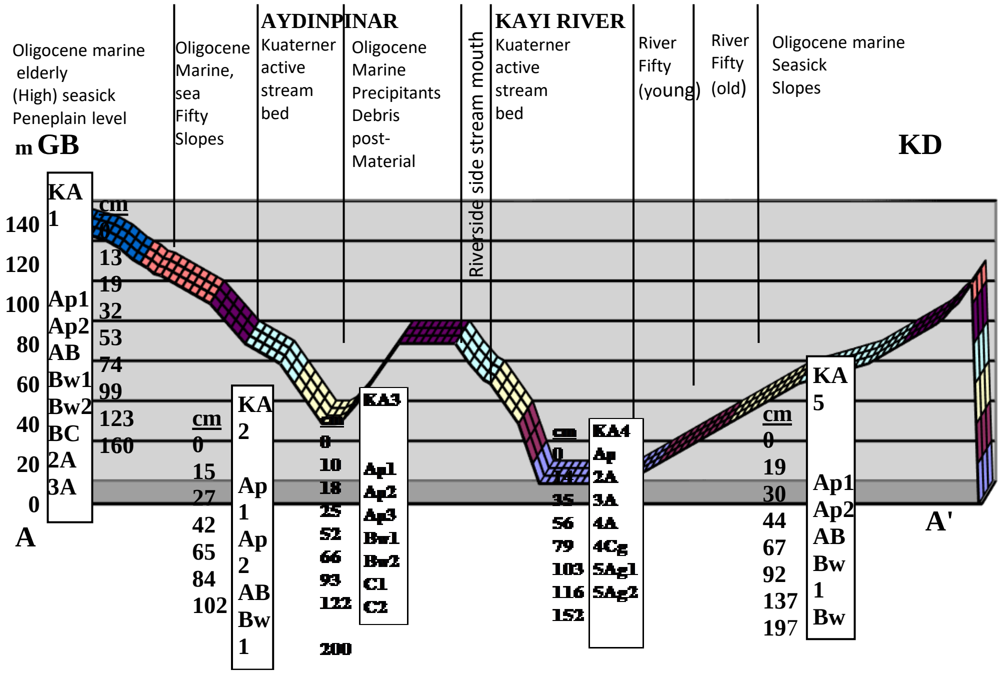

Figure 1. Physiographic location of the study area, Toposequence Dimensional Representation (A-A').

The morphological, physical and chemical properties of the samples taken from these profiles according to the genetic horizon principle were determined. The grain size distribution (texture) was determined according to Soil Survey Staff (1963). Texture triangles are used in the classification of soil textures (Soil Survey Divison Staff, 1993). Content of carbonates was determined by volumetric calcimeter method (Saglam, 2001). The soil reaction (pH) was determined with a glass electrode pH meter in soil suspensions diluted 1/2.5 with water (Jackson, 1958). Bulk density was determined by paraffin method (Schlichting & Blume, 1966). Solid density was found in the degraded soil samples by picnometer method (Black, 1965). Total porosity is calculated according to the method given in Cangir (1991). Hydraulic conductivity is determined according to the method given in Tüzüner (1990). Organic matter quantities were calculated by multiplying the % carbon value obtained by the Smith Weldon method by 1.724 (Saglam, 2001). Total salt ratios were determined by measuring with Wheatstone Bridge conductivity instrument in soil suspensions (Richards, 1954). The cation exchange capacity (CEC) was extracted with ammonium acetate and the Na^{+} content was determined by flame photometry (Sağlam, 2001). Conformity classes of soils to various plants were determined according to Mc Rae et al. (1981), Cangir (1988), Sys et al. (1991a), Sys et al. (1991b), Sys et al. (1993). Soils were classified acoording to Soil Survey Staff (2014).

RESULTS AND DISCUSSION

The slope of the soil studied in the toposequence relationship, altitude above sea level, physiography, the surrounding land shape in the and the main material properties are explained in Table 1. The state of the physiographic position of the land and the approximate location of the profile are illustrated in Fig. 1. Some physical and chemical properties of the soil formed on the topography and the parent material that underlie the influence of the drainage network system under the same climatic conditions in a region are given in Table 2–11. The photographs of profiles are given in Figs 2, 3 & 4.

Table 1. Location of physiographic units of research profiles, shape and main material of surroundings

Profile	Slope (%)	Altitude (m)	Coordinate	Physiography	The shape of the surrounding land	Main material
KA1	2–6	130	27º32’23’’Latitude 40º59’32’’ Longitude	High seasickness	Slightly wavy and wavy	Oligocene marine (marine) calcareous, clay- loam textured sediments.
KA2	2–6	30	27º33’11’’ Latitude 40º59’55’’ Longitude	Quaternary active stream bed side stream mouth	Sloping slope land	Limestone sediments; II. Lithologically interrupted low-limest sandy-tin textured fractals; III. Lithologically intermittent calcareous, diagenesis, locally scattered marno limestone.
KA3	2–6	50	27º33’34’’ Latitude 41º00’14’’ Longitude	Side stream mouth of river stream	Floating land	Pelitic (silt + clay) cemented, non-limestone sandstone
KA4	0–2	10	27º33’48’’ Latitude 41º00’35’’ Longitude	Forms of active stream bed of Kayı stream	Straight-near flat	Alluvial deposits with low calcareous texture, usually clay-loam texture
KA5	2–6	80	27º34’42’’ Latitude 41º00’51’’ Longitude	Seaside slopes	Slightly wavy and wavy	Non-calcined Oligocene marine (marine) sediments in the loam texture

Profile description:

Ap1 0–13 cm. Brown (10 YR 4/4, wet), dull yellowish brown (10 YR 5/4, dry); clay loam; strong, coarse and medium, subangular block structure; very hard, very firm, very sticky and very plastic; few, medium thick and very thin roots; no foaming with dilute HCl solution; precise and slightly wavy boundary.

Ap2 13–19 cm. Brown (10 YR 4/4, wet), dull yellowish brown (10 YR 5/3, dry); clay loam; strong, coarse, subangular block structure; very hard, very firm, very sticky and very plastic; little, medium thick and very thin roots; no foaming with dilute HCl solution; precise and slightly wavy boundary.

AB 19–32 cm. Between dull yellowish brown and brown (10 YR 4/3.5, wet), dull yellowish brown (10 YR 5/4, dry); clay loam; strong, coarse and medium, subangular block structure; extremely hard, very firm, very sticky and very plastic; very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

Table 2. Physical analysis results of profile KA1

Horizon	Depth cm	Bulk density g cm^{-3}	Solid density g cm^{-3}	Total porosity %	Hydraulic conductivity cm h^{-1}	Sand %	Silt %	Clay %	Texture classes
Ap1	0–13	1.75	2.69	34.94	0.5	36.55	31.10	32.35	CL
Ap2	13–19	1.58	2.69	41.26	1.2	38.23	27.00	34.77	CL
AB	19–32	1.61	2.64	39.02	0.6	39.03	30.23	30.74	CL
Bw1	32–53	1.61	2.64	39.02	3.2	40.09	25.84	34.07	CL
Bw2	53–74	1.53	2.68	42.91	2.5	40.42	26.96	32.62	CL
BC	74–99	1.63	2.65	38.49	1.2	42.44	27.00	30.56	CL
2A	99–123	1.62	2.67	39.33	5.7	33.45	34.65	31.90	CL
3A	123–160	1.59	2.66	40.23	0.7	41.34	29.12	29.54	CL

Table 3. Chemical analysis results of profile KA1

Horizon	Depth cm	pH 1/2.5 soil-water	Salt %	Organic matter %	CEC cmol kg^{-1}	$CaCO_3$ %
Ap1	0–13	7.12	0.018	2.17	28.48	0.0
Ap2	13–19	6.97	0.019	1.79	27.34	0.0
AB	19–32	7.28	0.031	1.30	29.08	0.0
Bw1	32–53	7.13	0.021	1.23	27.37	0.0
Bw2	53–74	7.64	0.028	0.94	28.99	0.0
BC	74–99	7.39	0.029	0.34	28.51	0.0
2A	99–123	7.53	0.029	1.48	29.70	0.0
3A	123–160	7.50	0.019	1.75	29.56	0.0

Bw1 32–53 cm. Dull yellowish brown (10 YR 4/3, wet), dull yellowish brown (10 YR 5/3, dry); clay loam; strong, very coarse and coarse, angular block structure; extremely hard, extremely firm, very sticky and very plastic; very, very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

Bw2 53–74 cm. Dull yellowish brown (10 YR 4/3, wet), dull yellowish brown (10 YR 5/4, dry); clay loam; strong, very coarse, angular block structure; extremely hard, extremely firm, very sticky and very plastic; plenty, very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

BC 74–99 cm. Dull yellowish brown (10 YR 4/3, wet), dull yellowish brown (10 YR 5/4, dry); clay loam; medium- strong, very coarse and coarse, angular block structure; very hard, very firm, very sticky and very plastic; few, thin and plenty, very thin roots; no foaming with dilute HCl solution; precise and wavy boundary.

2A 99–123 cm. Between dull yellowish brown and brown (10 YR 4/3.5, wet), dull yellowish brown (10 YR 5/4, dry); clay loam; medium – weak, fine, subangular block structure; hard, firm, very sticky and very plastic; very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

3A 123–160 cm. Dull yellowish brown (10 YR 4/3, wet; 10 YR 5/3, dry); clay loam; weak, medium, subangular block structure; hard, loose, very sticky and very plastic; very, very thin roots; no foaming with dilute HCl solution.

Table 4. Physical analysis results of profile KA2

Horizon	Depth cm	Bulk density g cm^{-3}	Solid density g cm^{-3}	Total porosity %	Hydraulic conductivity cm h^{-1}	Sand %	Silt %	Clay %	Texture classes
Ap1	0–15	1.58	2.69	41.26	3.4	34.54	38.25	27.21	CL–L
Ap2	15–27	1.45	2.71	46.49	4.2	43.02	25.48	31.50	CL
AB	27–42	1.65	2.68	38.43	4.0	40.47	25.68	33.85	CL
Bw1	42–65	1.60	2.66	39.85	1.8	40.45	33.74	25.81	L
Bw2	65–84	1.63	2.70	39.63	2.6	41.43	32.73	25.84	L
BC	84–102	1.58	2.66	40.60	2.0	42.85	33.57	23.58	L
C	102–138	1.70	2.62	35.11	3.4	42.64	31.59	25.77	L
2Cr	138–186	1.98	2.67	25.84	5.8	71.26	21.71	7.03	SL
3C	186–270	1.92	2.71	29.15	0.8	52.01	41.30	6.69	SL
3R	270+	-	-	-	-	-	-	-	-

Table 5. Chemical analysis results of profile KA2

Horizon	Depth cm	pH 1/2.5 soil-water	Salt %	OrganicMatter %	CEC cmol kg^{-1}	$CaCO_3$ %
Ap1	0–15	7.72	0.027	1.51	29.55	10.09
Ap2	15–27	7.68	0.024	1.84	29.98	9.52
AB	27–42	7.73	0.022	1.38	30.85	9.33
Bw1	42–65	7.38	0.021	0.99	28.98	9.24
Bw2	65–84	7.50	0.024	0.92	29.55	9.62
BC	84–102	7.53	0.024	0.77	28.65	10.20
C	102–138	7.56	0.027	0.52	29.55	9.45
2Cr	138–186	7.70	0.020	0.34	10.47	4.43
3C	186–270	7.80	0.018	0.17	9.81	19.63
3R	270+	-	-	-	-	58.08

Profile description:

Ap1 0–15 cm. Yellowish grey (2.5 Y 5/4, wet), dull yellow (2.5 Y 6/4, dry); between clay loam and loam; moderate, coarse, granular and weak, fine, subangular block structure; hard, firm, very sticky and very plastic; medium plenty, thin and very thin roots; medium foaming with dilute HCl solution; precise and wavy boundary.

Ap1 15–27 cm. Yellowish grey (2.5 Y 5/4, wet), dull yellow (2.5 Y 6/4, dry); clay loam; moderate, fine, subangular block structure; very hard, firm, very sticky and very plastic; medium plenty, thin and very thin roots; medium foaming with dilute HCl solution; precise and wavy boundary.

AB 27–42 cm. Yellowish grey (2.5 Y 5/4, wet), dull yellow (2.5 Y 6/4, dry); clay loam; weak- moderate, fine, subangular block structure; slightly hard, loose, very sticky and very plastic; few, thin and very thin roots; medium foaming with dilute HCl solution; precise and wavy boundary.

Bw1 42–65 cm. Olive brown (2.5 Y 4/4, wet), dull yellow (2.5 Y 6/4, dry); loam; strong –moderate, coarse, subangular block structure; hard, firm, very sticky and very plastic; few, thin and very thin roots; medium foaming with dilute HCl solution; smooth and gradual boundary.

Bw2 65–84 cm. Yellowish grey (2.5 Y 5/4, wet), dull yellow (2.5 Y 6/2, dry); loam; strong –moderate, coarse, subangular block structure; hard, firm, very sticky and very plastic; medium plenty, thin roots; medium foaming with dilute HCl solution; precise and wavy boundary.

BC 84–102 cm. Yellowish grey (2.5 Y 5/4, wet), dull yellow (2.5 Y 6/4, dry); loam; moderate, coarse- very coarse, subangular block structure; hard, firm, very sticky and very plastic; medium plenty, thin roots; medium foaming with dilute HCl solution; precise and wavy boundary.

C 102–138 cm. Light yellow (2.5 Y 7/4, wet), yellowish grey (2.5 Y 5/4, dry); loam; massive- moderate, medium- coarse, angular block structure; hard, firm, very sticky and very plastic; few, thin roots; medium foaming with dilute HCl solution; precise and wavy boundary.

2Cr 138–186 cm. Yellowish grey (2.5 Y 5/4, wet), dull yellow (2.5 Y 6/3.5, dry); sandy loam; massive- when they are broken up, they are scattered in the form of square and rectangle prisms of 1–1.5 cm; hard, firm, very sticky and very plastic; medium plenty, thin roots; clear foaming with dilute HCl solution; gradual and wavy boundary.

3C 186–270 cm. Light yellow (5 Y 7/3, wet), olive yellow (5 Y 6/4, dry); sandy loam; massive; soft, very friable, very sticky and very plastic; severe and persistent foaming with dilute HCl solution; gradual and wavy boundary.

3R 270+ cm. Severe and persistent foaming with dilute HCl solution diagenesis site diffracted marno limestone.

a) b)

Figure 2. Overview of the profiles KA1 and KA2: a)Profile KA1; b) Profile KA2.

Table 6. Physical analysis results of profile KA3

Horizon	Depth cm	Bulk density g cm^{-3}	Solid density g cm^{-3}	Total porosity %	Hydraulic conductivity cm h^{-1}	Sand %	Silt %	Clay %	Texture classes
Ap1	0–10	1.64	2.60	36.92	8.8	32.80	27.30	39.90	CL-C
2Ap2	10–18	1.78	2.62	32.06	5.1	60.75	14.57	24.68	SCL
2Ap3	18–25	1.75	2.62	33.21	7.0	60.48	15.71	23.81	SCL
2Bw1	25–52	1.74	2.73	36.26	9.9	61.02	17.35	21.63	SCL
2Bw2	52–66	1.74	2.64	34.09	9.1	64.98	14.32	20.70	SCL
2C1	66–93	1.69	2.73	38.10	3.2	63.33	15.55	21.12	SCL
2C2	93–122	1.69	2.69	37.17	13.2	70.65	12.41	16.94	SL
2Cr	122–200	1.71	2.67	35.96	6.0	73.69	10.37	15.94	SL

Table 7. Chemical analysis results of profile KA3

Horizon	Depth cm	pH 1/2.5 soil-water	Salt %	OrganicMatter %	CEC cmol kg^{-1}	$CaCO_3$ %
Ap1	0–10	7.44	0.016	1.84	27.72	0.0
2Ap2	10–18	7.25	0.011	1.65	25.73	0.0
2Ap3	18–25	7.32	0.016	1.50	21.29	0.0
2Bw1	25–52	7.77	0.029	1.45	21.73	0.0
2Bw2	52–66	7.74	0.026	1.06	20.48	0.0
2C1	66–93	7.68	0.026	0.55	21.96	0.0
2C2	93–122	7.59	0.020	0.45	17.47	0.0
2Cr	122–200	7.58	0.021	0.29	17.91	0.0

Profile description:

Ap1 0–10 cm. Dull yellowish brown (10 YR 5/3, wet), dull yellowish orange (10 YR 6/3, dry); clay loam; moderate, fine, subangular block structure; hard, firm, very sticky and very plastic; very, thin and very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

2Ap2 10–18 cm. Brown (10 YR 6/4, wet), between dull yellowish orange and light yellowish brown (10 YR 6/5, dry); sandy clay loam; weak, fine, subangular block structure; slightly hard, loose, sticky and plastic; very, thin and very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

2Ap3 18–25 cm. Brown (10 YR 4/5, wet), yellowish brown (10 YR 5/6, dry); sandy clay loam; moderate, medium, subangular block structure; hard, firm, very sticky and very plastic; very, thin and very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

2Bw1 25–52 cm. Brown (10 YR 4/5, wet), dull yellowish brown (10 YR 5/4, dry); sandy clay loam; moderate, medium, angular block structure; hard, firm, very sticky and very plastic; very, thin and very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

2Bw2 52–66 cm. Brown (10 YR 4/5, wet), between dull yellowish brown and brown (10 YR 5/5, dry); sandy clay loam; moderate, fine, subangular block structure; slightly hard, loose, very sticky and very plastic; very, thin and very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

2C1 66–93 cm. Brown (10 YR 4/4, wet), dull yellowish brown (10 YR 5/4, dry); sandy clay loam; massive-weak, fine, subangular block structure; slightly hard, firm, very sticky and very plastic; few, thin and very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

2C2 93–122 cm. Brown (10 YR 4/6, wet), yellowish brown (10 YR 5/6, dry); sandy loam; massive; hard, loose, sticky and plastic; few, very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

2Cr 122–200 cm. Brown (10 YR 4/6, wet), dull yellowish orange (10 YR 6/4, dry); sandy loam; partially consolidated parent material; hard, loose, sticky and plastic; few, very thin roots; no foaming with dilute HCl solution.

Table 8. Physical analysis results of profile KA4

Horizon	Depth cm	Bulk density g cm^{-3}	Solid density g cm^{-3}	Total porosity %	Hydraulic conductivity cm h^{-1}	Sand %	Silt %	Clay %	Texture classes
Ap	0–14	1.75	2.63	33.46	2.1	13.97	46.22	39.81	SiCL
2A	14–35	1.69	2.76	38.77	0.3	28.14	41.24	30.62	CL
3A	35–56	1.79	2.70	33.70	2.7	30.03	43.13	26.84	L
4A	56–79	1.78	2.69	33.83	1.5	24.41	43.29	32.30	CL
4Cg	79–103	1.73	2.69	35.69	0.7	25.96	44.46	29.58	CL
5Ag1	103–116	1.80	2.71	33.60	0.02	27.30	39.56	33.14	CL
5Ag2	116–152	1.80	2.64	31.82	0.5	26.99	42.52	30.49	CL

Table 9. Chemical analysis results of profile KA4

Horizon	Depth cm	pH 1/2.5 soil-water	Salt %	OrganicMatter %	CEC cmol kg^{-1}	$CaCO_3$ %
Ap	0–14	8.15	0.086	2.56	37.32	4.22
2A	14–35	8.11	0.049	3.15	34.61	4.22
3A	35–56	7.95	0.074	4.07	28.39	4.40
4A	56–79	8.15	0.057	3.61	30.58	4.58
4Cg	79–103	7.75	0.062	1.07	21.57	4.97
5Ag1	103–116	7.71	0.060	2.46	22.92	4.97
5Ag2	116–152	7.86	0.066	1.28	23.27	4.39

Profile description:

Ap 0–14 cm. Greyish olive (5 Y 4/2, wet; 5 Y 6/2, dry); silt clay loam; strongly-moderate, medium-fine, subangular block structure and strongly medium-fine granular structure; extremely hard, extremely firm, very sticky and very plastic; very medium and very, thin and very thin roots; clear foaming with dilute HCl solution; clear and wavy boundary.

2A 14–35 cm. Greyish olive (5 Y 4/2, wet; 5 Y 5/2, dry); clay loam; strongly, course, subangular block structure and strongly medium-fine granular structure; extremely hard, extremely firm, very sticky and very plastic; very medium and very, thin and very thin roots; clear foaming with dilute HCl solution; clear and wavy boundary.

3A 35–56 cm. Between dark greyish yellow and olive brown (2.5 Y 4/2.5, wet), dull yellow (2.5 Y 6/3, dry); loam; moderate, fine, granular and moderate, medium, subangular block structure; extremely hard, extremely firm, very sticky and very plastic; plenty, medium and very, thin and very thin roots; clear foaming with dilute HCl solution; gradual and wavy boundary.

4A 56–79 cm. Olive brown (2.5 Y 4/3, wet), Between dark greyish yellow and yellowish gray (2.5 Y 5/2.5, dry); clay loam; strongly medium, angular block structure; extremely hard, extremely firm, very sticky and very plastic; plenty, medium and very, thin and very thin roots; clear foaming with dilute HCl solution; gradual and wavy boundary.

4Cg 79–103 cm. Yellowish gray (2.5 Y 5/3, wet), dull yellow (2.5 Y 6/3, dry); clay loam; massive; extremely hard, extremely firm, very sticky and very plastic; plenty, medium and very, thin and very thin roots; widespread, medium to large, striking, lateral stripes and banded, sharp yellowish reddish color vests; clear foaming with dilute HCl solution; clear and smooth boundary.

5Ag1 103–116 cm. Grayish olive (5 Y 4/2, wet; 5 Y 5/2, dry); clay loam; massive-strongly, medium- course, prismatic structure; extremely hard, extremely firm, very sticky and very plastic; few, medium and very, thin and very thin roots; small, medium and large, round, like color spots, common, small and medium large, striking, banded, sharp reddish yellow color vests; clear foaming with dilute HCl solution; gradula and wavy boundary.

5Ag2 116–152 cm. Grayish olive (5 Y 5/3, wet), between grayish olive and olive yellow (5 Y 6/2.5, dry); clay loam; massive- moderate, medium- course, prismatic structure; extremely hard, extremely firm, very sticky and very plastic; very, thin and very thin roots; broad, medium and large, striking, banded and round, sharp reddish yellow vignettes; clear foaming with dilute HCl solution.

a) 

b) 

Figure 3. Overview of the profiles KA3 and KA4: a Profile KA3; b) Profile KA4.

Table 10. Physical analysis results of profile KA5

Horizon	Depth cm	Bulk density g cm^{-3}	Solid density g cm^{-3}	Total porosity %	Hydraulic conductivity cm h^{-1}	Sand %	Silt %	Clay %	Texture classes
Ap1	0–19	1.66	2.70	38.52	1.7	32.02	41.64	26.34	L
Ap2	19–30	1.60	2.68	40.29	0.7	42.12	36.62	21.26	L
AB	30–44	1.65	2.69	38.66	1.8	38.01	37.63	24.36	L
Bw1	44–67	1.71	2.69	36.43	1.0	36.79	38.78	24.43	L
Bw2	67–92	1.71	2.68	36.19	1.2	35.88	38.70	25.42	L
BC	92–137	1.69	2.61	35.25	1.0	36.76	38.80	24.44	L
CB	137–197	1.66	2.76	39.86	6.6	35.61	39.91	24.48	L
C	197+	1.82	2.76	34.06	8.6	33.07	40.18	26.75	L

Table 11. Chemical analysis results of profile KA5

Horizon	Depth cm	pH 1/2.5 soil-water	Salt %	Organic Matter %	CEC cmol kg^{-1}	$CaCO_3$ %
Ap1	0–19	7.67	0.027	2.10	25.85	0.0
Ap2	19–30	7.78	0.038	2.89	26.14	0.0
AB	30–44	7.75	0.026	2.04	24.19	0.0
Bw1	44–67	7.91	0.048	1.45	22.88	0.0
Bw2	67–92	7.75	0.025	0.84	22.84	0.0
BC	92–137	7.79	0.046	0.66	21.68	0.0
CB	137–197	7.91	0.040	0.69	25.24	0.0
C	197+	7.85	0.029	0.34	26.08	0.0

Profile description:

Ap1 0–19 cm. Dull yellowish brown (10 YR 4/3, wet; 10 YR 5/4, dry); loam; weak, fine, subangular block structure; hard, loose, very sticky and very plastic; few medium and very, thin and very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

Ap2 19–30 cm. Between dull yellowish brown and greyish yellow brown (10 YR 4/2.5, wet), dull yellowish brown (10 YR 5/3, dry); loam; weak, medium-fine, subangular block structure; hard, loose, very sticky and very plastic; few medium and very, thin and very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

AB 30–44 cm. Dull yellowish brown (10 YR 4/3, wet; 10 YR 5/2.5, dry); loam; strongly, medium- course, angular block structure; hard, firm, very sticky and very plastic; very, thin and very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

Bw1 44–67 cm. Between dull yellowish brown and brown (10 YR 4/3.5, wet), dull yellowish brown (10 YR 5/4, dry); loam; strongly, course, subangular block structure; very hard, firm, very sticky and very plastic; very, thin and very thin roots; no foaming with dilute HCl solution; clear and wavy boundary.

Bw2 67–92 cm. Dull yellowish brown (10 YR 4/3, wet; 10 YR 5/4, dry); loam; strongly, course, subangular block structure; very hard, very firm, very sticky and very plastic; very, thin and very thin roots; no foaming with dilute HCl solution; gradual and wavy boundary.

BC 92–137 cm. Dull yellowish brown (10 YR 4/3, wet), dull yellowish orange (10 YR 6/4, dry); loam; strongly-moderate, very course, angular block structure; very hard, very firm, very sticky and very plastic; few, thin and very thin roots; no foaming with dilute HCl solution; gradual and wavy boundary.

CB 137–197 cm. Between dull yellowish brown and dark brown (10 YR 3.5/3, wet), dull yellowish orange (10 YR 6/4, dry); loam; moderate- strongly, course, angular block structure; very hard, firm, very sticky and very plastic; few, thin and very thin roots; no foaming with dilute HCl solution; gradual and wavy boundary.

C 197+ cm. Dull yellowish brown (10 YR 4/3, wet), dull yellowish brown (10 YR 5/4, dry); loam; moderate, medium, subangular block structure; hard, firm, very sticky and very plastic; no foaming with dilute HCl solution.

Figure 4. Overview of the profile KA5.

The classification of the soils that differ in a toposequence relationship is presented in Table 12. It has been determined that the soils formed on a toposequence differ in Order and suboundary levels. Land suitability orders show whether land is suitable for different purposes. Land that is not dangerous to damage the land resources and meets the rentable farming conditions of the arrivals by covering the cost is included in the appropriate ‘S’. It is numbered according to the degree of eligibility. It is numbered according to the degree of eligibility. On the other hand, land without economic value in special agricultural practices, which will be harmful at the end of a certain period of time when it is used immediately or continuously, is considered in ‘N’ order which is not suitable.

Table 12. Classification of soil profiles according to of soil taxonomy (Soil Survey Staff, 2014)

Soil Taxonomy (2014)				Profiles
Orders	Suborders	Great groups	Subgroups	
Entisol	Fluvent	Xerofluvent	Typic Xerofluvent	KA4
Inceptisol	Xerept	Haploxerept	Calcic Haploxerept	KA2
			Typic Haploxerept	KA1, KA3, KA5

The 29 cultivated plants, which may be adapted to the ecological conditions of the lands of a toposequence, are given in Table 13 with the conformity classes under 7 families.

Table 13. Suitability classes of agricultural uses of research profiles

Land usage types	Profiles				
	KA1	KA2	KA3	KA4	KA5
A) Grass (*Poaceae*)					
Wheat	S1*	S1*	S2	S2	S1*
Barley	S1**	S1**[a]	S2	S2	S1
Rye	S1*	S1*	S2	S2	S1*
Maize	S2***	S1***	S2***	S3	S1***
Sudan grass	S1*	S1*	S3	S3	S2
B) Legume plants (*Fabaceae*)					
Soybeans	S1*	S2*	S2	S3	S2
Bean	S1*	S1*	S2	S3	S2
Peas	S1*	S1*	S2	S3	S2
Chickpea – lentil	S1*	S1*	S2	S3	S2
Alfalfa	S1*	S1*	S3	S3	S1*
Hungarian vetch	S1*	S1*	S2	S3	S2
Sainfoin	S1*	S1*	S1*	S3	S2
C) Onions (*Alliaceae*)					
Carrot	S2*	S2*	S2	S3	S3
Onion-garlic- leek	S1*	S2*	S1*	S3	S1*
D) Solanaceous plants (*Solanaceae*)					
Potato	S2*	S2*	S2	S3	S2
Pepper-eggplant	S2***	S2***	S2***	S3	S2***
Tomato	S1*	S2*	S3	S3	S2
E) Cucurbits (*Cucurbitaceae*)					
Watermelon-melon	S1*	S2*	S3	S3	S2
Zucchini- cucumber	S2*	S2*	S2	S3	S2
F) Brassiras (*Brassicaceae*)					
Cabbage	S1*	S1*	S1*	S3	S1
Canola	S1*	S1*	S2	S3	S2
G) Astereaous (*Astereceae*)					
Sunflower	S1*	S1*	S3	S3	S2
H) Pasture area					
Pasture	S1	S1	S1	S2	S1
I) Forestry and recreation areas					
Deciduous forest	S1	S1	S1	S2	S1
Coniferous Trees	S2	S2	S2	S3	S3

* 0–4% slope for S1; % 4–8 slope for S2; 8–16% slope for S3; ** % < 6 slope for S1; 6–12% slope for S2; *** 0–2% slope for S1; 2–4% slope for S2; 4–6% slope for S3; % > 6 slope for N2.

S1 – Products that do not have significant limitations against the continued application of a usage class that provides more than 85% of the maximum product efficiency at a high level, or that have insignificant limits that will not significantly reduce productivity or profitability, and will not exceed the acceptable levels of inputs.

S2 – Medium to medium-term limits for the continuous application of a usage class that provides 60–85% of maximum product yield. Disadvantages that provide limitations reduce productivity or profitability and increase the level of input required, while all the benefits of using the land provide the attractiveness of the destination. However, it is considerably lower than the anticipated productivity in class 1 (S1). Both feasible and economical are likely to require matching inputs.

S3 – This is a land that has collectively severe limitations against the continuous application of this use class, which provides 40–60% of the maximum product yield at marginal. This spending only provides marginal profitability, while the disability that limits them reduces productivity and profitability and increases the level of inputs required. It needs inputs that are applied but economical under favorable conditions.

The 2 order that fall into the non-conforming class is summarized below with typical characteristics.

N1 – Temporary unavailable Not suitable for currently used operation which provides 25–40% of maximum product efficiency. In today's conditions, cost-wise productivity has a certain limit. However, it should also be taken into account that over time, the apologies can be made. Limitations are so severe as to prevent successful and continuous use of the land at the desired level.

N2 – Continuous is not suitable and provides < 25% of maximum product efficiency and is never economically feasible given implementation practices. The intended use has severe limitations to the extent that it will prevent the possibility of successful and continuous use in the desired manner against the product.

CONCLUSIONS

The soil formed in a toposequence sequence is different for suitability of plant cultivation varies. KA1, KA2 and KA5 soils are highly suitable for grass families except maize and sudan grass while KA3 soil is medium suitable for grass families. KA1 and KA2 soils (except soybean) are highly suitable, KA3 (except alfalfa and sainfoin) and KA5 (except alfalfa) soils are medium suitable and KA4 soil is marginal suitable for legume plants. KA1 soil is highly suitable for onion-garlic-leek, tomato, watermelon-melon, cabbage, canola, sunflower, pasture, deciduous forest crops and is medium suitable for carrot, potato, pepper- eggplant, zucchini- cucumber, coniferous trees. KA2 soil is highly suitable for cabbage, canola, sunflower, pasture, deciduous forest crops and is medium suitable for onion-garlic-leek, carrot, potato, pepper-eggplant, tomato, zucchini- cucumber, coniferous trees. KA3 soil is highly suitable for onion-garlic-leek, cabbage, pasture, deciduous forest crops, is medium suitable for carrot, potato, pepper-eggplant, zucchini- cucumber, canola, coniferous tree and is marginal suitable for tomato, watermelon-melon, sunflower. KA4 soil is medium suitable for pasture, deciduous forest and is marginal suitable for carrot, onion-garlic-leek, tomato, watermelon-melon, cabbage, canola, sunflower, potato, pepper- eggplant, tomato, watermelon-melon, zucchini- cucumber, cabbage, canola, sunflower, coniferous trees. KA5 soil is highly suitable for onion-garlic-leek, cabbage, pasture, deciduous forest, is medium suitable for potato, pepper-eggplant, tomato, watermelon-melon, zucchini-cucumber, canola, sunflower and marginal suitable for carrot, coniferous trees.

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Agronomy Research **15**(2), 344–358, 2017

Utilization of waste biomass from post–harvest lines in the form of briquettes for energy production

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Abstract. A great amount of herbal waste biomass is produced nowadays during agriculture crop processing; also during 'post–harvest lines' operations. Such waste biomass occurs in the bulk form, thus, is not suitable for direct combustion; it can be improved by using of briquetting technology. Therefore, present paper provides chemical, mechanical and microscopic analyses of waste biomass originating from post–harvest lines and briquettes produced from it. Namely, waste biomass originated from production of oat (*Avena sativa*) – husks, wheat (*Triticum spp.*) – husks and poppy (*Papaver somniferum*) – straw and seed pods and mixture of all mentioned were investigated. Unprocessed materials were subjected to microscopic and chemical analysis and subsequently produced briquette samples were subjected to determination of its mechanical quality. A satisfactory level of moisture and ash content was observed, as well as, materials energy potential; oat – 17.39 MJ kg^{-1}, wheat – 17.04 MJ kg^{-1}, poppy – 14.48 MJ kg^{-1}. Also microscopic analysis proved suitability of all feedstock materials within evaluation of geometrical shapes of their particles. However, evaluation of briquette mechanical quality unsatisfactory results. Process of briquetting revealed unsuitability of oat feedstock for briquette production; other materials proved following values of volume density and mechanical durability (in sequence): wheat – 1,023.19 kg m^{-3}, 89.1%; poppy – 1,141.43 kg m^{-3}, 94.7%; mixture – 972.49 kg m^{-3}, 62.7%. In general, only poppy briquettes achieved requested mechanical quality level for commercial briquette production. However, undeniable advantage of investigated materials is the form they occurred in; no further feedstock preparation (drying, crushing) was needed.

Key words: solid biofuels, renewable energy, cereal husk, mechanical durability, calorific value.

INTRODUCTION

Biomass represents alternative but adequate solution of increasing energy demands and also represents possibility of reduction of net carbon emissions, greenhouse gas (GHG) emissions and harmful environmental pollution caused by fossil fuel consumption (Li & Hu, 2003). Bapat et al. (1997) has proved that biomass is third most extensive source of energy worldwide; specifically provides approximately 14% of the global annual energy supply which is equivalent of 1.25 billion tons of oil (Btoe). Fossil fuels as a coal and oil are still in leading positions, but in contrast with them biomass is considered as an environmental friendly renewable source of energy (Werther et al., 2000; Purohit et al., 2006; Zeng et al., 2007). Biomass can vary in accordance to its origin; a waste biomass originates from agriculture sector in most cases and is produced during technological processing of agricultural crops (Lantin, 2001).

During cereal crops harvesting a great amount of waste biomass is produced; Kim & Dale (2004) have proved that during processing of agriculture crops (oats, wheat, rice, corn or sorghum) approximately 1.5 billion metric tonnes of waste biomass is produced worldwide. Mentioned waste biomass occurs primarily in the form of straw but there is also great amount of waste biomass produced during operations of post–harvest lines which removes remnants of native plants and husks from processed crops. Such waste biomass occurs in the bulk form, thus, is not suitable for transportation and combustion. Technology of briquetting could be appropriate solution of material properties improvement (Sahiti et al., 2015). It is common practise to use agriculture crop straw for solid biofuel production (Kirsten et al., 2016). Niedziółka & Szpryngiel (2014), Tumuluru et al. (2015) and Stasiak et al. (2017) have proved possibilities and advantages of briquette production from wheat, rye, barley, and oats straw.

Focused on the subsequent utilization of waste biomass originating from post-harvest lines, namely husks, seed pods and other plant remnants (Lantin, 2001) previous researches proved advantage of production of briquette fuel from rice husk (Muazu & Stegemann, 2015; Obi & Okongwu, 2016) maize husk (Adetogun et al., 2014) or husk of sunflower, buckwheat and flax (Riga Technical University, 2013). Another source reports mention about the possibility of production of briquettes from poppy wastes materials but detail information are not available (Osobov, 1966). Report of Riga Technical University (2013) proved advantage of briquettes produced from oat and wheat middlings (dust) which are also separated from crops during post-harvest lines processing. Chemical analyses of those briquettes proved required low level of moisture content (8.66%) and ash content (3.61%) of materials as well as satisfactory level of gross calorific value (19.0 MJ kg^{-1}). Within the fuel heat input, tested briquette samples represents great efficiency (31.4 MJ) in compare with buckwheat hulls (31.8 MJ), as well as, with wood (35.2 MJ). However, determination of mechanical quality proved that volume density of briquettes did not exceed the level of 900 kg m^{-3}.

In the context of mentioned facts the main aim of present research was to determine the advantages and suitability of briquette production from waste biomass originating from post–harvest lines, specifically from processing of oat (*Avena sativa*), wheat (*Triticum spp.)* and poppy (*Papaver somniferum*) and partly also barley (*Hordeum vulgare L.*) residues.

MATERIALS AND METHODS

At the beginning of present chapter it should be mentioned that whole process of briquette production (feedstock preparation, technical specifications of machinery) and subsequent quality determination (testing and data evaluation) was conducted to mandatory technical standards. Namely, European Standards EN 14918 (2010), EN 15234–1 (2011), EN 643 (2014), EN ISO 16559 (2014), EN ISO 17225–1 (2015), EN ISO 18122 (2015), EN ISO 18134–2 (2015), EN 15148 (2010), EN ISO 16948 (2016), ISO 1928 (2010) and EN ISO 17831–2 (2015).

Sample production

Waste biomass investigated in present experimental research originated from cereal crop production; concretely from its technological processing by post–harvest lines. Specifically, following cereal crops were chosen for research purposes (feedstock materials for briquette production): (i) oat (*Avena sativa*) and (ii) wheat (*Triticum spp.*) both in the form of husks, (iii) poppy (*Papaver somniferum*) in the form of chopped straw and seed pods and (iv) mixture of oat, wheat and barley husks. Chosen materials occurred in the form perfectly suitable for briquette production (proper feedstock moisture content is stated ± 10% by standard EN ISO 17225–1 (2015) and optimal particle size ranges between 6–12 mm (Brunerová & Brožek, 2016) due to previous crops treatment during harvesting and processing by post–harvest lines. Thus, no further processing or preparation of feedstock materials were needed. A hydraulic piston briquetting press type BrikStar 30–12, Briklis (Malšice, Czech Republic) were used for briquette samples production. There was an issue observed during briquetting of one investigated material; present oat waste material in unchanged raw form obtained directly from post–harvest line was not suitable for briquette production. Process of densification was not successful, thus, oat wastes material remained in its original bulk form and briquette samples were not produced. Mentioned issue might be caused by inhomogeneous composition of material proved by microscopic analysis; material contained except husk also tufts in proportion 1:1 (see in Fig. 5, C). All samples from other feedstock materials were produced under the same operation conditions (used pressure ± 100 MPa, die temperature ± 32 °C) into the cylindrical shape with diameter equal to 50 mm. Mean dimensions of produced briquette samples are expressed in Fig. 1 while statistically significant differences were not proved.

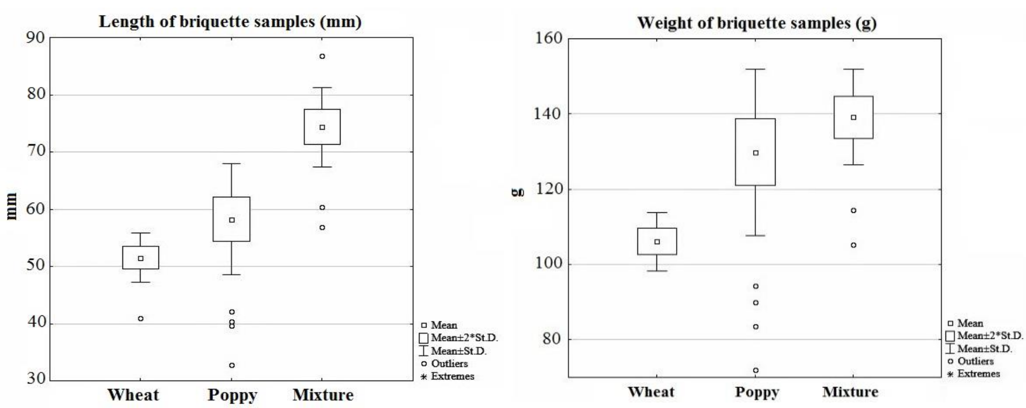

Figure 1. Dimensions of produced briquette samples.

Length of all briquette samples was equal to 61.13 mm in average (with min. 32.80 mm; max. 86.84 mm) and weight of all briquette samples was equal to 125.38 g in average (with min. 72.10 g; max. 160.30 g).

Microscopic analysis

Within the microscopic analysis the shapes and dimensions of selected waste materials were subjected to image analysis by stereoscopic microscope Arsenal, type

SZP 11-T Zoom (Prague, Czech Republic); observed data were processed by evaluation software Quick Photo Industry (Prague, Czech Republic) within what the elementary shape parameters of investigated materials were determined.

Image analysis of specific materials surface was performed by scanning electron microscope TESCAN, type MIRA3 GMU (Brno, Czech Republic). The description of shapes and dimensions of biomass material contributed to understanding of the emergence of solid binding between materials sub-parts. Based on image analysis of materials in comparison with the mechanical properties of final briquettes the proportion of the geometrical arrangement of the material to the final product will be determined. By using of image analysis of briquettes surface and its fractures during different intermediate stage of pressing it was possible to determine the dependence of individual material particles deformation. It leaded to detailed understanding of emergence of the briquettes made from various waste biomass.

Fig. 2 shows an example of detailed surface analysis of selected investigated material (Mixture feedstock material). Fig. 2 part A expresses a macroscopic view of the sample. Fig. 2 parts B, C, D and E were taken by using of SEM technology (scanning electron microscopy) by microscope MIRA 3 TESCAN at the accelerating voltage of the pack (HV) 5.0 kV. Investigated samples were dusted with gold by means of the equipment Quorum Q150R ES – Sputtering Deposition Rate using Gold. Fig. 2 parts B, C, D and E definitely indicated miscellaneous surfaces of investigated sample particles. Observed diverse textures of particles surface will affect final mechanical quality of the briquettes (strength, mechanical durability).

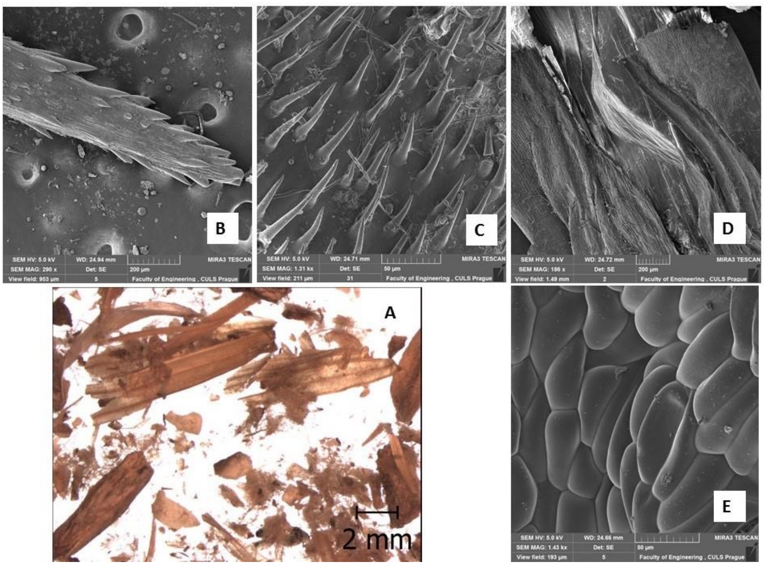

Figure 2. Microscopic analyses of Mixture feedstock material: A – Macroscopic view (MAG 3.5 x); B – SEM images (MAG 290 x); C – SEM images (MAG 1.31 kx); D – SEM images (MAG 186 x); E – SEM images (MAG 1.43 kx).

Chemical analysis

For the purposes of investigated materials chemical analysis were all samples primarily grounded into fine powder (< 0.1 mm) and subsequently dried and subjected to determination of moisture, ash and volatile matter contents, further to elemental composition and also to calorific value statement. The first three parameters were analysed by using of thermogravimetric analyser type LECO TGA 701 (Saint Joseph, United States) in accordance to European Standards EN ISO 18134–2 (2015): Solid biofuels – Determination of moisture content – Oven dry method – Part 2: Total moisture – Simplified method, EN ISO 18122 (2015): Solid biofuels – Determination of ash content, EN 15148 (2010): Solid biofuels – Determination of the content of volatile matter.

Elemental composition of investigated materials was analysed according to European Standard EN ISO 16948 (2016): Solid biofuels – Determination of total content of carbon, hydrogen and nitrogen. The experimental measurements were carried out by instrument type LECO CHN628+S (Saint Joseph, United States) with helium as carrier gas in attempt to determined carbon (C), hydrogen (H), nitrogen (N) and sulphur (S) contents. Chosen instrument operated by principle of analysing the flue gases of samples burned in oxygen. C, H and S contents were measured in infrared absorption cells; N content was measured in a thermal conductivity cell.

Gross calorific value was measured by an isoperibol calorimeter type LECO AC 600 (Saint Joseph, United States) according to European Standard EN 14918 (2010): Solid biofuels – Determination of calorific value. The samples were primarily pressed into pellets (or left in powder form if practicable) and subsequently burned. At least three reliable results were acquired for all samples. Gross calorific value was determined using the supplied software. The relationship between gross calorific value Q_s (MJ kg^{-1}) and net calorific value Q_i (MJ kg^{-1}) and was expressed according to European Standard ISO 1928 (2010): Solid mineral fuels – Determination of gross calorific value by the bomb calorimetric method and calculation of net calorific value.

Mechanical analysis

A volume density ρ in kg m^{-3} of produced samples was chosen as a first indicator of briquette mechanical quality; dimensions of each specific briquette sample were measured and following formula was used for calculation of final volume density:

$$\rho = \frac{m}{V} \tag{1}$$

where: ρ – volume density (kg m^{-3}), m – mass of briquette sample (kg), V – volume of briquette sample (m^3).

Subject of next measurements was a rupture force (RF) in Newton of produced briquette samples; this quality indicator is not defined by any mandatory technical standard, but it expressed the maximal stress force which is a briquette sample able to hold before it disintegrates. Present quality indicator can be used for evaluation of briquette biofuel (Lindley & Vossoughi, 1989; Brožek, 2013; Nováková & Brožek, 2016) because it simulates damage caused during transportation, handling and storage of briquettes in real. Experimental testing within rupture force was performed by plate-loading test principle (see in Fig. 3) with a hydraulic universal tensile compression testing machine type ZDM 50 (Dresden, Germany) as a source energy (loading speed 20 mm·min.$^{-1}$, maximal force 500 kN).

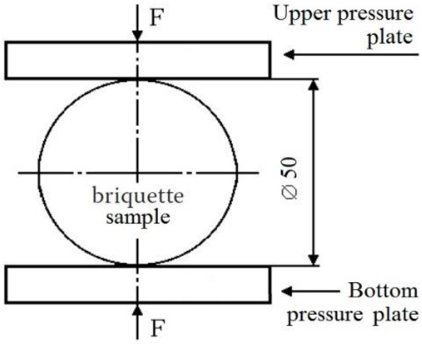

Figure 3. Schema of rupture force plate–loading test.

Determination of mechanical durability, main inficator of briquette mechanical quality, was performed directly after briquette samples production in accordance to European Standard EN ISO 17831–2 (2015): Solid biofuels – Determination of mechanical durability of pellets and briquettes – Part 2: Briquettes. Experimental testing was performed by using of electricity powered special dustproof rotating drum with rectangular steel partition inside which is also defined by mentioned standard.

Briquette samples were subjected to controlled deformation testing and final mechanical quality if investigated briquette samples was calculated by following formula:

$$DU = \frac{m_a}{m_e} \cdot 100 \quad (2)$$

where: DU – mechanical durability (%); m_a – weight of samples after testing (g); m_e – weight of sample before testing (g).

RESULTS AND DISCUSSION

Results obtained within experimental testing were divided into several separate parts according to specific parameters of investigated feedstock materials as well as the ‘Materials and methods’ chapter. All parts of ‘Results and discussion’ chapter together subsequently represented overall evaluation of investigated feedstock suitability for briquette production.

Microscopic analysis

Evaluation of geometrical dimensions of investigated waste biomass from postharvest lines and the form of ‘fixed’ bonds between specific feedstock particles were performed.

Measured result values of investigated feedstock materials are presented in the Table 1. As a mean diameter of feedstocks particles were considered dimensions of two orthogonal lengths of largest particles. Fig. 5 presents image analysis of investigated feedstock materials, specifically pictures A, B, C, D. Result images E, F, G and H of

Fig. 4 exhibited evident diverse of investigated materials shape dimensions. Evaluation of microscopic analysis of specific feedstock materials proved smallest particle dimensions for poppy material sample, while, wheat, oat and mixture samples exhibited larger particle dimensions.

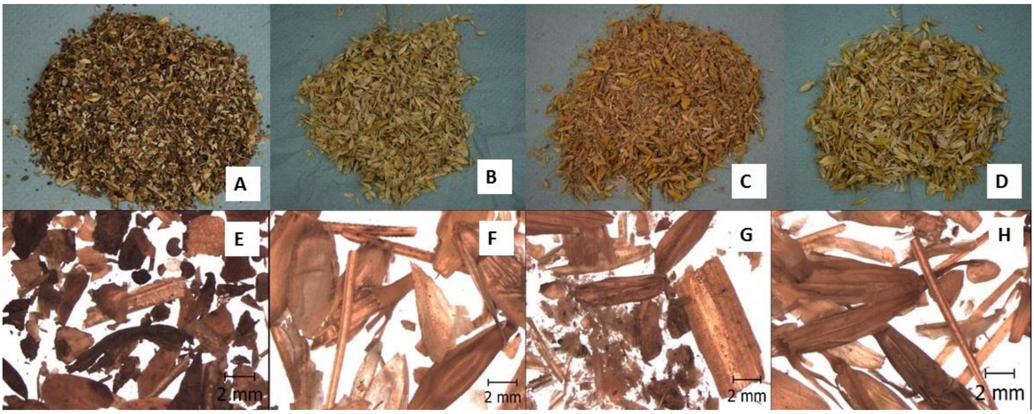

Figure 5. Feedstock materials: A, E – poppy; B, F – wheat; C, G – oat; D, H – mixture.

Observed results also indicated differentiations between specific measured dimensions within one specific feedstock material. It can be highlighted that oat feedstock material exhibited noticeable different values, i.e. differences in oat feedstock average length was equal to approximately 125% and differences in area of oat feedstock particles differed by 163%.

Table 1. Basic geometrical parameters of investigated waste biomass kinds

Waste biomass kind	Average length of particles			Area of particles			Circumference of particles		
	AM (mm)	SD (mm)	CV (%)	AM (mm^2)	SD (mm^2)	CV (%)	AM (mm)	SD (mm)	CV (%)
Poppy	1.93	1.56	81.02	2.88	2.38	82.66	6.93	3.55	51.20
Oat	1.24	1.55	124.86	4.97	8.11	163.16	8.55	8.00	93.59
Wheat	3.60	3.59	99.53	9.24	6.79	73.48	15.01	6.46	43.01
Mixture	3.68	3.73	101.24	12.54	9.90	79.06	17.77	7.61	42.83

(AM – Arithmetic mean, SD – Standard Deviation, CV – coefficient of variation).

For statistical analysis of measured geometric data was used the analysis of variance (ANOVA) using F–test. For the null hypothesis H_0 was indicated state where there between the compared data sets was not (in terms of their mean values) statistically significant difference: $p > 0.05$. Within the statistical analyses of specific kinds of feedstock materials, it was proved that tested materials are statistically inhomogeneous groups, e.i. a difference between geometric shapes of poppy, oat and wheat feedstocks was proved. The null hypothesis H_0 was not accepted; there was a statistically significant differences (in significance level of 0.05) between investigated feedstock materials, i.e. $p < 0.05$ ($p = 0.000$). In general, the difference between geometric parameters of feedstock materials was statistically proved.

More detailed descriptions of investigated feedstock properties are showed in Fig. 6 and Fig. 7. Result values expressed at Fig. 6 clearly explained that poppy and oat feedstock materials contained from 74–79% particles with area $< 5\ mm^2$. Those feedstock materials did not contained particles with area $> 20\ mm^2$. In compare, wheat and mixture feedstock materials contained particles with area $< 45\ mm^2$. If compare mentioned investigations, it can be concluded that considerable differences between feedstock materials within its particles areas were observed.

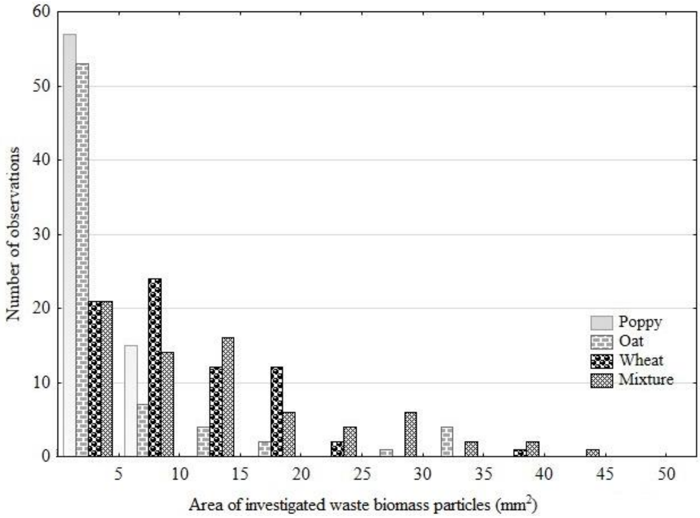

Figure 6. Histogram of areas of particle size of feedstock materials from post–harvest lines.

Similar result values were obtained for average length of particle fraction; detail expression is visible from Fig. 7.

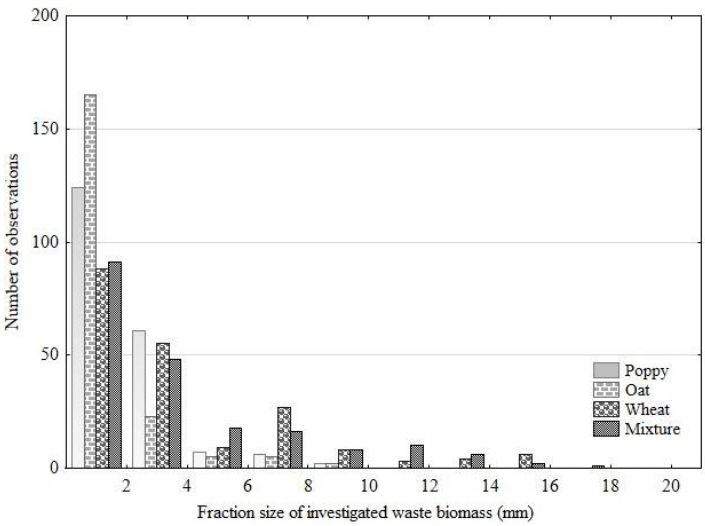

Figure 7. Histogram of average length of size fraction of feedstock materials from post–harvest lines.

The largest faction was measured for oat feedstock material; monitored average length of fraction < 2 mm occurred in 83% of measurements. Evaluation of wheat and mixture result values proved average length of fractions < 18 mm.

Chemical analysis

Final evaluation of chemical parameters of investigated materials were performed according to related technical standards (described in chapter Materials and Methods); in general, all parameters results reached satisfactory level. Specific result values of performed experimental testing are noted in Table 2. Despite the fact that waste biomass originating from processing of oat was not suitable for briquette production, it was subjected to its chemical quality determination as well as all other waste biomass materials.

Table 2. Chemical analysis result of investigated feedstock parameters

	Water content (% wt.)	Ash content (% wt.)	Volatile matter content (% wt.)	Gross calorific value (MJ kg^{-1})	Net calorific value (MJ kg^{-1})
Oat	9.95	2.65	85.86	19.31	17.39
Wheat	6.95	5.01	88.17	18.31	17.04
Poppy	13.70	10.13	85.37	16.78	14.48
Mixture	7.26	3.21	86.30	18.83	17.46

Level of moisture content reached satisfactory level for oat, wheat and mixture materials. Recommended maximum level of moisture content for briquette feedstocks is < 10% (Kaliyan & Morey, 2009). Higher level of moisture content, which was measured for poppy feedstock material (> 13.7%), can negatively influence compaction ability of material (Guo et al., 2015).

Poppy feedstock material also exhibited worse result within ash content experimental testing. A low level of this quality indicator is required while the Kofman (2007) showed that densified biofuels produced from high quality wood indicate ash content < 0.7%. On the other hand, obtained result values of poopy wastes ash content are still acceptable in compare with other cereal waste biomass, namely, rice husks which ash content was determined equal to 20.74% (Brunerová et al., 2017). Focused on different waste materials originating from oat and wheat production, it is commonly straw which is reused for solid biofuel production. Tumuluru et al. (2015) proved following ash content of cereal straw: oat – 2.19%, wheat – 2.36%. Other study of McKendry (2002) proved ash content of wheat straw equal to 4%. High level of ash content influence negatively combustion properties of briquettes due to airflow during burning, and thereby, causes decreasing of calorific value (Malaťák & Passian, 2011). This trend was proved during the calorific value determination and is expressed in Figs 8 & Fig. 9.

According to related technical standard EN 15148 (2009) a lower level of volatile matter content (VMC) is required, but precise allowed value is not stated. All investigated waste materials exhibited VMC higher than 85%. Present result values can be considered as higher in compare with other biomass types. McKendry (2002) has proved following level of volatile matter contents: pine wood – 71.6%, barley straw – 46.00%, rape straw – 35.00% and Miscanthus – 66.8%.

Within energy yield of investigated waste materials the result of experimental measurements proved satisfactory level of oat, wheat a mixture samples and lower result value of poppy samples. For clear comparison a gross calorific values of other commonly used feedstock materials are shown in Fig. 8.

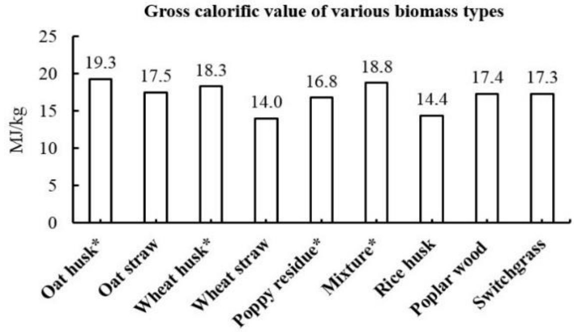

Figure 8. Comparison of investigated materials GCV with other biomass types.
(*Authors data; McKendry, 2002; Sahiti et al., 2015; Brunerová et al. 2017)

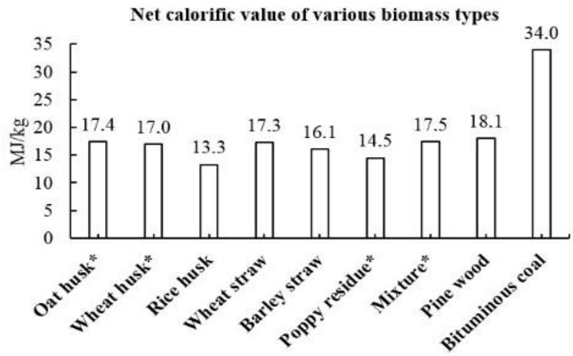

Figure 9. Comparison of investigated materials NCV with other biomass types.
(*Authors data; Stolarski et al., 2013; McKendry, 2002)

Both graphs related to calorific values of investigated materials confirmed its satisfactory level of energy yield in compare with other biomass types (renewable sources of energy); in comparison with bituminous coal (fossil fuel), was observed large difference. However, bituminous coal is non–renewable source of energy which causes environmental pollution, thus, its advantage in the form of higher energy yield is not relevant or sustainable (Montiano et al., 2015).

Mechanical analysis

First investigated indicator of mechanical quality of produced briquette samples was its volume density. Result values of all produced briquette samples were transformed into BoxPlot graph (Fig. 10) for clearer expression.

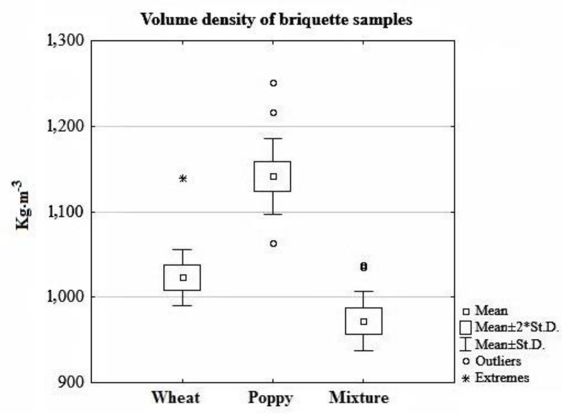

Figure 10. Suitability of investigated feedstock materials for densification process.

As is visible, highest volume density was measured for briquette samples produced from poppy residues (1,141.43 kg m^{-3} in average), then for wheat briquette samples (1,023.19 kg m^{-3} in average) and worst result was obtained by mixture briquette samples (972.49 kg m^{-3} in average). Those results did not supported previously mentioned trend which stated that the briquette mechanical quality decreases with increasing of feedstock moisture content (ASABE, 2015). In conclusion, the relation between lower level of volume density of mixture briquette samples and composition of this mixture can be highlighted. Mixture partly contained also oat husk which was proved as an unsuitable for briquette production, thus, it could have negative influence. However, according to mandatory technical standard all investigated feedstock materials exhibited satisfactory level of volume density, namely ≥ 1,000 kg m^{-3} (ASAE 269.4, 1996). Other studies of Tumuluru et al. (2015) and Adapa et al. (2009) have proved volume density of oat straw briquette equal to 547.4 kg m^{-3} and 930.0 kg m^{-3}; wheat straw briquette volume density was stated equal to 549.52 kg m^{-3} and 868.5 kg m^{-3} (in sequence) while the compaction pressure ranged between 63–94 MPa.

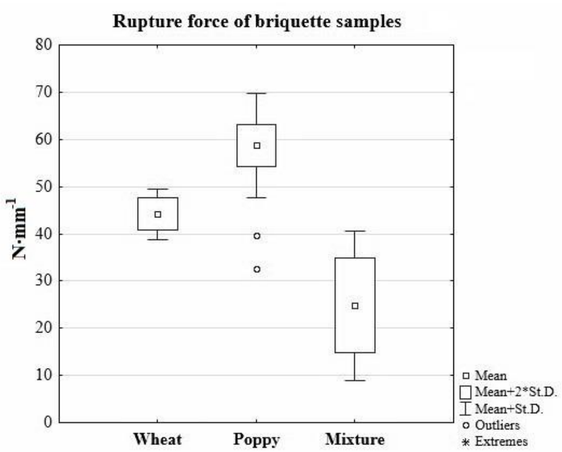

Figure 11. Mechanical strength of investigated briquette samples.

As was mentioned next tested quality indicator was rupture force of produced briquettes. Considering the fact, that this indicator is not stated by any mandatory technical standards, evaluation of obtained result values were performed by comparison with previously published studies. Measured values were noted in $N\,mm^{-1}$; this expression considers maximal briquette strength and briquette length. Average rupture force of investigated briquette samples (expressed in Fig. 11) were following: Poppy – 58.73 $N\,mm^{-1}$, Wheat – 44.18 $N\,mm^{-1}$ and Mixture – 24.79 $N\,mm^{-1}$. Obtained results occurred at very low level in compare with other materials commonly used for combustion purposes. Namely, rupture force for waste paper briquettes was stated equal to 32 $N\,mm^{-1}$, for waste wood briquettes (plane tree chips) was equal to 176.1 and 203.4 $N\,mm^{-1}$ (depends on feedstock moisture contents) and for waste cardboard briquettes was equal to 153 $N\,mm^{-1}$ (Brožek, 2015; Brožek, 2016).

Mechanical durability (DU) was the last evaluated criterion of produced briquette samples. All briquette samples must achieved level of mechanical durability ≥ 90% for commercial production according to mandatory technical standards. As is visible from Fig. 12 only briquette samples produced from poppy residues achieved this level which means that other investigated feedstock materials are not suitable for commercial sale.

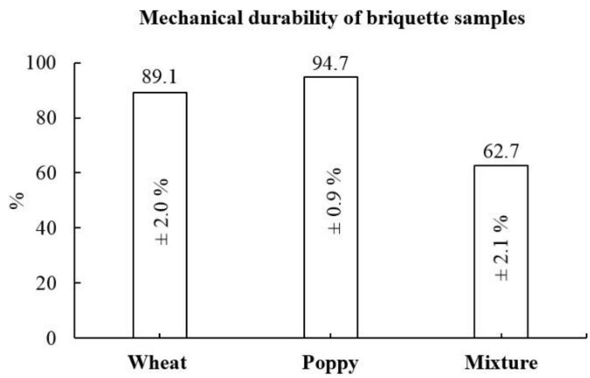

Figure 12. Level of main indicator of briquette mechanical quality determined for investigated briquette samples.

Lowest level (DU = 62.7%) was achieved by Mixture briquette samples as well as in the case of volume density determination. The reason also could be the content of oat husk in the mixture. Mechanical durability level of Wheat briquette samples occurred just below requested level ≥ 90%, while Poppy briquette samples as the only one fulfilled it, thus, proved its suitability for commercial production. Production of oat and wheat straw briquettes indicated higher level of DU, specifically, for oat straw it was stated equal to 78.87% and wheat straw briquettes exhibited DU equal 83.46% (Tumuluru et al., 2015). Low level of most of investigated briquette samples could be caused by low level of lignin, which is natural binder in the cells of lignocellulosic plants. As have been proved by Tumuluru et al. (2015) content of lignin in oat husk is 12.85% and in wheat husk it is 13.88%. Which can be considered as a low level in compare with wood; lignin content in pine wood was stated equal to 34.5% (Klass, 1998).

CONCLUSIONS

Microscopic analysis primarily indicated future issue during briquetting process related to diverse texture and surface of investigated feedstock materials. This observation was subsequently confirmed by low level of mechanical quality of tested briquette samples and complete inappropriateness of oat waste material (husk) for briquette production. Specifically, only Poppy waste material briquette samples achieved mandatory level of mechanical durability for commercial production. On the contrary, chemical analysis of Poppy briquette samples proved lower (but still satisfactory) level of Net calorific value (NCV) while other investigated samples proved high NCV level. Utilization of Poppy waste material (by extension, all tested waste materials utilization) for briquette production can be recommended, however, with necessary improvements related to their mechanical parameters. It can be recommended using of extremely high briquetting pressure (> 60 MPa) or using of external additives, for example wood dust or chips (with high level of lignin), to improve mechanical properties of briquettes. Overall evaluation of all obtained results proved satisfactory level of chemical quality and high energy potential of all investigated materials but low level of their mechanical quality.

On the contrary, chosen materials occurred in the form perfectly suitable for briquette production (proper feedstock moisture content and particle size) due to previous crops treatment during harvesting and processing by post–harvest lines. Thus, no further processing or preparation of feedstock materials were needed. This fact was definitely considered as an indisputable advantage of investigated materials within significant reduction of financial costs and time demands of such briquette production due to no previous feedstock preparation.

ACKNOWLEDGEMENTS. The research was supported by Internal Grant Agency of the Faculty of Engineering, Czech University of Life Sciences Prague, grant number 2017:31140/1312/3112 and further then by the Internal Grant Agency of the Czech University of Life Sciences Prague, grant number 20173005 (31140/1313/3108).

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Tropical waste biomass potential for solid biofuels production

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Abstract. Subsequent utilization of waste biomass in developing countries occurs at poor level, despite the fact, that it has great potential in solid biofuel production. Densified waste biomass is utilized for direct combustion, therefore, its suitability (energy potential, chemical composition) must be determined in attempt to protect environment and reduce air pollution. Main aim of present research was to determine suitability of waste biomass originating from production of rice (*Oryza sativa*), Date fruit (*Phoenix dactylifera L.*) and Jatropha fruit (*Jatropha curcas*) for solid biofuel production. Within a moisture, ash and volatile matter contents, major chemical elements (C, H, N, O) and net calorific value (NCV) were determined. Rice waste analysis proved low NCV (14.33 MJ kg^{-1}) and high ash content (20.74%), which presented problems during combustion. Jatropha fruit waste (cake) analyses exhibited outstanding NCV (24.44 MJ kg^{-1}) caused by residual oil content. Within major elements analysis a low content of oxygen (26.61%) was proved (recommended). Date fruit waste exhibited average NCV (16.40 MJ kg^{-1}). However, high oxygen content (44.01%) was defined as limiting factor. Overall evaluation proved greatest suitability for Jatropha fruit waste (cake), followed by Date fruit waste and lowest potential was determined for Rice waste. However, investigated plants are not cultivated for energy production purposes, thus, observed results achieved satisfactory level of their suitability for solid biofuel production.

Key words: briquettes, renewable energy, calorific value, Jatropha curcas, rice husk.

INTRODUCTION

The impact of intensive form of agriculture production, as well as extensive form (in many cases), leads to production of uncontrollable amount of various waste materials, in other words a waste biomass. If considered, such large amount of produced waste biomass its subsequent utilization is necessary and cannot be overlooked. Increasing popularity of intensive agriculture production is presented to public as a key to improve human living standards, but the side effect of establishment of such agriculture production represents serious negative impact on environment (Goldemberga & Coelho, 2004; Fullerton et al., 2008).

According to United Nations Environment Programme (UNEP) the agriculture sector produces approximately 5 billion metric tons of waste biomass every year. The equivalent of mentioned amount of waste biomass is 1.2 billion tons of oil, which represents approximately 25% of global production nowadays (UNEP, 2017). In this light, our challenge is to reduce dependence on petroleum as a source of energy. Our society requires food and energy independence so that the area, either at national, regional or local level, can become independent both materially and in terms of energy usage (Osaki, 2011) and therefore it is important to use waste biomass for further energy purposes. Because unused and irresponsibly stored waste biomass can cause spontaneous production of leachate and methane (CH_4), also carbon dioxide (CO_2) and other pollutants due to open burning of waste biomass, thus, contributes to soil, air and water contamination (United Nations, 2017). Also, the impact of using carbon based fuels for energy generation leads to environmental degradation and climate changes (Suzuki et al., 2016). Thus, it is time to consider waste, in general, as a choice for sources of fuel for further power generation. In view of these facts, the effort and obligation of subsequent utilization of waste biomass should represent major goal of agriculture sector. Moreover, several of the United Nations Sustainable Development Goals (SDGs) are related to environment conservation, thus, overall protection of planet Earth within sustainable development agenda. Specifically, Goal 7: 'Ensure access to affordable, reliable, sustainable and modern energy for all' focused on global expansion of clean renewable energy (biomass) and its fossil fuels substitution (United Nations, 2017).

It is essential to realize that developing and emerging economies are facing a two-fold energy challenge in the 21st century, as they need to meet needs of billions of people who still lack access to basic, modern energy services while simultaneously need to participate in a global transition to clean, low-carbon energy systems (Ahuja & Tatsutani, 2009). Of course, a much debated question is how to achieve this challenge. However, with rising demands for clean energy and recurrent fuel scarcity there is need to diversify fuel supply and maximize use of natural resources and reuse of waste materials. Furthermore, progress toward increased efficiency, de-carbonization, greater fuel diversity and lower pollutant emissions needs to be accelerated (Ben-Iwo et al., 2016; Suzuki et al., 2016). Approximately 80% of energy production in developing countries is accounted for biomass (UNEP, 2017). Focused on Asian countries a cultivation of rice (*Oryza sativa*) represents major part of local agriculture production which implies also great amount of herbaceous waste biomass production in the form of husks and straw (Lantin, 1999). Waste is a serious and growing problem throughout tropical Asia, as waste management technologies and policies are not keeping up with the rapid increase of waste production (MacRae, 2012). Both waste materials are commonly burned by farmers in order to clear their fields without any energy purposes, see in Fig. 1 (Author's data), nevertheless, utilization of rice straw for heating purposes was investigated by previous authors with satisfactory energetic results (Chou et al., 2009; Eissa et al., 2013).

Focused on fruit waste biomass, a cultivation of Date palm (*Phoenix dactylifera L.*) is mainly located in North Africa, Middle East and China and plays important role in local agriculture sector. Date fruit production and consumption is considered as an inherent part of nutrition dietary in many cultures (Said et al., 2014). After processing of Date fruits a wastes biomass in the form of fruit pits or skins are left behind (fruit biomass) having minimal economic value and only in small quantities are used for combustion purposes or occasionally as fillers in composite systems (Said et al., 2014; Ruggiero et al., 2016). A Gravalos et al. (2016) have proved possibility of reusing of fruit pits, seeds and kernels for combustion purposes, namely, the olive pits, cherry seeds, apricot kernels, peach kernels, watermelon seeds or grape seeds.

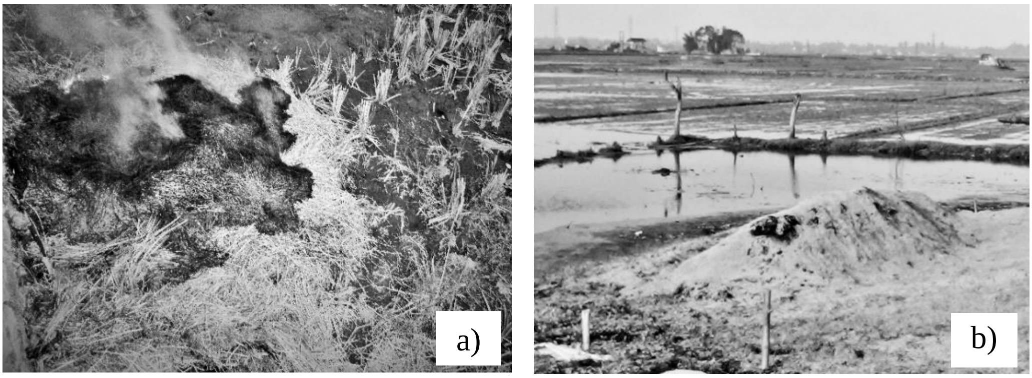

Figure 1. Burning pile of a) rice straw and b) rice husk on the rice fields in Socialist Republic of Vietnam.

Oil production sector situated in tropical and subtropical countries purposely cultivates different plants as a source of vegetable oil; *Jatropha Curcas L.* is one of mentioned plant (Samsuri et al., 2014). This crop is cultivated on large plantations and the oil from seeds is widely used throughout the world; in small scale is used as fertilizer and for soap or local medicine production but the larger utilization is in biofuels production (biodiesel). Jatropha seeds are pressed for the oil extraction purposes and during this process also a by–products (i.e. de-oiled press cake or pomace) are generated (Joshi & Khare, 2011). Subsequent utilization of such secondary raw material for solid biofuel energy generation purposes was investigated previously by Singh et al. (2008) with positive results.

In the view of these facts, present study deals with the issue of reusing of specific waste biomass for solid biofuel production. Main aim of experimental testing of present study was to determine the energy potential of specific waste materials originating from production of Rice, Jatropha oil and Date fruit products, and therefore, state the suitability of investigated waste materials for combustion purposes in case of use as feedstock materials for solid biofuel production.

MATERIALS AND METHODS

All process of experimental testing of present research was conducted to regulations and recommendations in accordance to related mandatory technical standards. Detail information about specific procedures are described below.

Material preparation

Two different types of waste biomass originating from agriculture sector were investigated for the purposes of present research. Firstly, (i) herbaceous biomass represented by rice husks and secondly, (ii) fruit biomass represented by Date fruit skins and pits and Jatropha press cakes and shells. All chosen waste materials were produced during technological processing of specific agriculture crops or products in different countries of origin. Namely, waste materials from rice production originated from Socialist Republic of Vietnam (SRV), Date fruit waste materials originated from People's Republic of China (CN) and Jatropha wastes originated from Republic of Indonesia (ID). Initial preparation of investigated materials performed before experimental testing consisted materials drying by using of laboratory drier LAC (Rajhrad, Czech Republic) for 20 hours at 105 °C. Secondary, all investigated samples were milled by hand knife mill working with 20,000 rpm min^{-1}.

Moisture, ash and volatile matter determination

Within performance of actual experimental testing all investigated samples (n = 5), namely Rice husk, Date skin, Date pits, Jatropha press cake and Jatropha shells, were primarily ground into fine powder with particle size < 0.1 mm. Subsequently, investigated samples were analysed for moisture content, ash content, volatile matter content, elemental composition and calorific value. The first three parameters were analysed by using of thermogravimetric analyser LECO TGA 701 (Saint Joseph, United States). The temperature programme was set at 107 °C and samples were dried to constant weight at first, within what its moisture content was determined. Further, the volatile matter content of samples was determined after seven minutes lasting drying at 900 °C; correction was performed against a coal standard with 41.4% volatile matter content. As the last, the ash content was determined after samples burning in oxygen at 550 °C until constant weight.

Elementary composition determination

Elemental composition (carbon (C), hydrogen (H), nitrogen (N) and sulphur (S) contents) of investigated waste materials was analysed in laboratory instrument LECO CHN628+S (Saint Joseph, United States) working with helium as carrier gas. Within present testing the investigated samples were burned in oxygen and resulting flue gases were analysed. Contents of C, H and S were measured in infrared absorption cells and content of N was measured in a thermal conductivity cell. For determination of C, H and N contents a 0.15 g of sample was wrapped into a tin foil and burned at 950 °C; the EDTA (ethylenediaminetetraacetic acid) and rye flour were used as a calibrating standard. Within S content determination the samples weighing 0.2 g were poured into a crucible and burned at 1,350 °C; calibrating standards for S module were rye flour and coal. Every investigated sample was analysed repeatedly in attempt to get at least three good measurements of each element during present experimental testing.

Calorific value determination

Gross calorific value of specific selected waste material was measured in an isoperibol calorimeter LECO AC 600 (Saint Joseph, United States). Investigated samples were primarily pressed into pellet form (or let in powder form, if practicable) and subsequently burned. Gross calorific value was determined using the supplied software and least three reliable results were acquired for every sample. The relationship between gross calorific value Q_s (MJ kg^{-1}) and net calorific value Q_i (MJ kg^{-1}) was expressed according to ISO 1928 (2010). For complete calorific value determination, the following measurements and calculations described in Equations (1), (2), (3) and (4) were performed:

The theoretical amount of oxygen O_{min} (m^3 kg^{-1}) was stated by the equation (real molar volumes were used):

$$O_{min} = \frac{22.39}{12.01} \cdot C + \frac{22.39}{4.032} \cdot H + \frac{22.39}{32.06} \cdot S - \frac{22.39}{31.99} \cdot O \quad (1)$$

where: C – carbon content in wet basis (%), H – hydrogen content in wet basis (%), S – sulphur content in wet basis (%), O – oxygen content in wet basis (%).

The theoretical amount of dry air L (m^3 kg^{-1}) was determined by equation:

$$L = O_{min} \cdot \frac{100}{21} \quad (2)$$

where: O_{min} – theoretical amount of oxygen (m^3 kg^{-1}).

The theoretical amount of dry flue gases $v^s_{sp_{min}}$ (m^3 kg^{-1}) was based on the equation:

$$v^s_{sp_{min}} = \frac{22.27}{12.01} \cdot C + \frac{21.89}{32.06} \cdot S + \frac{22.40}{28.013} \cdot N + 0.7805 \cdot L \quad (3)$$

where: C – carbon content (%); S – sulphur content (%); N – nitrogen content (%); L – theoretical amount of dry air (m^3 kg^{-1}).

The theoretical amount of emission concentrations of CO_2 (m^3 kg^{-1}) was based on the equation:

$$CO_2 = \frac{\frac{22.27}{12.01} \cdot C}{v^s_{sp_{min}}} \cdot 100 \quad (4)$$

where: C – carbon content (%); $v^s_{sp_{min}}$ – theoretical amount of dry flue gases.

RESULTS AND DISCUSSION

Considering the fact that investigated waste materials differed from a taxonomical point of view the evaluation of obtained result values were performed individually with focus on waste materials originated from each plant.

If focused on Date fruit waste biomass, obtained result values exhibited satisfactory level of energy potential expressed by Net calorific value in dry basis equal to 16.40 MJ kg^{-1} for Date skin samples and equal to 17.84 MJ kg^{-1} for Date pits samples. Previous study of Nasser et al. (2016) focused on energy potential of different parts of Date palm (*Phoenix dactylifera L.*) proved Gross calorific value of Date fruit pits equal to 19.85 MJ kg^{-1} which corresponds to the result value obtained from experimental testing of present paper. According to other study made by Gravalos et al. (2016) fruit pits are suitable for combustion purposes within what a calorific value of olive pits (*Olea europaea*) was stated 17.97 MJ kg^{-1}. However, overall evaluation of present waste materials suitability for combustion purposes indicated undesirable high oxygen content, specifically 44.01% for Date pits and 45.06% for Date skins (bolded in Table 1). This observation was defined as a limiting factor of Date biomass because elementary composition of biofuels affects both its calorific value and behaviour during combustion.

Especially high content of oxygen in biofuel will change the combustion air consumption and amount of flue gas.

Table 1. Composition analysis of waste biomass from Dates, Jatropha and rice plants

Sample / Average values	Water Content (% wt.)	Ash content (% wt.)	Volatile matter content (% wt.)	Gross Calorific Value (MJ kg^{-1})	Net Calorific Value (MJ kg^{-1})	Carbon (% wt.)	Hydrogen (% wt.)	Nitrogen (% wt.)	Sulphur (% wt.)	Oxygen (% wt.)
	W	*A*	*VM*	Q_s	Q_i	*C*	*H*	*N*	*S*	*O*
Date skin, os.	6.88	2.65	75.71	16.52	15.10	42.20	5.72	0.52	0.08	41.97
Date skin, db.	–	2.84	81.30	17.74	16.40	45.31	6.09	0.55	0.08	**45.06**
Date pits, os.	5.90	1.18	79.31	18.13	16.65	44.24	6.13	1.04	0.10	41.42
Date pits, db.	–	1.25	84.29	19.26	17.84	47.01	6.52	1.11	0.10	**44.01**
Rice waste, os.	6.06	**19.48**	64.65	14.43	13.32	37.28	4.43	0.38	0.06	32.32
Rice waste, db.	–	**20.74**	68.82	15.36	14.33	39.68	4.71	0.41	0.06	34.40
Jatropha press cake, os.	4.94	4.36	83.96	24.83	**23.12**	54.83	7.32	3.05	0.21	25.30
Jatropha press cake, db.	–	4.58	88.33	26.12	**24.44**	57.67	7.70	3.21	0.22	26.61
Jatropha shell, os.	7.39	1.45	69.58	19.59	18.29	49.77	5.15	0.49	0.04	35.71
Jatropha shell, db.	–	1.57	75.12	21.16	19.94	53.73	5.56	0.53	0.05	38.56

(os. – original sample, db. – in dry basis).

Results observed within Jatropha fruit waste analyses exhibited Net calorific value in dry basis at outstanding level for Jatropha press cake samples (24.44 MJ kg^{-1}) and at high level for Jatropha shell samples (19.94 MJ kg^{-1}) which was caused by residual oil content (bolded in Table 1). According to Ružbarský et al. (2014) the calorific value of Jatropha fruit differs in accordance to different parts of fruit. Following values were stated by their previous research: seeds coat – 18.21 MJ kg^{-1}, seeds kernel – 29.27 MJ kg^{-1}, seeds – 24.88 MJ kg^{-1}, oil-cake from kernel – 20.38 MJ kg^{-1}, oil-cake from seeds – 19.63 MJ kg^{-1}. Focused on energy consumption (financial input) of Jatropha fruit processing (oil production) it was proved that energy required to pressing of different parts of fruit was equal to 147,052 J for seeds and equal to 76,849 J for kernels, thus, difference between investigated samples was approximately 50%. This observation must be considered within evaluation of Jatropha waste efficiency (Müller et al., 2015).

Such high level of calorific value was observed also for waste materials of other agriculture crops cultivated for oil production such as the Sunflower and Rapeseed which exhibited calorific value equal to 21.23 MJ kg^{-1} and 21.57 MJ kg^{-1} (Gravalos et al., 2016). Husain et al. (2002) also proved calorific value of oil palm shells equal to 16.4 MJ kg^{-1} which is lower level in compare with Jatropha shells (19.94 MJ kg^{-1}) tested in present research. Subsequent utilization of waste biomass originating from Jatropha technological processing was proved as a suitable and advantageous previously (Jingura et al., 2010) and the possibility of reusing of Jatropha waste biomass as a feedstock for briquette production was also proved (Singh et al., 2008).

If compare all result values of investigated samples (see in Table 1), the highest ash content was stated for waste biomass from rice production (rice husks), namely, equal to 20.74% (bolded in Table 1). Likewise, unsatisfactory result of rice husks ash content equal to 19.2% was proved by Vassilev et al.(2015). On the contrary, other authors dealing with rice waste chemical composition issue proved level of ash content of rice straw equal to 15.6% (Thy et al., 2006) and equal to 11.25% (Chou et al., 2009). In general, non-woody biomass contains more ash (Gürdil et al., 2009) in compare with woody biomass (Johansson et al., 2004). Nevertheless, such high level of ash content observed in present research represented problems during combustion. This phenomenon was reflected in low level of Net calorific value of rice husk samples which was stated 14.33 MJ kg^{-1}. Previous studies of Chin (2000) and Gravalos et al. (2016) proved similarly low level of rice husk calorific value, namely 14.77 MJ kg^{-1} and 15.97 MJ kg^{-1}, however, the ash contents of investigated samples were not mentioned. Apart from low calorific value, high level of ash content also causes the clog of combustion devices grates by bottom ash, thus, obstructing the way for combustion air (Malaťák & Passian, 2011). Other authors, however, point out the possibility of subsequent reusing of rice husk ash as a cleaner and novel adsorbent of Methylene Blue and Congo Red in Aqueous Phases (Chowdhury et al., 2009; Foo & Hameed, 2009). This fact adds a value to produced waste material (rice husk ash) and support its subsequent utilization.

Biomass elementary composition influences result level of calorific value as well as biomass behaviour during combustion. Within major elements analysis a required low content of oxygen was proved for Jatropha waste samples (see in Table 1). During experimental combustion of Jatropha press cake and shell were observed a different amounts of combustion air resulted in different flue gas concentrations. This phenomenon can be seen in Table 2 within the comparison of result values of Jatropha press cake samples with the rest of analysed materials. The resulting high combustion air intake and high flue gas production might require specific setting of combustion device (Skanderová et al., 2015; Malaťák et al., 2016) as it hinders the energy use.

Table 2. Result values of combustion air intake and flue gas production

Sample / Average values	Theoretical amount of combustion air (2)		Theoretical amount of dry flue gases (3)		Theoretical concentration of carbon dioxide in dry flue gases (4)	
	($kg\ kg^{-1}$)	($m^3\ kg^{-1}$)	($kg\ kg^{-1}$)	($m^3\ kg^{-1}$)	(% wt.)	(% vol.)
Date skin, os.	5.02	3.86	7.34	3.80	21.08	20.58
Date pits, os.	5.42	4.09	7.72	4.09	21.00	20.08
Rice husk, os.	4.42	3.4	6.71	3.35	20.37	20.62
Jatropha press cake, os	7.74	5.97	9.89	5.70	20.33	17.84
Jatropha shells, os.	5.96	4.59	8.33	4.51	21.91	20.46

(os. – original sample).

In general, knowledge based on observation of present parameters and their result values represent important step within setting and optimal performance of combustion devices. Moreover, using of such a knowledge can positively influence and improve technologies for processing of waste biomass into solid biofuels (Jourabchi et al., 2016).

CONCLUSIONS

Overall evaluation of observed result values indicated suitability of investigated materials for combustion purposes, thus, proved their suitability for possible solid biofuel production. Specific parameters of tested samples exhibited satisfactory level.

In general, these results indicate that even though all selected plants are not commonly cultivated for energy production purposes, they proved high level of energy potential (especially in case of Jatropha wastes). In case of rice wastes a high content of ash was detected, nevertheless, the potential of rice husk ash reusing as a cleaner and novel adsorbent was proved by previous authors. Undesirable higher oxygen content of Date wastes can negatively influence combustion properties of materials, but the calorific value achieved satisfactory level, hereby, it can be concluded that a balance between the positives and negatives of this material was achieved. Taken together, reusing of all present waste materials is highly recommended, as well as all kinds of waste materials (especially the biological ones) in attempt to keep the main key factors of proper waste management 'Reduce – Reuse – Recycle'. A natural progression of this work is to analyse further tropical waste biomass in order to extends our knowledge of appropriate waste materials for further energy purposes.

ACKNOWLEDGEMENTS. The research was supported by Internal Grant Agency of the Faculty of Engineering, Czech University of Life Sciences Prague, grant number 2017:31140/1312/3112 and further then by the Internal Grant Agency of the Czech University of Life Sciences Prague, grant number 20173005 (31140/1313/3108).

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Agronomy Research **15**(2), 369–375, 2017

Lifetime milk productivity and quality in farms with different housing and feeding systems

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Abstract. Housing and feeding systems in farms are main factors that affects cow milk productivity and its quality. The largest proportion of Latvian farms are small farms with tie stall housing system and grazing in summer. The aim of our study was to determine to what extent different housing and feeding systems affect the milk productivity, quality and cow longevity characterizing traits of Latvian dairy cows. In study we analysed 3,179 Holstein Black and White (HBW) and Latvian Brown (LB) breed cows from which 2,383 were located in 2 farms with loose housing system and TMR feeding and 796 cows were located in 8 small farms with tie stall housing system and different feed in summer and winter periods. The average daily milk yield significantly higher ($p < 0.05$) were in farms with loose housing system – 23.53 kg ECM, but in farms with Tie stall housing system was obtained 18.46 kg ECM per day. HBW breed cows characterized with lower somatic cell count in milk than Latvian brown in both housing systems. The highest somatic cell count in milk was obtained from third lactation LB breed cows in Tie stall housing system (249.11 thous. in $1mL^{-1}$ milk) and the lowest from HBW cows in loose housing system (127.57 thous. in $1mL^{-1}$ milk). Cows in smaller farms characterized with longer lifespan – 2,098.7 and 1,890 days for large farms, but lifetime milk productivity was significantly higher in farms with loose housing system where was obtained 21,315.9 kg ECM whereas in Tie stall system farms average life productivity was 19,740.2 kg ECM.

Key words: Housing systems, milk productivity, milk quality, longevity.

INTRODUCTION

Housing and feeding systems in farms are main factors that affects cow milk productivity and its quality. With the increased level of dairy farm modernization, there also comes higher milk productivity, but with the cost of poorer udder health and shorter lifespan (Weigel, et al., 2003). The larger proportion of Latvian dairy cows are keeping in small and medium size farms and in those farms the most often are tie stall housing system with grazing cows in pasture period. Tie stall housing farms with grazing system characterizes with lower fed quality and unbalanced rations that leads to significant decrease of milk productivity (Beever et al., 2000). One of the greatest problems connected with cow feeding in tie stall housing farms is pasture. There are not one fully precise technology that can detect and measure amount and quality of consumed grass.

That leads farmers to compile rations by using estimated measurements (Oudshoorn et al., 2011).

Dairy cow longevity is one of the most important traits in dairy farming. The length of cow lifespan can depend from different environmental conditions that varies in different farms (Vukasinovic, et al., 1997; Buenger, et al., 2001). The indicator of environmental conditions in each farm can be evaluated by the housing system used in given farm. Housing system determines not only farms welfare conditions, but also it serves as indicator of used feeding and milking systems (Krohn & Munksgaard, 1993; Corazzin et al., 2010). In farms with loose housing system feed rations are well balanced and fed as totally mixed ration (TMR) that leads to better consumption rates and more effective use of nutrients (Bunger et al., 2001).

In farms with more than 100 cows usually applied loose housing system with milking in milking parlours, but in smaller farms (up to 50 cows) most commonly used Tie stall housing system with grazing in summer period and milking in milk line (Popescu et al., 2010; Oudshoorn et al., 2012).

In intensive dairy farming system the main emphasis is put on higher milk productivity and better milk quality. However with the intensive farming strategies and high milk productivity also comes shortened average lifespan (Bielfieldt et al., 2006). On the other hand cows that are kept in Tie stall housing system usually characterizes with longer lifespan, but lower lifetime milk productivity and poorer milk quality than cows kept in loose housing farms (Smulski et al., 2011).

The aim of our study was to evaluate the milk productivity, quality and cow longevity characterizing traits of Latvian dairy cows in different housing systems.

MATERIALS AND METHODS

For study purposes was used data about 3,179 Holstein Black and White (HBW) and Latvian Brown (LB) breed cows – 2,383 cows were located within two farms with loose housing system and 796 cows were located in eight small farms with tie stall housing system and grazing in pastures.

In study were analysed data about cows that were born in time period from year 2007 to 2014 and concluded at least one full lactation. Farms were located in the central part of Latvia.

In farms with loose housing system cows were secured with optimal welfare conditions, and milking was organized in milking parlours. Feed rations in those farms are compiled periodically and distributed as Totally Mixed Ration (TMR), whereas in small farms with grazing system cows are milked in milk lines located in tie stall farm, feed ration differs in winter and summer periods. In analysed tie stall housing farms feed rations are not balanced and in grazing periods there are used pasture feeding with additional fodder in ration.

For study purposes from Latvian Agricultural Data Centre were collected data about:

- dates of cow birth, first calving and culling dates,
- milk yield, milk fat and protein content in full lactation,
- milk quality in first three lactations.

The lifespan, length of productive life and count of milking days were calculated as well as milk productivity in life, one life day, one productive life day and one milking day.

To characterize milk productivity were calculated energy corrected milk (ECM) by formula:

$$ECM = milk\ yield \times \frac{[(0.383 \times fat, \%) + (0.242 \times protein, \%) + 0.783]}{3.14} \quad (1)$$

Data in tables are represented as mean ± standard error. The factor of farm impact on cow longevity and productivity traits was determined by analysis of variance. Pairwise comparisons between farms occurred by using Bonferroni test. Significant differences *($P < 0.05$)* in the tables were marked with different superscripted letters of the alphabet (A, B). The mathematical processing was performed using the SPSS program package.

RESULTS AND DISCUSSION

The length of dairy cow lifespan indicates of its effectiveness in herd, but length of productive life and count of milking days is one of the economically most important longevity traits.

In our study group with longest lifespan – 2,098.7 days (5.7 years) – characterized cows that were kept in tie stall housing system (Table 1).

Table 1. Average longevity traits in loose and tie stall housing systems

Longevity trait, days	Loose housing	Tie stall housing	Difference
Lifespan	1,890 ± 14.2	2,099 ± 27.9	208*
Length of productive life	1,059 ± 13.9	1,250 ± 27.4	191*
Milking days	876 ± 11.8	1,037 ± 23.2	161*
Age at first calving	832 ± 8.5	848 ± 7.6	16*

* – traits signed with asterisks shows significant differences between traits in different housing systems.

Cows that were kept in loose housing system characterized not only with significantly ($p < 0.05$) shorter lifespan (1,890.7 days), but also with shorter productive life and lesser milking days (accordingly 1,058.8 and 875.9 days) in their life. Also cows in loose housing system characterized with earlier age at first calving – 831.9 days (27.7 months), whereas cows in tie stall housing system first time calved 16.5 days older that indicates of better heifer rearing conditions in farms with loose housing system.

Milk productivity, obtained from one cow in its lifetime, is one of most important economic indicators – it shows the balance of invested and yielded financial resources in cows rearing and maintenance period. The average lifetime productivity significantly *($P < 0.05$)* higher (21,315.9 kg ECM) was obtained from cows that was located in farms with loose housing system (Table 2).

Table 2. Average lifetime and life day milk productivity in different housing systems

Milk productivity traits, kg ECM	Loose housing (N = 2383)	Tie stall housing (N = 796)	Difference
Lifetime milk productivity	21,315.9 ± 296.49	19,740.2 ± 584.96	1,575.7*
Life day milk productivity	10.2 ± 0.08	8.6 ± 0.17	1.6*
Productive life day milk productivity	19.3 ± 0.11	15.3 ± 0.22	4.0*
Milking day milk productivity	23.5 ± 0.11	18.5 ± 0.22	5.0*

* – traits signed with asterisks shows significant differences between traits in different housing systems.

Cows that were located in loose housing farms characterized with higher milk productivity in one life day (10.2 kg ECM), one productive life day (19.3 kg ECM) and one milking day (23.5 kg ECM) than cows in tie stall housing systems. This tendency is mainly explained with rapid changes of feed ration and the fact that in small farms ration is not balanced and there is little knowledge about amounts of feed consumed (Krisstensen, et al., 2005; Van Calker et al., 2005; Meyer, 2007).

HBW breed cows characterizes with shorter lifespan, length of productive life and lower number of milking days, whereas LB and other red breed group cows has a potential for extended longevity traits (Parna, et al., 2006). This tendency was confirmed in our previous studies in LB and HBW breed cow populations (Cielava, Jonkus & Paura, 2014). Average lifespan for HBW breed cows were 1,826.4 days in loose housing system, but in Tie stall housing system it was 194 days longer (Table 3).

Table 3. Longevity traits for different breed cows in loose and tie stall housing systems

Longevity trait, days	Loose housing	Tie stall housing
Holstein Black and White (HBW)	N = 1,620	N = 796
Lifespan	$1{,}826 \pm 24.7^{A}$*	$2{,}020 \pm 43.9^{A}$*
Length of productive life	$1{,}023 \pm 24.3^{A}$*	$1{,}205 \pm 43.1^{A}$*
Milking days	880 ± 20.6*	$1{,}021 \pm 36.5^{A}$*
Age at first calving	803 ± 10.4^{A}*	815 ± 12.9^{A}*
Latvian brown (LB)	N = 763	N = 354
Lifespan	$1{,}910 \pm 17.3^{B}$*	$2{,}103 \pm 36.3^{B}$*
Length of productive life	$1{,}076 \pm 16.9^{B}$*	$1{,}282 \pm 35.6^{B}$*
Milking days	874 ± 14.4*	$1{,}050 \pm 30.2^{B}$*
Age at first calving	834 ± 11.3^{B}*	821 ± 21.4^{B}*

* – traits signed with asterisks shows significant differences between traits in different housing systems; $^{A;B}$ – traits with different superscriptions shows significant differences between breeds.

LB breed cows had the highest milking day count (1,050.1 days) in study group, but in the same time from them was obtained the lowest amount of energy corrected milk per one life (8.2 kg ECM), productive life (14.4 kg ECM) and milking day (17.4 kg ECM) (Table 4).

Lifetime milk productivity for HBW and LB cows were higher in loose housing system, but cows that were kept in tie stall farms and grazed in summer period characterized with significantly lower milk productivity traits. It could be explained with problem that in the tie stall farms feed rations are usually unbalanced because There are not regulary compted a forage analysis which can lead to decreased milk productivity (Bargo et al., 2002).

Table 4. Lifetime milk productivity traits in loose and tie stall housing systems from different cow breeds

Milk productivity traits, kg ECM	Loose housing	Tie stall housing
Holstein Black and White (HBW)	N = 1620	N = 796
Lifetime milk productivity	21,066.1 ± 517.96^{A*}	19,707.9 ± 919.33^{A*}
Life day milk productivity	10.7 ± 0.15	9.1 ± 0.27 ^{A}
Productive life day milk productivity	20.5 ± 0.19 ^{A*}	16.6 ± 0.34 ^{A*}
Milking day milk productivity	23.8 ± 0.19 ^{A*}	19.2 ± 0.33 *
Latvian brown (LB)	N = 763	N = 354
Lifetime milk productivity	20,458.0 ± 361.96^{B*}	18,754.6 ± 760.22^{B*}
Life day milk productivity	9.9 ± 0.11 *	8.2 ± 0.22 ^{B*}
Productive life day milk productivity	18.7 ± 0.13 ^{B*}	14.4 ± 0.28 ^{B*}
Milking day milk productivity	22.8 ± 0.13 ^{B*}	17.4 ± 0.28 *

* – traits signed with asterisks shows significant differences between traits in different housing systems; $^{A;B}$ – traits with different superscriptions shows significant differences between breeds.

The somatic cell count (SCC) is one of the main indicators of the milk quality. SCC has tendency to increase in the milk of the older cows (Pösö & Mäntysaari 1996; Regula et al., 2004; Mdgela et al., 2009). In different study's authors found the connection between increased SCC in milk and in lowered cow milk productivity (Juozaitiene, et al., 2006; Sasaki, 2013; Cinar et al., 2015). Milk quality in the first three lactations is shown in Table 5.

Table 5. Somatic cell count in milk for HBW and LB cows kept in different housing systems

Somatic cell count, thous. in 1mL^{-1}	N	Loose housing	N	Tie stall housing
HBW				
First lactation	1,620	127 ± 8.1	442	130 ± 14.1 ^{A}
Second lactation	1,134	184 ± 10.7^{A}	306	184 ± 18.7
Third lactation	849	161 ± 13.2 ^{A*}	159	224 ± 22.9 ^{A*}
LB				
First lactation	763	131 ± 10.8 *	354	148 ± 16.2 ^{B*}
Second lactation	486	147 ± 14.4 ^{B*}	237	198 ± 21.6*
Third lactation	403	139 ± 17.6 ^{B*}	170	249 ± 26.5 ^{B*}

* – traits signed with asterisks shows significant differences between traits in different housing systems; $^{A;B}$ – traits with different superscriptions shows significant differences between breeds.

HBW breed cows characterized with lower somatic cell count in the milk than LB in both housing systems. The highest somatic cell count in milk was obtained from third lactation LB breed cows in tie stall housing system (249.11 thous. in 1mL^{-1} milk) and the lowest from HBW cows in loose housing system (127.57 thous. in 1mL^{-1} milk).

CONCLUSIONS

Housing system not only refers to the way that cows are located in farm, but also it is main indicator of feeding and milking conditions. In loose housing system cows characterized with shorter lifespan, but average lifetime and daily milk production was higher in those farms. On the other hand in tie stall housing farms cows characterized with lower productivity, and lower culling rates, which indirectly points of better health situation in this housing groups. In tie stall housing farms there are high potential of improvement in milk productivity and also quality aspect, and as one of main steps in this direction could be rationalized and balanced feeding. The tendency showed that Holstein Black and White cows had higher milk productivity than Latvian Brown cows, but their productivity is strongly dependant from the housing conditions. As Latvian Brown breed cows have better adaptability to rapid environment changes they are more suitable for grazing system and tie stall housing than Holstein Black and White breed cows.

ACKNOWLEDGEMENTS. For financial support during preparation of study: National Research Programme Project 2014–2017.Agricultural Resources for Sustainable Production of Qualitative and Healthy Foods in Latvia. *Project No. 3* Genetic research on local dairy cows and pigs economically important traits.

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Agronomy Research **15**(2), 376–387, 2017

The economic sustainability of small–scale biogas plants in the Italian context: the case of the cover slab technology

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Abstract. The growing interest on renewable energies, together with the public financial incentive systems established in several countries, has driven a fast innovation in the field of energy technologies, with the main objective to increase their sustainability.
This paper focuses on the production of biogas from agro–residues and animal manure; with particular attention to small-scale plants.
Based on a real case located in northern Italy, and taking into consideration the Italian public financial incentive system currently in force, the economic profitability of the cover slab technology is analysed, putting into evidence the main factors that affect it.

Key words: Anaerobic digestion, small–scale biogas plants, Italian biofuel plants.

INTRODUCTION

It is a fact that energy demand is growing worldwide, due both to population growth and economic development. At the same time, pressure on the environment to satisfy energy needs is increasing and the risk of compromising the possibility for future generations to get access to natural resources is concrete.

It is therefore our duty to seek for sustainable processes and technologies, in order to control this risk. In this sense, biogas energy seems to be a great opportunity to exploit.

Biogas energy comes from biomass, which is the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as biodegradable fraction of industrial and municipal waste. In the last two decades, a lot of interest has been posed to the development of technologies capable to optimize the entire biogas energy process (Eder et al., 2007; Deublein & Steinhauser, 2010; Villarini et al., 2011).

To improve the biogas energy diffusion and to exploit its potential, one of the necessary conditions is the availability of sustainable technologies for biogas plants, particularly from the environmental and economic point of view (Berglund & Börjesson, 2006; Hartmann, 2006; Murphy & Power, 2009; Pöschl et al., 2010; Blengini et al., 2011; Akbulut, 2012). In this regard, public financial incentives for biogas producers guaranteed by different Countries play an important role (Massaro et al., 2015).

This paper is focused on the economic sustainability small sized biogas plants and in particular on the cover slab technology.

To date, small sized plants have been the most diffuse solutions for the production of biogas in developing countries (Food and Agricultural Organisation (FAO), 1996; Asikainen, 2004; Balasubramaniyam et al., 2008; Ulrich et al., 2009; Rakotojaona, 2013; Vögeli et al., 2014), where several technologies have been adopted (Kumar et al., 2015).

Today, the interest around small–scale plants is growing even in some developed countries, such as in Italy, where most biogas plants are of large scale (0.5–1 MW of power) and where recently public financial incentives have been redirected in order to favour small–scale plants.

In this paper, after an analysis of the technologies spreading today in Italy for small–scale plants, the economic sustainability of the cover slab technology is assessed through the analysis of a real case in the context of northern Italy. In the same context, the cover slab technology has demonstrated to be a promising solution with respect to the environmental sustainability (Collotta & Tomasoni, 2017).

Finally, conclusions are drawn also in order to evaluate the dependence of the economic profitability of each technology on public financial incentives.

MATERIALS AND METHODS

The Italian biogas context

General framework

In 2014, the EU biogas energy production was estimated to be about 14,9 Mtoe (Million tonnes of oil equivalent) coming from different sources as landfill gas, sewage sludge gas and other biogas from anaerobic fermentation (agricultural feedstock and agro–residues) (EurObserv'ER, 2015).

With regard to the Italian context, at the end of 2013, the whole biogas plants installed power was about 756 MWe, while the number of plants was close to a thousand (994). Almost all plants are installed in northern regions and about 58% allows the co–digestion of animal manure and energy crops, for example maize, sorghum, and agro–residues. Biogas in Italy is estimated to have the potential capacity to produce about 6.5 billion of m^3 $year^{-1}$ of CH_4 and about 20 t Wh $year^{-1}$ of electric energy (Colonna, 2011; Piccinini, 2013).

Installed power and number of plants are fast growing, as shown in Table 1. In the period 2011–2015, for example the number of biogas plants moved from 521 to the 994: an increase of about 47% in only one year 2011–2012). The same trend is observed also with regard to the whole electric power installed (Fabbri et al., 2013).

Table 1. Biogas plants installed in Italy

	April 2007	March 2010	May 2011	December 2012	December 2013	December 2014
Number of plants	154	273	521	994	1,391	1,491
Whole electric power (MW_e)	49	140	350	756	1,105	n/a
Average power (kW_e)	318	513	672	761	n/a	n/a

With regard to the size of the plants installed, in terms of electric power and its trend, Table 2 shows the distribution of the number of new plants among different electric power classes in the period 2005–2012.

Table 2. Trend of Biogas plants in Italy

Electric power	2005	2006	2007	2008	2009	2010	2011	2012
≤ 100 kW_e	1	1	6	7	1	11	5	9
101–500 kW_e	3	3	7	7	14	17	57	68
501–1,000 kW_e	1	4	11	20	33	74	193	256
> 1,000 kW_e	1	3	0	3	1	3	7	2
Total	7	11	24	37	50	106	273	350

As it clearly appears, the large majority of the plants installed in Italy up to the end of 2012 are medium to large sized plants, with an electric power that goes from 500 to 1,000 kW_e.

The public financial incentive system and the small sized plants

The fast growing of the number of biogas plants observed in Italy in the last few years can be largely ascribed to the presence of generous public financial incentives to the exploitation of biogas (Massaro et al., 2015), and in particular to the production of electric energy from biogas 280 € MWh^{-1}), established by the so called 'D.M. 18 December 2008' law (Ministero dello Sviluppo Economico, 2008).

On 1st of January 2013, the structure of the financial incentive system was modified with the coming into force of the so called 'D.M. 6 July 2012' law, which outperformed the former legislation (Ministero dello Sviluppo Economico, 2012). More recently, on 23th June 2016 new financial incentive system has been introduced to encourage the production of electricity and heat using renewable sources (Ministero dello Sviluppo Economico, 2016a).

D.M. 23 June 2016 aims at reaching the objectives defined in the European Directive 2009/28/EC of the European Parliament and of the Council of 23rd April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (European Parliament, 2009). It establishes new ways of encouraging the production of electricity from plants renewable energy sources other than photovoltaic panels, with a power not exceeding 1 kW.

The financial incentives provided by D.M. 23 June 2016 apply to new facilities, fully rebuilt or re–activated plants which came into operation from 29 of June 2016 onwards. This decree establishes also a maximum national cap of €5.8 billion for public funds supporting renewable energy plants.

Further, in December 2016 a national decree allowed for the first time the use of biomethane as a transport fuel (Ministero dello Sviluppo Economico, 2016b). This law encouraging the production and use of biomethane in Italy, where currently circulates more than 800.000 Natural Gas Vehicles (NGV) (Seisler, 2014).

The financial incentives for biogas plants consist of two different parts. A first part, called 'basic incentive', which include also the price of electric energy, is based both on the electric power installed and on the organic matrices used for the anaerobic digestion process. The second part, regardless of the size, is related to the presence of a high efficiency cogeneration system and to the reduction of the nitrogen concentration in the digestate). All financial incentives for biogas plants are guaranteed for a time period of 20 years. Table 3 shows the values of the basic incentives.

Table 3. Public financial incentives for biogas plants in Italy (€ MWh^{-1})

Organic matrices	Electric power (kW_e)				
	1–300	300–600	600–1,000	1,000–5,000	> 5,000
Products of biological origin	170	140	120	97	85
By–products of biological origin > 70 %	233	180	160	112	–

As clearly shown, the highest incentive rates are targeted at small sized plants, which is an innovation with respect to the former legislation. Moreover, small sized plants are today advantaged by the simplified bureaucratic procedure for the authorization. In particular, plants with power installed under 100 kW_e do not require any authorizations, while for larger plants it is required to apply in advance to special registers or to win dedicated auctions.

Finally, plants up to 100 kW_e are connected at low voltage electrical grid instead of medium voltage, which may reduce costs for grid connections. Considering all these evidences, it is expected to observe in the next future a growing interest and an increasing market demand for small sized plants.

Biogas technologies for small sized plants

As stated above, recent Italian legislation favors the diffusion of small sized plants for the production of biogas. At any rate, to improve the biogas energy diffusion and to exploit its potential, one of the necessary conditions is the availability of sustainable technologies for biogas plants, particularly from the environmental and economic point of view (Walla & Schneeberger, 2008).

Technologies for small sized plants are not as mature as technologies for medium or large sized plants (Eder et al., 2007; Deublein & Steinhauser, 2010; Villarini et al., 2011). The most adopted approach consists in the miniaturization and simplification of the structure of larger plants (Singh & Sooch, 2004; Kimming et al., 2011; Patterson et al., 2011).

In a biogas plant, the critical element is the 'digester', in which the biodegradable fraction of biomass is fermented through anaerobic digestion and produces biogas that primarily consists of methane (CH_4) and carbon dioxide (CO_2). The percentage of methane depends on the type of organic substances that constitute the biomass, on the technology and on the size of the plant, and generally moves from 50% up to 80%.

The anaerobic digestion of biomass is made of four subsequent phases: hydrolysis, acidogenesis, acetogenesis and methanogenesis. Traditional medium or large sized plants have a structure that reflects these phases, with one or more digester devoted to each of the four phases, plus other facilities for preparatory or conclusive phases (Eder et al., 2007).

In small sized plants, one or more of the digestion phases are grouped in order to minimize or reduce the plant costs related to the civil structure (cement tanks) and to the electro–mechanical components such as pumps and mixers (Berglund & Börjesson, 2006; Ishikawa et al., 2006; Poeschl et al., 2012). Fig. 1 shows three possible structures for small sized plants.

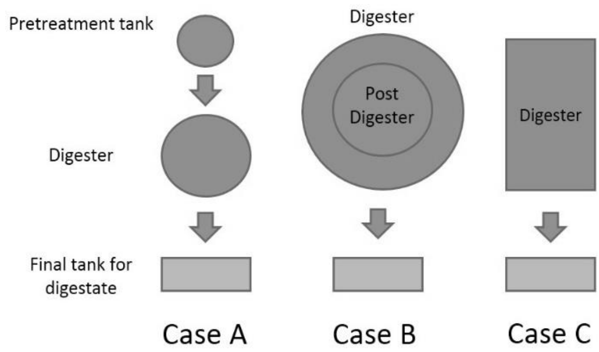

Figure 1. Schemes for biogas small sized plants.

Currently, even though the market is still limited, it is possible to identify different available technologies for small sized plants (presented in Fig. 1). In the following, three different alternatives of case A (bags technology, balloon cover technology and cover slab technology) for plants with a 100 kW_e cogenerator with 8,000 h y^{-1} are introduced.

Bags technology

In this case, the digestion of biomass takes place within a bag. Bags were initially used as a flexible system for the storage of liquid and manure and were subsequently converted in bags digester for the anaerobic fermentation. The scheme of a biogas plant with bags technology is presented in Fig. 2; this scheme is one of the most diffuse even in developing countries (Aguilar, 2001; Cheng et al., 2014). The plant consists of a pre–treatment tank, a digester, a cogenerator and an adjoining room with an adjoining heat exchanger.

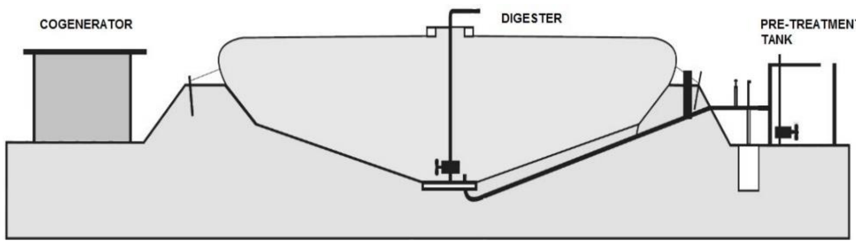

Figure 2. Scheme of a biogas plant with bags technology.

The digester is made of a bag in which the fermentative phenomena generated by the organic substance take place. The structure of the bags, made of polyester fabric, is generally capable to store up to 3,000 m^3 of matter. For the case of a small sized plant considered, two bags of 1,800 m^3 each may be necessary, with an area occupation of about 1,200 m^2.

The digester is equipped with internal mixers allowing agitation of the slurry, which optimizes the anaerobic digestion process. Besides this, each bag is heated through a heat exchanger plate placed externally.

The pre–treatment tank is a special tank equipped with an agitator that homogenizes manure with substrates that are inlaid. Also during pre–treatment biomass is heated.

Balloon cover technology

This type of biogas plants are provided with a pre–treatment tank for loading the manure to the digester and a stationary mixer feeder for loading the substrates (Sasse, 1988; Villarini et al., 2011). The digester consists of a concrete circular structure with a balloon cover with a volume of 2,000 m^3 in which biogas is stored (presented in Fig. 3). The digester is equipped with a heating system and mixers that agitates the liquid inside the tank.

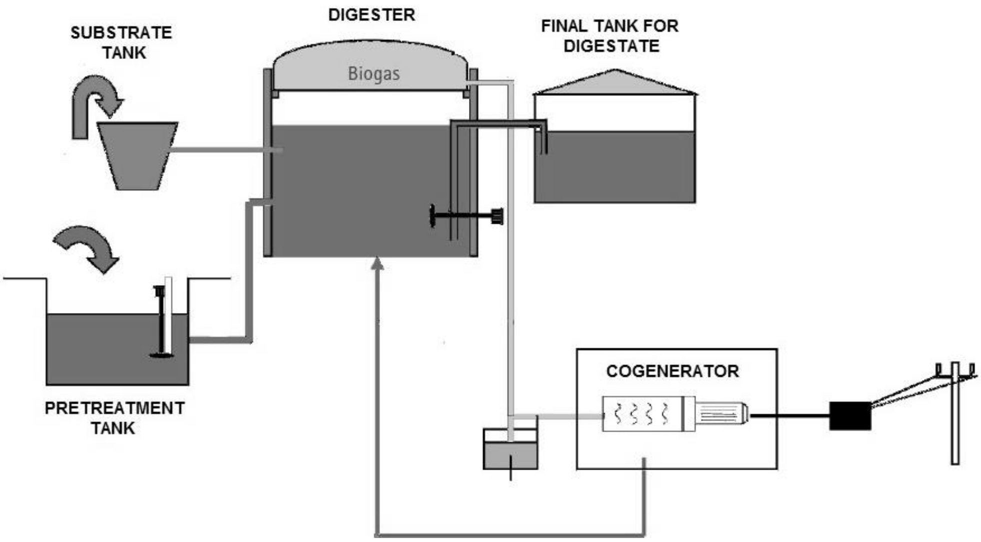

Figure 3. Scheme of a biogas plant with balloon cover technology.

In a typical configuration, the pre–treatment facility needs two different tanks as manure and molasses are loaded in the digester separately through a pump. By–products are loaded with a mixer feeder without preheating treatment. The fermentation phase follows the pre–treatment phase and the digester occupies an area of about 800 m^2.

Cover slab technology

A biogas plant with cover slab technology consists of: a pre–treatment tank, a volumetric pump with shredder, a compact digester, a final tank for digested material and a co–generator (Villarini et al., 2011; Ramatsa et al., 2014; Shukla et al., 2015). The pre–treatment tank volume is about 50 m^3 and is equipped with a system for the mixing and homogenization of manure with substrates.

To ensure a better performance, especially in winter, the pre–treatment tank is also equipped with a heating system. A volumetric pump and a shredder send the heated fluid to the digester and circulate it inside the pre–treatment tank.

The digester consists of a compact circular tank with a volume 700 m^3 and is sealed with a rigid cover slab which allows a high thermal insulation; it is equipped with a heating system that allows maintaining constant internal temperature of 40 °C. Moreover, the presence of the mixers allows agitating automatically the liquid inside the tank. The final tank for digestate collects through a pipe the digestate that comes out of the digester. The scheme of the biogas plant with cover slab is presented in Fig. 4.

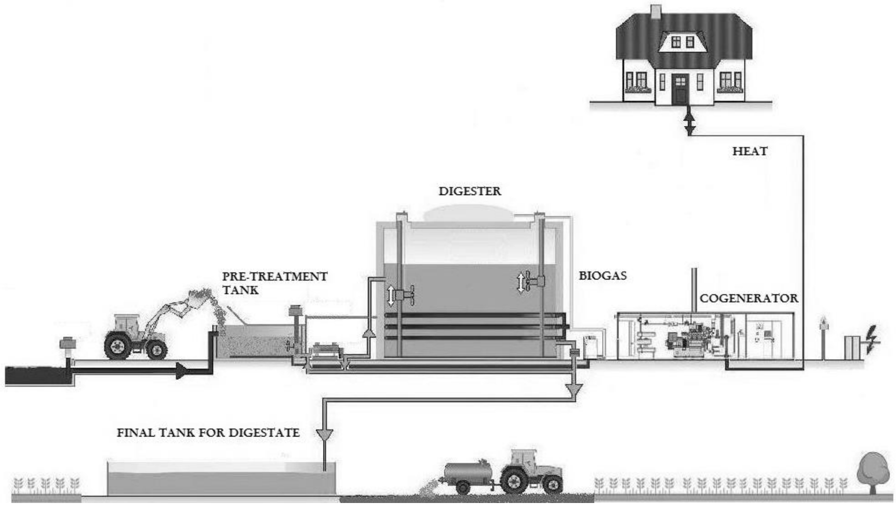

Figure 4. Scheme of the biogas plant with cover slab technology.

This kind of technology introduces the innovative slab in the digester; this structure increases the energy performance of the plants.

Economic analysis

The economic performance of a technology is an important aspect when evaluating its sustainability. In general, leading an economic analysis of biogas plants, it is opportune to consider revenues, coming from electric energy and heat produced, and costs sustained (Murphy & Power, 2009; Akbulut, 2012). With regards to costs, common classifications identify two main types of costs: plant costs and operational costs (including maintenance, insurance, feeding materials, etc.).

With reference to the three technologies above introduced, based on some interviews with several designers, manufacturers and users of biogas plants operating in Italy, it is possible to say that the balloon cover technology has the lower plant cost, avoiding most of the civil works, and the highest operational costs, requiring a higher energy consumption to heat the digestate. On the contrary, the balloon cover technology has the highest plant cost. This is mainly due to the presence of a stationary mixer feeder. Moreover, with reference to operational costs, the net heat production is lower with respect to the cover slab and the self consumption of electric energy is higher.

With reference to the environmental performance of the same three alternative technologies, in a previous work from the authors, a comparison among them has been carried out through a life cycle assessment analysis, which is a methodology to assess the environmental impacts associated with all the stages of a product's life from–cradle–to–grave (Collotta & Tomasoni, 2017).

The results obtained, referred to the Italian context showed that the balloon cover technology has the worst performance in all environmental impact categories, while the cover slab technology seems to be the most preferable, mainly thanks to a consistent energy saving, in terms of heat and electricity, due to the reduction of energy dispersions and thus of energy self–absorption, which is about 10% less with respect to bags technology and 20% less with respect to balloon technology.

Scenarios overview

For this reason, it is of great importance to conduct a deeper analysis of the economic performance of the cover slab technology. The analysis refers to a real case of a plant located in the Lombardia Region (northern Italy). In particular, plant and operational costs, as far as revenues, were first estimated before the design and the construction of the plant and then refined gathering data on the field for 6 months after the start of plant operations.

To obtain more interesting results, for the estimation and the calculation of the revenues, it was anyway hypothesized to consider the financial incentives of the new D.M. 23/06/2016 law.

Table 4 summarizes the main technical characteristics of the plant under study.

Table 4. Technical characteristics of the plant under study

Capacity of the digester (gross)	858 m^3 (6 m height, 13.5 m diameter)
Capacity of the digester (net)	770 m^3
Biogas storage volume	165 m^3 (90 m^3 digester + 75 m^3 gasometer)
Methane concentration in biogas	55–60%
Retention time of digestate	32 days 2 days pre–treatment + 30 days digester)
Electric power of the cogenerator	100 kW_e
Organic load of the digester	3.29 kg VS m^{-3} day^{-1}
Energy efficiency	0.46 m^3 biogas per kg VS

For the economic analysis, it was originally hypothesized to feed the plant with 7,753 ton $year^{-1}$ of biomass, composed by 7,198 tons $year^{-1}$ of animal slurry with a quantity of straw allowing to reach a solid substance concentration of about 10% to 13%, 360 tons $year^{-1}$ of olive pomace and 195 tons $year^{-1}$ of molasses. Employing a cogenerator with an electric power of 100 kW_e, the expected yearly gross electric energy production was 760,000 kWh_e, while the expected yearly gross heat production was 540,000 kWh_{therm}. All net heat energy recovered is used within the farm where the plant is located.

The comparison between expected and actual data highlighted surprising differences, in particular with respect to costs. In fact, a substantially modified recipe of the biomass feeding the plant was observed and this had a strong effect on the operational costs.

Table 5 shows the expected and the actual quantities of all biomass components, while.

Table 5. Expected and actual biomass composition

Components	Expected values	Actual values
Animal slurry	7.198,0 ton $year^{-1}$	7.198,0 ton $year^{-1}$
Olive pomace	360,0 ton $year^{-1}$	150,0 ton $year^{-1}$
Molasses	195,0 ton $year^{-1}$	0,0 ton $year^{-1}$
Total	7.753,0 ton $year^{-1}$	7.348,0 ton $year^{-1}$

RESULTS AND DISCUSSION

Table 6 shows the expected and actual values of gross and net heat and electric energy production.

Table 6. Expected and actual heat and electric energy production

Output	Expected values	Actual values
Gross electric energy	760,000 kWh_e	–
Net electric energy	690,000 kWh_e	681,160 kWh_e
Gross heat	540,000 kWh_{therm}	–
Net heat	125,000 kWh_{therm}	122,233 kWh_{therm}

The main differences observed belong to the reduction of the employ of biomass other than animal slurry. In fact, the quantity of olive pomace is halved and the molasses are completely avoided. This had a positive impact both on the environmental performance of the plant and on the profitability of the investment, especially for the high cost of molasses, as specified below.

A first effect of the avoidance of molasses consumption is related to plant costs, as it would be possible to avoid the storage tank and pipelines for molasses feeding (for this analysis, this effect was not considered, as the plant studied has both the storage tank and pipelines for molasses feeding).

A second and most important effect is related to operational costs, as it is not necessary to bear the cost of molasses, which can have a great influence on the whole profitability of the investment. This is due to the fact that the thermal insulation of the digester obtainable with the cover slab technology, which is higher than those reachable with other technologies, allowed to reach temperatures above the mesophilic status (about 42–45 °C), as measured on the field, allowing higher efficiency in biogas production even without molasses and olive pomace.

An important issue to highlight relates to the composition of the animal slurry and, in particular, to the particular straw used. In fact, for the specific case considered, the animal straw consisted of pellets straw, instead of bulk straw commonly used.

Pellets straw is a matter that is now spreading among farmers and is a substitute of bulk straw, i.e. it is used to create a layer of litter on the mats of the bunks. The special shape (the diameter of pellets varies from 7 to 8 mm), the specific weight and the high absorption capacity of pellets straw allow farmers to obtain a very persistent and dry layer of litter. Thin dimensions of pellets straw favors also the anaerobic digestion of animal slurry and thus increase its efficiency.

The following Table 7 and Table 8 show the expected and actual annual revenues and costs.

No significant differences were observed between expected plant costs and actual plant costs, which were equal to 600,000 €.

For the economic analysis, the net present value and the payback time were calculated with a discounting rate of 4% and an useful life of 20 years. Even though this is a long time period for the evaluation of investment returns, we adopted it as it is the time period in which the financial incentives are guaranteed. Table 9 shows the results of the analysis.

Table 7. Expected annual revenues and operational costs

Revenue items	Quantity	Unit revenue	Total revenues
Net electric energy	690,000 kWh_e	0.233 € kWh_e^{-1}	160,770.00 €
Net heat energy	125,000 kWh_{therm}	0.01 € kWh_{therm}^{-1}	1,250.00 €
Total revenues	–	–	162,020.00 €
Cost items	**Quantity**	**Unit cost**	**Total costs**
Service and maintenance	760,000 kWh_e	0.03 € kWh_e^{-1}	22,800.00 €
Supervision and external assistance	–	–	4,000.00 €
Olive pomace	360 ton	25 € ton^{-1}	9,000.00 €
Molasses	195 ton	200 € ton^{-1}	39,000.00 €
Insurance	–	–	4,000.00 €
Other costs	–	–	6,000.00 €
Total costs	–	–	84,800.00 €

Table 8. Actual annual revenues and operational costs

Revenue items	Quantity	Unit revenue	Total revenues
Net electric energy	681,160 kWh_e	0.233 € kWh_e^{-1}	158,710.28 €
Net heat energy	122,233 kWh_{therm}	0.01 € kWh_{therm}^{-1}	1,222.33 €
Total revenues	–	–	159,932.61 €
Cost items	**Quantity**	**Unit cost**	**Total costs**
Service and maintenance	760,000 kWh_e	0.03 € kW_e^{-1}	22,800.00 €
Supervision and external assistance	–	–	4,000.00 €
Olive pomace	150 ton	25 € ton^{-1}	3,750.00 €
Molasses	0 ton	200 € ton^{-1}	0.00 €
Insurance	–	–	4,000.00 €
Other costs	–	–	6,000.00 €
Total costs	–	–	40,550.00 €

Table 9. Expected and actual annual profit and payback period

	Net present value	Payback period
Expected values	449,445 €	9.4 years
Actual values	880,717 €	5.7 years

As Table 9 shows, the net present value is almost doubled and the payback period almost halved, bringing to a result that is quite better that what was expected. Greater results could be obtained with further simplification of the plant, in particular avoiding the adoption of the storage tank and pipelines for molasses feeding.

CONCLUSIONS

To improve the biogas energy diffusion and to exploit its potential, the availability of sustainable technologies for biogas plants is a necessary condition, particularly from the environmental and economic point of view.

In Italy, a recent innovation of the public financial incentive system for biogas energy, due to a renewed legislation, favors small sized plants instead of traditional larger plants.

In this paper, an economic analysis of the cover slab technology for small sized biogas plant has been carried out. In particular, an investment profitability assessment is reported, referred to a real case of a plant installed in northern Italy and adopting the cover slab technology. Thanks to the high insulation of the digester obtainable with the rigid cover slab, this technology allows to reach high temperature of biomass and enhance efficiency reducing the use of biomass other than animal slurry. This has a positive effect on the operational costs, which are halved.

Considering the overall profitability of the investment, public financial incentives for biogas energy still play an important role, as without them revenues would be halved and payback time would not be acceptable.

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Agronomy Research **15**(2), 388–394, 2017

Physical properties of wastes from furniture industry for energy purposes

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Abstract. The aim of the study was to determine the physical properties such as moisture content, particle size distribution, density and calorific value of wastes from wood-based boards and to determine their suitability for energy purposes. The tested material included wastes from tooling fibreboards (MDF) and raw (PWP) and laminated (PWO) chipboards. Tests were conducted according to the standards. The materials from wastes after mechanical boards tooling were characterized by a similar low moisture content. The geometric mean of particle size values were 0.38 mm, 0.64 mm and 0.57 mm, respectively for MDF, PWO and PWP. The particle size distributions were right-hand skewed and non-aligned. It was found that the prevailing share had the smallest fraction and its largest share had wastes from MDF. Regarding to the high calorific value and low moisture content and high bulk density, it could be stated that the wastes from furniture industry are a good raw materials for energy purposes. These wastes can be combusted at proper conditions of this process.

Key words: wastes, furniture industry, fibreboards, chipboards.

INTRODUCTION

The intensive development of new technologies conducive to modern composite materials production such as wood-based boards that have a majority share of wood raw material in a different form. Other materials used in board production are i.e. flax, bagasse or straw (Thoemen et al., 2010). In the furniture industry the production of boards includes shredding and binding lignocellulose particles with organic or synthetic binders throw bonding and compressing at high pressure and temperature values. Products made of wood or boards are produced according to high standards under quality control of each raw material (Kaputa, 2004). These products have to meet restrictive requirements of standards and quality and safety certificates.

Popular boards used in the furniture industry are chipboards and fibreboards (Fierek, 2013). They contain about 90% of pure biomass in the form of wood chips and also because of the low moisture they have a high calorific value (at least 17 MJ kg^{-1}). They should be a great source of energy in the plants that produce a large amounts of chips, sawdust and dust during cutting of wood-based boards. Although these residues meet all the criteria of biomass, in Poland they are regarded as wastes another than hazardous (Dz.U. 2013 poz. 21), due to the share of synthetic ingredients, adhesives and other additives. Disposal of waste products from furniture plants is not yet sufficiently resolved, however, it can be done by burning, which also provide valuable energy (Kajda-Szcześniak, 2013). Boilers for burning such waste are different from standard boilers to biomass and, above all, they should be equipped with exhaust gas cleaning system, and additionally at least one auxiliary burner for each combustion chamber (Wasilewski & Hrycko, 2010). During the combustion process the minimum temperature of the gases in the plant must be at least 850°C, and in the case of hazardous waste, where the proportion of chlorinated compounds is more than 1%, the minimum temperature is 1,100°C. Moreover, slag and ash may not contain more than 3% organic carbon.

The energy use of wood residues incudes processing of dust and sawdust is similar to biomass conversion and properties of the raw material should be comparable. The main property of biomass is the moisture content. A high moisture content of raw material affects negatively on the calorific value of biomass (Dzurenda et al., 2011) and worsens the mechanical properties, which has an impact on the process of combustion – can results in lowering the temperature of the process (Głodek, 2010). The bulk density depends on type of biomass and affects the transport and storage. A property inversely proportional to the density is the particle size (Bitra et al., 2009). The mean value of particle sizes and standard deviation depend on the type of material and setting of machines technical parameters (Hejft, 2002).

Therefore, a thermal processing of such wastes requires knowledge of the characteristic physical parameters and properties of the raw materials that could be used for energy purposes. For that reason, the aim of the study was to determine the moisture content, particle size distribution, density and calorific value of the wastes from wood-based boards.

MATERIALS AND METHODS

For tests the material from three types of wood-based boards after tooling were used. The raw material were obtained from furniture manufacture BOMA Ltd. in Poland. Samples were collected from tooling the fibreboards by milling machine (marked in the manuscript as MDF), laminated chipboard (PWO) and raw chipboards (PWP) (Fig 1).

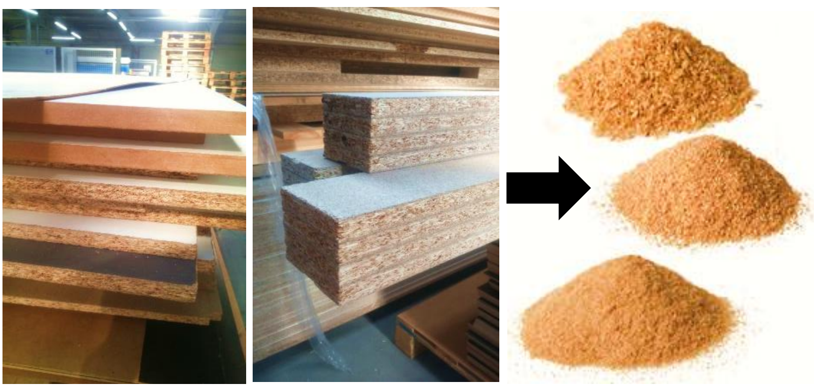

Figure 1. Chipboards and fibreboards and their residues (wastes) after tooling.

MDF boards were made of 88% of wood from pine and fir, 10% of amine glue and 2% of water and emulsion. Chipboards were made of 85% of chips from pine and spruce, the rest were resin, repellents and in the case of PWO the decorative paper. The products were produced without the addition of chlorinated compounds and wood preservatives and they can be burned for energy.

Studies of physical properties of these wastes were carried out at the Department of Agricultural and Forest Machinery, WULS. The waste material was analysed regarding to its usefulness not only for direct combustion, but also to its suitability for the pressure agglomeration and production of pellets.

The scope of research included determination of parameters of random chosen samples of biomass in the form of wastes from wood-based panels: moisture content, particle size distribution, bulk density and gross calorific value. The all tests were performed according to standards. To sieve analysis the separator with oscillatory motion in the vertical plane was used. Each type of tested material was sieved five times and a single sample was 50 g. All parameters of particle size distribution were calculated according to the standards and formulas described by Rosin & Rammler (1993), Folk & Ward (1957) and CFI (1982). The heating value was measured using the standard KL-10 calorimeter. The milled sample of 1 g of the material was weighted with accuracy of 0.0001 g on the electronic scale RADWAG WPA 40/160/C/1 and combusted. Each trial was repeated five times.

RESULTS AND DISCUSSION

The tested material from MDF, PWO and PWP had a low similar moisture 4.95%, 5.18% and 5.2%, respectively. The MDF was characterized by the lowest bulk density and it was 321 kg m^{-3}. Wastes from chipboards had clearly higher bulk density. The PWP material was characterized by the highest density 361 kg m^{-3} and the density of PWO was 351 kg m^{-3}. The bulk density of tested materials were similar to the density of other raw materials used for energy purposes. It was similar to chips from spruce 328 kg m^{-3} and higher than sawdust 160 kg m^{-3} but in turn, the pellets i.e. from straw has higher bulk density 620–650 kg m^{-3} (Komorowicz et al., 2009).

The appropriate structure of particles length is one of the most important parameters characterizing the material to be used for energy purposes. Uniformity and fineness of waste from wood-based panels affect the quality of the material to be burned or used for other purposes, eg. production of pellets. On the basis of results obtained from sieve analysis it could be stated that the particle size distributions were non-aligned (Fig. 2). The percentage mass share of fraction decreased with diagonal screen opening size increase. That indicates that in all cases, most of the material remained on the sieves with the smallest dimensions and at the bottom. Whereas the least material was on the sieves 2.81 mm, 3.99 mm and 5.65 mm. For MDF and PWO on the two highest sieves was no material but the PWO and PWP particle size distributions had similar characteristics. It follows from this that, regardless of the type of tooling and laminating, chipboards had similar particle size distributions, in contrast with the MDF waste, which had considerably more fine particles and dust. The longest particles (0.64 mm) had PWO material and the smallest had MDF (0.38 mm) (Fig. 3).

Particle size distributions shown in the Fig. 2 were asymmetrical with right-hand skewness. This is evidenced by the value of skewness, on the basis of which it can be concluded about the prevalence of the share of fine particles and by the value of inclusive graphic skewness (*GS*) with values from 0.32–0.43. According to Folk & Ward (1957) all of particle size distributions were fine skewed ($0.3 \leq GS \leq 1.0$) and mesokurtic ($0.90 \leq K \leq 1.11$).

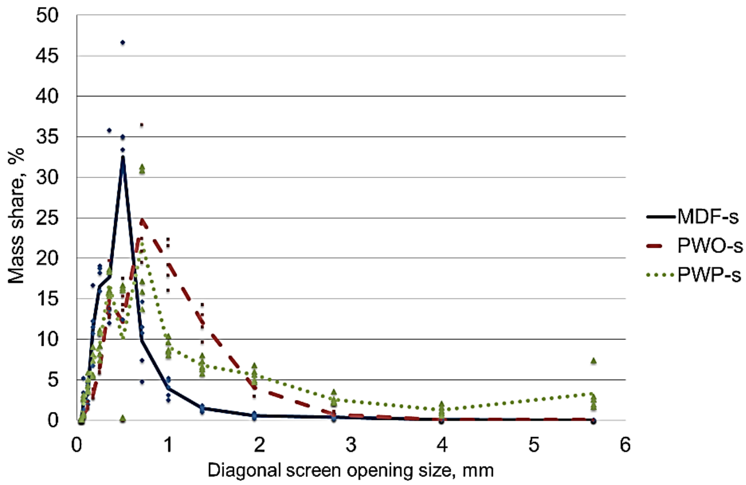

Figure 2. The MDF, PWO and PWP particle size distribution.

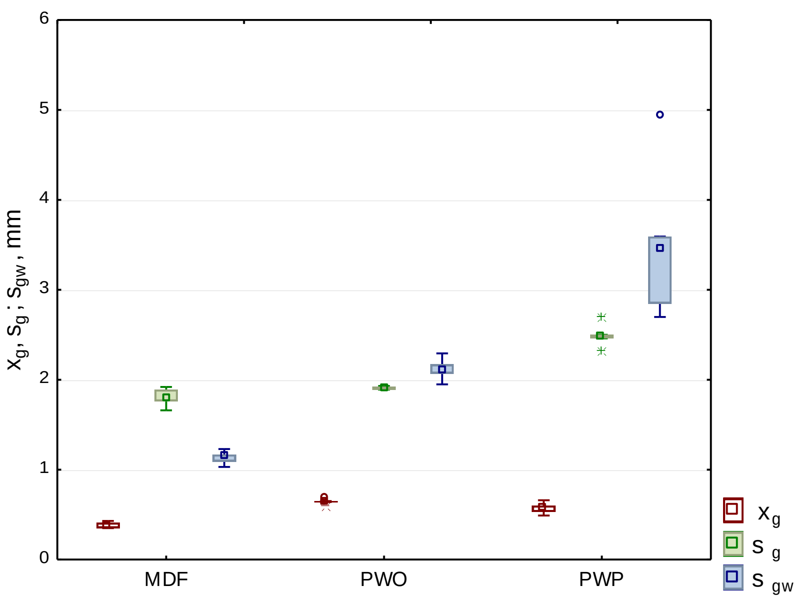

Figure 3. The MDF, PWO and PWP particle size distribution.

The Rosin-Rammler n parameter was inversely proportional to the kurtosis values (Table 1) what indicates the distribution width. Relatively high share of fine particles and dust in tested material is confirmed by high values of RS_m parameter which was inversely proportional to the Rosin-Rammler n parameter and that is consistent with other studies (Bitra et al., 2009).

The kurtosis coefficients in all cases were positive (Table 1). That indicates the distribution steepness and a slight predominance of slenderness in comparison to the normal distribution. The material of the most flat distribution was waste from tooling raw chipboard (PWP). The uniformity indexes (I_u) for wastes were differentiate and it could be stated that the type of tooling had the high influence on this indicator values.

Table 1. The average values of characteristics parameters of wastes particle size distribution

Material	x_g	x_R	n	x_{10}	x_{50}	x_{90}	RS_m	GS	K	I_u	N_{sg}	C_u	C_g	GSD_1	GSD_2	GSD_3
MDF	0.38	0.49	1.15	0.07	0.36	1.01	2.65	0.40	1.04	3.66	26.18	6.56	1.27	2.33	3.32	2.78
PWO	0.64	0.78	1.32	0.14	0.59	1.47	2.24	0.32	1.02	5.60	10.61	5.15	1.23	2.09	2.85	2.44
PWP	0.57	0.83	1.08	0.10	0.59	1.80	2.86	0.43	1.06	2.95	6.41	7.41	1.29	2.46	3.59	2.97

x_g is the geometric mean of biomass particle size; x_R is the parameter or geometric mean of Rosin-Rammler dimension; n is the Rosin-Rammler distribution parameter; x_{10}, x_{50} and x_{90} are the corresponding particle lengths in mm at respective 10%, 50%, 90% cumulative undersizes, which are also known as percentiles; RS_m is the relative span based on length; GS is the inclusive graphic skewness; K is the graphic kurtosis; I_u is the uniformity index; N_{sg} is the size guide number; C_u is the coefficient of uniformity; C_g is the coefficient of gradation; GSD_1, GSD_2, GSD_3 are the distribution geometric standard deviation of the high, low and total regions, respectively.

The coefficient of uniformity with values of 6.56 (MDF), 5.15 (PWO), 7.41 (PWP) indicates the higher scatter of particle size values, which means that particle size distributions were poorly aligned. The coefficient of gradation were similar in the range of 1–3, therefore it couldbe stated that particle size distributions were well graded.The highest values of geometric standard deviations in all regions had PWO. The tests results were close to parameters of fine fraction from straw and hay biomass (Lisowski et al., 2016).

In Table 2 the regression coefficients and their statistical asessments were shown. On the basis of obtained results can be concuded that t-Student values were quite high and p values were significant for MDF and PWO. The exception was PWP, where the insignificance of constant b in the regression equation was found. The values of regression model were high too. The values of Fisher-Snedecor test exceeded 100 at the significance level at $p < 0.0001$ and the determination coefficient R^2 was above 83% for all of the wastes.

Table 2. The values of regression coefficients and their statistical assessments

Material	Regression coefficient	Rate	Error	t-Student value	P-value	F-test	P-value for regression	R^2, %
MDF	index n	1.15	0.09	12.66	< 0.0001	160.2	< 0.0001	83.78
	constant b	0.36	0.06	5.90	< 0.0001			
PWO	index n	1.32	0.10	12.75	< 0.0001	162.68	< 0.0001	83.98
	constant b	0.14	0.07	2.00	< 0.05			
PWP	index n	1.08	0.08	12.69	< 0.0001	160.94	< 0.0001	83.84
	constant b	0.09	0.06	1.58	0.12			

The highest calorific value had the residue after MDF board tooling and it was 18.22 MJ kg^{-1}. The calorific value of PWO and PWP were 17.59 MJ $kg^{-1}$and 16.61 MJ kg^{-1}, respectively. These values are comparable to calorific values of pure wood materials and energy plants (Komorowicz et al., 2009) and wood residues such as chips and sawdust (Dzurenda et.al., 2011). These parameter indicates good suitability of tested materials for energy purposes.

CONCLUSIONS

1. In all tested materials from wastes obtained from tooling the wood-based panels, the dominated fraction was the finest one and the particle size distributions were right-hand skewed and asymmetrical and non-aligned. The biggest share of the fine fraction was characterized by the material from fibreboard (MDF).
2. Wastes from tooling of chipboards and fibreboards contain too much fine particles and dust, so they cannot be used to the pressure agglomeration process and pellets production without additional treatment.
3. Due to the high calorific value and low humidity and relatively good bulk density, residues from mechanical tooling of chipboards (PWO and the PWP) and fibreboards (MDF) are a good raw material for energy purposes. According to their good physical properties they could be a good binder to the material for pellets what requires further studies.
4. Wastes from wood-based panels are characterized by physical properties similar to materials that are commonly used for energy purposes, therefore, can be used as a source of renewable energy if the relevant parameters of thermal processing of raw materials specified in the laws are respected.

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Agronomy Research **15**(2), 395–405, 2017

Degradation of diclofenac and triclosan residues in sewage sludge compost

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Abstract. Land application of sewage sludge compost is an important and efficient tool in the remediation of industrial landscapes and agricultural soils in Estonia. A number of studies have shown that, as a rule, pharmaceuticals and personal care products (PPCPs) are neither completely removed by sewage treatment, nor completely degraded in the environment. In this study, degradation rates of diclofenac sodium (DFC) and triclosan (TCS) were determined during sewage sludge composting. Anaerobically digested and dewatered sewage sludge was mixed with sawdust at two different ratios (1:2 and 1:3 sludge/sawdust, v:v). Then aerobic composting was carried out. These ratios were chosen on the basis of previous studies on sewage sludge composting with different bulking agents. The initial concentration of DFC and TCS was 2 mg kg^{-1} in relation to dry weight (dw). Low quantities of the studied pharmaceuticals were present in sewage sludge that was used for preparing the compost mixtures used in our experiments. The background concentrations of DFC and TCS were never equal to zero. The results showed that the difference between sewage sludge and bulking agent ratios (1:2 vs 1:3) in compost samples did not significantly affect temperature profiles during the experiment. The degradation of pharmaceuticals was more complete in the compost samples where the ratio of bulking agent was higher (1:3 by volume). The average degradation level (in all compost mixtures) was 95% for DFC and 68% for TCS. Pharmaceuticals entering into the soil may affect microbial activity, plant growth and development, and may have adverse effects on living organisms.

Key words: sewage sludge compost, sawdust, fertilizers, diclofenac, triclosan.

INTRODUCTION

Compost has proven to be a valuable matter in land recultivation and forestry (Haiba et al., 2016; Järvis et al., 2016). Estonia has the world's largest exploited oil-shale basin covering about 4% of its territory. In 2001−2013 the number of active landfills in Estonia decreased from 159 to 13. Recultivation of the landscapes covered by semi-coke, oil-shale ash mountains, abandoned opencast mines and closed landfills appears to be one of the major environmental tasks in Estonia (Haiba et al., 2016). The formation of soil with its typical biota is crucial for the restoration of former mining areas and remediation of waste heaps (Kalda et al., 2015). Compost based on sewage sludge could be a useful tool in overcoming the problems associated with land recultivation. Sewage sludge contains useful organic matter and nutrients for plants (Kaonga et al., 2010). The contents of nitrogen, phosphorus and organic matter are up to 10 times higher in sewage sludge and its compost, if compared to common Estonian agricultural soils.

Composting is the major way of making the soil application of sewage sludge safer. Still, its usage as a fertilizer is limited due to a large number of toxic pollutants found in this matter (Lillenberg et al., 2010). In particular, the presence of pharmaceutical residues, even in very low concentrations. in sewage sludge compost is of great concern. The widespread use of antibiotics is the most important factor for the emergence, selection, and dissemination of antibiotic-resistant bacteria (Baquero et al., 2008; Roasto et al., 2009; Munir et al., 2011; Naquin et al., 2015; Mäesaar et al., 2016). Due to the occurrence of antibiotic resistance genes in the wastewater treatment systems, the impact of the antibiotic combinations is greater than the sum of their independent activities (Aydin et al., 2015). As a result the bacteria may develop several resistance mechanisms; this will ultimately result in multidrug resistance (Baharoglu & Mazel, 2011).

Recent years have shown intensive work directed to the development of reliable methods for the determination of pharmaceutical residues in the environment (Lillenberg et al., 2009; Kipper et al., 2011; Garcia-Rodriguez et al., 2014; Casado et al., 2015; Morales-Toledo et al., 2016), showing the increasing importance of this phenomenon. Pharmaceuticals can be degraded during composting (Poulsen & Bester, 2010; Kim et al., 2012). Among the factors which possibly promote micropollutants degradation during composting is the presence of fungi in the composted matter (Zhang et al., 2011). However, the literature data on this topic are scarce and more research is required in this area (Butkovskyi et al., 2016).

Diclofenac (DFC) is one of the most popular non-prescription medications. It is non-steroidal anti-inflammatory drug and widely used for relieving pain (Chen et al., 2015). DCF together with its human metabolites enter wastewater treatment plants (WWTPs) through sewers (Zhang et al., 2008; Sagristà et al., 2010). This is one of the most frequently detected drugs in WWTPs, having low removal efficiency and often found in high concentrations in effluent water (Stülten et al., 2008; Al-Rajab et al., 2010; Bartha et al., 2014; Osorio et al., 2014). DFC residues have been detected in sewage sludge with concentrations reported from 2 ng g^{-1} to 140 ng g^{-1} (Jelić et al., 2009; Dobor et al., 2010; Jelić et al., 2011; Loos et al., 2013). DCF residues have been detected in aqueous environment (Al-Rajab et al., 2010) where they can cause DNA damage with induced immunosuppression and genotoxicity in fish (Ribas et al., 2014). Chemical structure of DCF involves a chlorine atom and therefore its residues are not readily biodegradable in the environment. Metabolism of DFC has been studied and described in mammals, fungi and microorganisms (Huber et al., 2012; Bartha et al., 2014). DFC is acutely toxic to birds and presumably could leach into soil beneath the corpses of livestock containing DFC residues (Stülten et el., 2008; Al-Rajab et al., 2010).

Triclosan (TSC) is a broad-spectrum antimicrobial compound, commonly used in personal care products (soaps, creams, toothpastes, detergents) and housewares (cutting boards, even textiles and toys). This compound has been used for over 40 years. The use of antimicrobials and -bacterial products is increasing all over the world (Lozano et al., 2010). Today, TSC compounds are consumed in Europe at approximately 350 tons per year (Pintado-Herrera et al., 2014). TSC residues have been detected in wastewater (in concentrations ranging from 1–10 μgL^{-1}) as well as in sewage sludge (concentration range 2–8 mg kg^{-1} dry matter) (Chen et al., 2011; Loos et al., 2013). TCS residues have been found in soil fertilized with sewage sludge compost up to a concentration of 4 μg kg^{-1}. Various studies have shown that already at relatively low concentration TSC may have adverse effects to the environment – prevents bacterial metabolism, affects microbial respiratory activity and populations (Lozano et al., 2010; Chen, et al., 2011; Pintado-Herrera et al., 2014).

Though a variety of compounds and their metabolites are present in the environment, their biodegradation and ecotoxicological effects are not well known (Li et al., 2014). Toxic compounds and pharmaceutical residues in soil can affect microbial activity, plant growth and development and may have adverse effects on living organisms (Lillenberg et al., 2010). Accumulation of antimicrobials from soil into foodplants may pose a danger, as very small amounts of these drugs in everyday food may generate the strains of resistant bacteria in humans (Kipper et al., 2010).

Sawdust has proven to be an efficient bulking agent for sewage sludge composting (Banegas et al., 2007). The purpose of this pilot study was to determine the impact of different proportions of bulking agent (sawdust) on the degradation of DFC and TCS residues in sewage sludge compost.

MATERIALS AND METHODS

Chemicals and materials

Standard substances of pharmaceuticals were obtained from Sigma-Aldrich: diclofenac sodium salt (99.9%) and triclosan (99.7%). As liquid chromatography – mass spectrometry (LC-MS) eluent components, methanol (≥ 99.9%; LC-MS Ultra CHROMASOLV; Fluka), water purified in-house using Millipore Milli-Q Advantage A10 system, 1,1,1,3,3,3-hexafluoroisopropanol (HFIP, Sigma-Aldrich), NH_4OH (25%; eluent additive for LC-MS; Fluka) and formic acid (≥ 98%; puriss p.a., Sigma-Aldrich) were utilized. For sample preparation, vortex mixer VWR International, shaker Elpan 358S, centrifuge Eppendorf 5430R and ultrasonic bath Bandelin Sonorex were used. Sample extracts were filtered through Sartorius Minisart RC4 (regenerated cellulose, pore size 0.2 μm, membrane diameter 4 mm) syringe filters using disposable 2 ml syringes (Brand).

Sample collection

The anaerobically digested and dewatered by centrifugation sewage sludge samples were collected from municipal wastewater treatment plant in Tallinn (440,000 inhabitants), Estonia. The sewage sludge was mixed with sawdust at two different ratios (1:2 and 1:3 sludge: sawdust, v:v) and submitted to a process of aerobic composting. These ratios were chosen on the basis of literature (Banegas et al., 2007) and our previous studies on sludge composting with different bulking agents (straw, sawdust, oil-shale ash, wood chips) (Haiba et al., 2013; Nei et al., 2014; Nei et al., 2015). The initial concentration of every pharmaceutical was 2 mg kg^{-1} in relation to dry weight (dw). In addition to this, two reference piles (without additions of pharmaceuticals) were prepared. The content of compost samples is presented in Table 1.

Table 1. Compost samples

Sample No	Compost mixture	Mixture ratio (v:v)	Dry matter*, %	Added pharmaceuticals in compost sample
K1	Sewage sludge: sawdust	1:2	35.3	2 mg kg^{-1} (dw)
K2	Sewage sludge: sawdust	1:2	35.2	Not added
K3	Sewage sludge: sawdust	1:3	40.3	2 mg kg^{-1} (dw)
K4	Sewage sludge: sawdust	1:3	40.8	Not added

* – dry matter in the beginning of experiment.

Sample preparation

Samples were thawed at room temperature and mixed by vigorous shaking. For extraction, about 5 g of sample was precisely weighted into 50 ml polypropylene centrifuge tube. The following extraction procedure was used:

1. 15 ml of extraction solvent (1% v/v formic acid in ethanol) was added to a sample tube.
2. The mixture was Vortex-mixed for 30 s.
3. The sample tube was tightly capped and placed horizontally on a shaker (200 rpm) for 10 min.
4. The tube was turned into vertical position and shaken by hand to ensure that the solid contents are in contact with extraction solvent.
5. Extraction was continued by sonicating for 10 min.
6. Samples were centrifuged at 7,830 rpm for 5 min.
7. The extract was removed from the tube using pipette.

Extraction steps 1–7 were repeated five times with each sample. Extracts were combined in 100 ml polypropylene bottles, mixed and weighted. From each extract 15 ml was taken into 15 ml polypropylene centrifuge tube for further treatment.

Prior to LC-MS/MS analysis, sample extracts were diluted: to 100 µl extract 1,400 µl of MilliQ water were added in 1.5 ml Eppendorf tube. Automatic pipette was used for dosing, but all the solutions were weighted. The solutions were vortex-mixed and filtered through syringe filter. First five drops of filtrate were discarded and the remaining (ca 1 ml) was collected into auto-sampler vial (2 ml glass vial).

Calibration and quality control samples

Calibration and quality control samples were prepared by diluting stock solutions of analytes. Stock solutions were prepared by dissolving appropriate amount of analytes in methanol. Working standards were prepared in 1.5 ml Eppendorf tubes by diluting 600 µl of stock solution with 400 µl MilliQ water. Similarly to preparation of sample solutions, all solutions were prepared by weight, vortex-mixed and filtered through syringe filters. Concentration of calibration and quality control solutions were chosen according to the linear range for each analyte.

LC-MS/MS analysis

Sample extracts were analyzed using LC-MS/MS system consisting of ultra-high performance liquid chromatograph UHPLC Agilent 1290 Infinity and mass spectrometer Agilent 6495 Triple Quad. The liquid chromatograph consisted of the following modules: binary high-pressure gradient pump with built-in degasser, autosampler with sample compartment cooling and column thermostat. Waters XBridge C18 (150 mm ×

3 mm, 3.5 μm) analytical column and Waters Guard Cartridge (20 mm × 4.6 mm) (Waters) precolumn were used for sample analysis.

For analyte detection triple quadrupole mass spectrometer equipped with heated electrospray interface (HESI) Agilent JetStream was used. Chromatographic separation was carried out using gradient elution. As the weak component of eluent (A), 5 mM HFIP buffer solution (pH adjusted to 9 using NH_4OH) was used. The strong component of the eluent (B) was methanol. The gradient program started from 10% B and content of B was increased to 100% during 33 minutes. For the following 3 minutes isocratic (100% B) elution was used, followed by 3 min gradient to 10% B. For equilibration the column was eluted with 10% B for 4 minutes. Eluent flow rate was 0.3 ml min^{-1}, column temperature maintained at 30 °C and injection volume 10 μl. Multiple reaction monitoring (MRM) mode was used for analyte detection. MRM transitions used are presented in Table 2.

Table 2. MRM transitions, collision energies (CE) and ionization polarities used for analysis

Analyte	Precursor ion, *m/z*	Product ion, *m/z*	CE	Polarity mode
Diclofenac	296	250	10	Positive
	296	214*	40	Positive
Triclosan	289	37*	20	Negative
	289	35	10	Negative
	287	35	15	Negative

* – quantitative transition.

The following ion source and MS parameters were used for analysis: drying gas temperature 250°C and flow rate 14 l min^{-1}, nebulizing gas pressure 20 psi (138 kPa), heating gas temperature 350 °C and flow rate 11 l min^{-1}, capillary voltage 3,000 V. As drying, nebulizing, heating and collision gas nitrogen was used. The instrument was controlled using Agilent MassHunter Workstation ver B.07.00 software. For quantitative analysis Agilent MassHunter Workstation Quantitative analysis ver B.07.01 software was used.

Composting

Experiments were performed in non-transparent plastic containers. With the aim of preventing heat loss from the sides and bottom of the containers, a 5 cm thick insulation (glass wool) was used. Compost samples of about 30 L were prepared with each mixture. The solutions of pharmaceuticals were prepared as follows: 2 mg of each pharmaceutical was dissolved in 100 ml ethanol and after that 400 ml distilled water was added to the solution. Then the solutions of the studied pharmaceuticals (DCF and TSC) were mixed with compost samples. The room temperature was 23–26 °C. Compost samples were turned periodically (5–6 times per week) to provide sufficient aeration and homogenization. The moisture content of the mixtures was maintained at 60–70% of their water holding capacity throughout the composting period. The temperature of each mixture was monitored daily at 3–4 different points in each sample with a digital temperature probe and mercury thermometer. The duration of experiment was 30 days. The samples were homogenized before analysing – taken randomly from different parts of the sample.

Determination of the microbial characteristics of sewage sludge compost

The methodology used for the determination of microbial characteristics of sewage sludge compost is presented in Nei et al. (2014). Soil microbial Substrate Induced Respiration rates (SIR) were measured using manometric respirometers (Oxitop®, WTW) (Platen & Wirtz, 1999). 50 g of fieldmoist compost was amended with glycose and incubated in a closed vessel at 22 °C in the dark for 24 hours. After incubation the microbial biomass C was calculated.

To determine the microbial to fungal ratio, selective inhibition technique was used. In order to assess the fungal biomass, samples were treated with streptomycin (12 g kg^{-1}) and glucose (5 g kg^{-1}); for the determination of bacterial biomass, samples were treated with cyxloheximide (6 g kg^{-1}) and glucose (5 g kg^{-1}). Reference samples were treated with cyxloheximide (12 g kg^{-1}) and streptomycin (6 g kg^{-1}). All the samples were incubated in closed vessels at 22 °C in the darkness for 24 hours and then the biomass C was calculated (Nei et al., 2014).

RESULTS AND DISCUSSION

In the beginning of the experiment the growth of microbial population caused the rise of temperature drastically in compost samples with pharmaceuticals (samples K1 and K3), if compared to reference samples (K2 and K4) (Fig. 1). Although SIR profiles seemed similar in the case of all four compost samples (Table 3), the highest temperatures in compost samples K1 (57.5 °C) and K3 (52.5 °C) differed from the temperature peaks in samples K2 (42.2 °C) and K4 (41.4 °C) more than 10 °C. The reason for that might have been the difference in the ratios between fungi and bacteria (Table 3). Compost samples with pharmaceuticals (K1 and K3) had a lower ratio of fungi and bacteria. The formation time of bacteria is much shorter than that of fungi. They are smaller and therefore abundant in compost (Chroni et al., 2009). Bacteria have a more active metabolism and due to this it was natural that in the beginning of the experiment the temperature rose faster in compost samples K1 and K3.

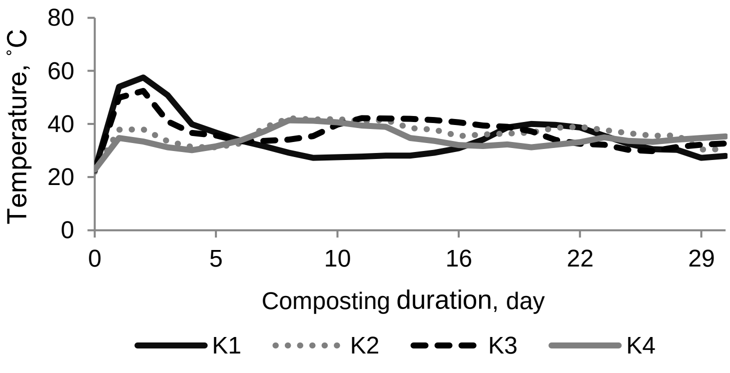

Figure 1. Temperature profiles during one month composting for 1:2 (v:v) sewage sludge – sawdust mixtures: K1 – containing pharmaceuticals; K2 – without pharmaceuticals and for 1:3 (v:v) sewage sludge – sawdust mixtures: K3 – containing pharmaceuticals; K4 – without pharmaceuticals.

After one week the ratio of fungi and bacteria was reduced in compost samples with additional pharmaceuticals, but biomass of microorganisms had increased in the case of samples K2 and K4. It could be the reason for higher temperatures in samples K2 and K4 (Fig. 1).

Table 3. The average bacterial-to-fungal ratio, substrate induced respiration (SIR) profiles and moisture content during 30 days

Sample No	Ratio of fungal to bacteria	SIR, mg biomass C g^{-1} dw	Moisture, %
K1	0.974 ± 0.072	13.8 ± 3.5	62.6 ± 0.4
K2	0.980 ± 0.075	19.9 ± 1.2	62.6 ± 0.3
K3	0.909 ± 0.062	17.3 ± 3.2	61.6 ± 0.4
K4	0.965 ± 0.065	16.2 ± 1.1	62.2 ± 0.4

The results of the analyses indicated that none of the compost samples was originally free of DCF and TSC residues (see Table 4). Although DFC concentrations were found in relatively low amounts, the concentrations of triclosan were up to 2 mg kg^{-1} (dw). A well-managed composting process resulting in an efficient decline of residual pharmaceuticals, as shown in Kim et al. (2012), requires some extra source of organic matter, as the organic matter can elevate temperatures and provide a wide range of additional binding sites during composting. Sawdust is an organic source able to initiate efficient composting, as exhibited by elevated composting temperatures. According to Kim et al. (2012), this consequently resulted in the reduction of residual concentrations of pharmaceuticals to acceptable levels in a relatively short composting period.

After adding the pharmaceuticals to the compost mixtures their initial concentrations in dry matter were determined again. All of the concentrations were above the expected values (see Table 4) probably due to the rapid adsorption of pharmaceuticals (from liquid phase) to solid particles of sewage sludge or bulking agent. This is in agreement with the data presented in previous publications (Golet et al., 2003; Göbel et al., 2005; Yang et al. 2011; Nei et al., 2014). After one week, the concentrations of the studied pharmaceuticals were determined again. The concentrations of DFC and TCS residues had decreased by 51% and 29% in compost mixtures with sludge-sawdust ratios 1:2 (v:v). In the case of compost samples with the ratios of 1:3 (v:v) the relevant concentration drops were 42% (DFC) and 28% (TCS).

Table 4. Concentrations of diclofenac and triclosan in sewage sludge – sawdust compost samples (mg kg^{-1}, dw)

Compound	Sample No	Before spiking	1 day	1 week	1 month
Diclofenac	K1	0.086 ± 0.004	2.646 ± 0.319	1.307 ± 0.035	0.209 ± 0.010
	K3	0.064 ± 0.005	2.381 ± 0.212	1.369 ± 0.044	0.036 ± 0.002
Triclosan	K1	**1.768 ± 0.062**	4.541 ± 0.378	3.241 ± 0.202	**2.068 ± 0.138**
	K3	**1.232 ± 0.070**	3.528 ± 0.143	2.538 ± 0.089	**0.682 ± 0.019**

According to the data presented in Table 5 it is evident that the degradation of pharmaceuticals was more complete when higher ratio of sawdust was used in preparing compost mixtures.

Table 5. Extent of degradation (%) for diclofenac and triclosan during one month composting

Sample No	Diclofenac	Triclosan
K1	92	55
K3	98	81
Average	95	68

These results show clearly, that the degradation of TCS takes place only partly during one-month composting period, indicating that longer periods are needed for the more complete removal of pharmaceutical residues from sewage sludge based compost.

CONCLUSIONS

The study was carried out to demonstrate the degradation of DCF and TCS in composting processes using different ratios of sewage sludge and bulking agent (sawdust). There is strong evidence that biotic and abiotic factors contributed to the decomposition of pharmaceuticals during composting. The selection of appropriate composting technologies is clearly important in the view of decreasing the levels of pollutants in compost to acceptable levels. Higher ratios of sawdust in the mixture with sewage sludge clearly speeded up the degradation of both DCF and TCS. The results showed that the difference between sewage sludge and bulking agent ratios (1:2 vs 1:3) in composts did not significantly affect temperature profiles during the experiment. The degradation of pharmaceuticals was more complete in the compost samples where the ratio of bulking agent was higher (1:3 by volume). 30-days composting period was not sufficient for degrading TCS residues present in sludge-sawdust mixtures, whereas almost full degradation (98%) of DCF took place in the case of 1:3 sludge-sawdust sample. It is an extremely complicated task to secure the removal of organic pollutants from sewage sludge compost. More research is needed to clarify the factors speeding up the degradation of different pharmaceuticals during composting. Special attention should be payed to the intelligent and safe application of such composts.

ACKNOWLEDGEMENTS. The authors would like to thank Environmental Investment Centre of Estonia for funding this work.

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Agronomy Research **15**(2), 406–416, 2017

Regulatives for biorefineries

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Abstract. The relationship between uncertainty and risk–taking behaviour towards innovations and Common Market protection are investigated in this article. Therefore, the aim of this article is to assess points of control over market regulation protecting innovative products. It was found that risk of creative destruction due to implementation of innovations is increased by regulators due to antimonopoly metric they use. EU fiscal policy implementation in renewable fuels in Czech Republic of both EU and CZ calculations is compared. Historical data has shown that regulators have collapsed market of high condensed biofuels. Pattern of fine calculation has explained a market collapse. Comparison of excise duty of favoured biofuels was compared with subsidies for photovoltaics. Substitution of former fossil fuels taking into account excise duty and subsidies of alternative or renewable energies is less market distorting than recent tariffs of excise duty and fines to first generation biofuels.

Key words: biofuel, biodiesel, diesel, excise duty, tax policy.

INTRODUCTION

Biorefinery is understood as processing of any biomass into products, except of fuels. Still, biofuels are observed in this article to investigate impact of market access and crude oil market prices. Impact of both is valid for innovations generally, including of biorefinery ones. It is expected that biorefinery innovation has no competitors yet but, traditional crude oil substitutes will kill it by pushing forward regulation criteria, which cause irregular support and punishments of alternatives. Market access criteria may undercompensate or overcompensate one alternative against others or one country against other countries.

For example Czech biodiesel is exposed to excise duty compensations and fines while photovoltaic energy is supported until 2035 year. This example is generalising different phases of commercialisation by calculation pattern and with feedback of historical data for biofuel. This calculation with time series data has created sustainable economic environment other biorefinery or circular economy innovations oppose to alternatives and substitutes. Alternatives are products only partly satisfy future demand, oppose to substitutes. Substitutes for biorefinery products are non–renewable like products made of crude oil (De Wit & Faai, 2010; Mezule et al., 2016; Kall et al., 2016). Relationship between fossil fuels satisfying recent demand is neither alternative nor substitute but competitive.

Objective of this article was to assess points of control over market regulation of to protect innovative products of biorefineries against non–renewable or global competitors. Sustainability, social responsibility principles and efficiency indicators in derived pattern remunerating impact of regulations will allow innovative products survive into market maturity (Dumortier et al., 2011; Gorter et al., 2011).

For example, B99 blends from the United States were offered for sale at USD 53.25 per 100 liters ($2.78 a gallon) while the German cost of production for biodiesel was USD 64 per 100 liters ($3.34 a gallon). Therefore, European Biodiesel Board (EBB) forecasts that the European biodiesel industry would stagnate in coming years oppose to annual growth between 30% and 65% of past five years (Kram, 2007). Maximal volume of biofuel in fossil fuel is technically limited by standards EN 590 for diesel fuel and EN 228 for gasoline. At least 6% vol. of FAME (Fatty Acids Methyl Ester) and 4.1% vol. are sold in Czech Republic according to air protection law 201/2012. Maximal volume of FAME is 7% vol. in diesel fuel according to EN 590.[3] Biodiesel at petrol stations is called either B100 with 100% of FAME or B30 eventually synonymously SMN30 with 30% of FAME in diesel fuel and ethanol E85 with 85% vol. of bioethanol in gasoline for modified engines minimising its negative impact are highly concentrated biofuels at Czech market. It is important to distinguish between B100 in EU or B99 in USA market. The small ‘splash’ of fossil diesel, if added to a tanker of biodiesel from, for example, Malaysia, in a U.S. port, would qualify the entire shipment for the U.S. tax credit. After getting the credit, the tanker could continue to Europe–the ‘dash’–and receive European fuel tax credits. In effect, the fuel would be subsidized once by U.S. taxpayers and again by the Europeans (Kram, 2007). This repeated global story of support and collapse of biofuels, including of development and ban of biofuels in Brazil, is worth of standardisation of market access in this article.

Biofuels are supported by decreased excise duty according to law about mineral oils 353/2003. Certified origin and savings of carbon equivalent emissions according to sustainability criteria are two obligatory conditions for awarding decreased excise duty to high concentrated biofuels. Size of biofuel support is derived from need of competitiveness of biofuel and agriculture sectors and connected industry. Also policy objectives as decreased import dependence of renewable energy sources according to EU objectives decreasing emissions of greenhouse gases (GHG) justify excise duty relief for biofuels. Technically, excise duty is paid for total volume of fuel and fuel blending or producing company receives difference between total and decreased excise duty from fuel back (Bansea et al., 2011; Nazlioglu, et al., 2013). EU Commission has approved continuous support of biofuels from first July 2015 until end of 2020. Czech law has implemented this EU directive by law 382/2015 innovating laws about excise duties and air protection from 1st January 2016.

Biodiesel must be mixed with fossil diesel fuel according to EN 590 standard if sold by distributor. Higher costs of biofuels are offset by subsidy or lower excise duty, which EU regulations has changed in year 2016. Actually the new excise duty was collected with half year delay. This retroactive rule and decrease of fossil fuel prices is analysed in this article in selected months before and after rules were changed. But B100 will not return to the biofuel market immediately without corresponding subsidy.

Presented data allow to evaluate whether this policy implementation failure had positive or negative effects later (Kumar et al., 2013; Kochaphum et al., 2015; Pointner et al., 2014).

MATERIALS AND METHODS

Analysis of time series of interval indices has assessed average monthly prices for years 2015 and 2016.

Data were collected from:

- Research Institute of Agricultural Engineering, p.r.i.;
- Ministry of Industry and Trade of the Czech Republic;
- ČEPRO, joint stock company;
- Ministry of Agriculture of the Czech Republic (patterns bellow);
- Ministry of the Environment of the Czech Republik;
- Union zur Förderung von Oel– und Proteinpflanzen (UFOP).

Excise duty for biofuels was introduced in Czech Republic first time for year 2016. Therefore, relief from excise duty rate was calculated for B100 biodiesel for selected months of 2015 and 2016 years for comparison.

Following patterns were used:

$$PRb = Db - Pb \tag{1}$$

where: *PRb* is calculated level of compensation or overcompensation of biofuel in EUR per l. Negative value means no overcompensation. Overcompensation shows size of excise duty, which should be implemented for biofuel or biofuel blend with fossil fuel. *Db* is tax rate relief of biofuel in EUR per l. *Pb* is needed support for biofuel in EUR per l.

$$Pb = \frac{Nb - Nf}{Sb} \tag{2}$$

where: *Pb* is needed support for biofuel in EUR per l. *Nb* are costs of using biofuel in EUR per 100 km; *Nf* are costs of using fossil fuel in EUR per 100 km; *Sb* is biofuel consumption in l per 100 km.

$$Nf = VOCf \cdot Sf + Uf \tag{3}$$

where: *Nf* are costs of using fossil fuel in EUR per 100 km; *VOCf* is wholesale price of fossil fuel in EUR per l including full excise duty; *Sf* is fossil fuel consumption in l per 100 km; *Uf* are cost of maintenance of vehicle using fossil fuel in EUR per 100 km.

$$Nb = (VOCb + Db + CMb) \cdot Sb + Ub \tag{4}$$

where: *Nb* are costs of using biofuel in EUR per 100 km; Part of pattern in bracelets symbolises not supported price of biofuel or fuel blend. *VOCb* is wholesale price of fossil fuel in EUR per l; It can comprise also part of excise duty; *Db* is valid tax rate relief for biofuel in EUR per l; *CMb* is price motivation of consumer to use biofuel in EUR per l; *Sb* is biofuel consumption in l per 100 km; *Ub* are vehicle maintenance costs, which runs on biofuel in EUR per 100 km.

$$Uf = \frac{CO \cdot 100}{Vf} \tag{5}$$

where: *Uf* are vehicle maintenance costs, which runs on fossil fuel in EUR per 100 km;

CO is price of oil replacement in EUR; *Vf* is km distance between oil replacements in vehicle running on fossil fuel;

$$Ub = \frac{CO \cdot 100}{Vb} \qquad (6)$$

where: *CO* is price of oil replacement in EUR; *Vb* is km distance between oil replacements in vehicle running on biofuel.

$$Us = \frac{CO \cdot 100}{Vs} \qquad (7)$$

where: *Us* are vehicle maintenance costs, which runs on fuel blend in EUR per 100 km; *CO* is price of oil replacement in EUR; *Vs* is km distance between oil replacements in vehicle running on fuel blend.

$$Sb = Sf \cdot Kb \qquad (8)$$

where: *Sb* is biofuel consumption in l per 100 km; *Sf* is fossil fuel consumption in l per 100 km; *Kb* is coefficient of increased biofuel consumption, dimensionless.

Biofuel or fuel blend consumption calculation pattern 8 can be applied in case that mileage consumption is not default and only coefficients of increased consumption of biofuel or fuel blend are available.

$$Ss = Sf \cdot Ks \qquad (9)$$

where: *Ss* is fuel blend consumption in l per100 km; *Sf* is fossil fuel consumption in l per100 km; *Ks* is coefficient of increased fuel blend consumption, dimensionless.

Biofuel or fuel blend consumption calculation pattern 9 can be applied in case that mileage consumption is not default and only coefficients of increased consumption of biofuel or fuel blend are available.

$$Ks = \frac{CVf}{CVb} \qquad (10)$$

where: *Ks*… is coefficient of increased fuel blend consumption, dimensionless; *CVf*... calorific value of fosil fuel (MJ/l); *CVb*… calorific value of biofuel (MJ l^{-1}).

Coefficient of increased fuel consumption and consumer motivation coefficient was assessed due to higher price of vehicles with adapted engines for emission standards EURO 5, EURO 6 and standard for storage by operators according to Czech standard 65 6500/2012.

$$CMb = kp + kt + ka \qquad (11)$$

where: *CMb*… total consumer motivation (EUR l^{-1}). From that: *kp*… coefficient of increased costs of vehicles or engines (1.3); *kt*… coefficient storage and shelf life (0.5); *ka*... coefficient of used additives and reagents (0.2).

These patterns were applied in Fig. 1. Development of local market (Fig. 2), export and import (Fig. 3), consumption (Fig. 4) and reserves (Fig. 5) is summarised in calculation of needed support (Fig. 6). Consequences of missing needed support are shown in Fig. 7.

RESULTS AND DISCUSSION

Historical data and calculation of variables were applied in search of sustainable climate for selected innovative product oppose to alternatives and substitutes. Each innovation is notified according to EU rules to receive support allowing it to become market competitive.

Comparison of B100 biodiesel compensation shows difference of some EUR 0.30 for selected months of 2015 and 2016 years. Special attention should be driven to the end of the year, which explains next year compensation level, probably due to leaking or confusing information (Fig. 1).

B100 (FAME biodiesel) has lost competitiveness due operation of excise duty policy. This calculation proved to be true as B100 fuel is disappearing from list of offered assortment of petrol stations. Volume of excise duty overcompensation in 2015 should be repaid until 30 June 2017 year. Overcompensation occurs for positive values and undercompensation for negative values.

Therefore, 2016 prices with excise duty, which was associated with fine for its late introduction, which is further called undercompensation for B100 oppose to year 2015 in the case of this article (Fig. 1).

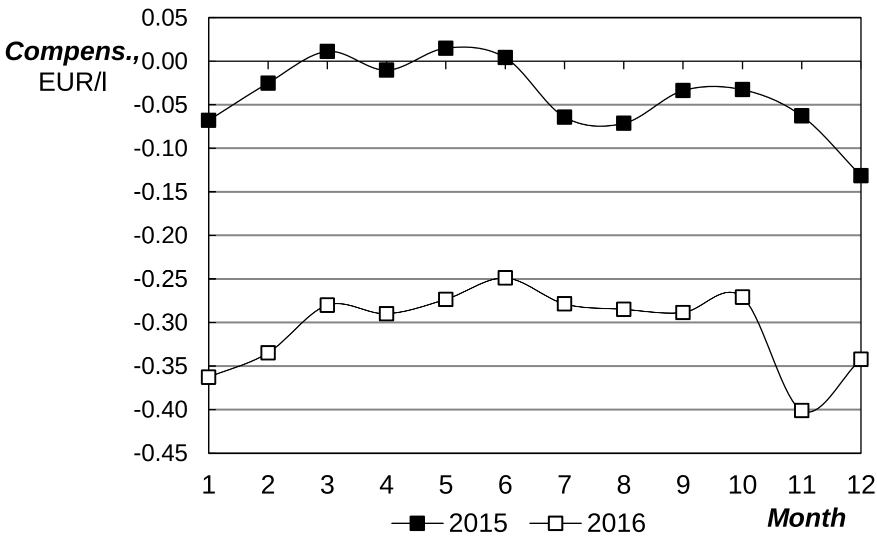

Figure 1. Calculated compensation in 2015 and 2016.

Till 30 June 2017 the excise duty rate will be decreased back to standard level of other EU countries. But, crude oil price development is hardly to predict. Therefore, calculation of undercompensation or overcompensation should be adapted for actual crude oil prices and tax rate changes. Than used patterns will standardise market access for all involved parties.

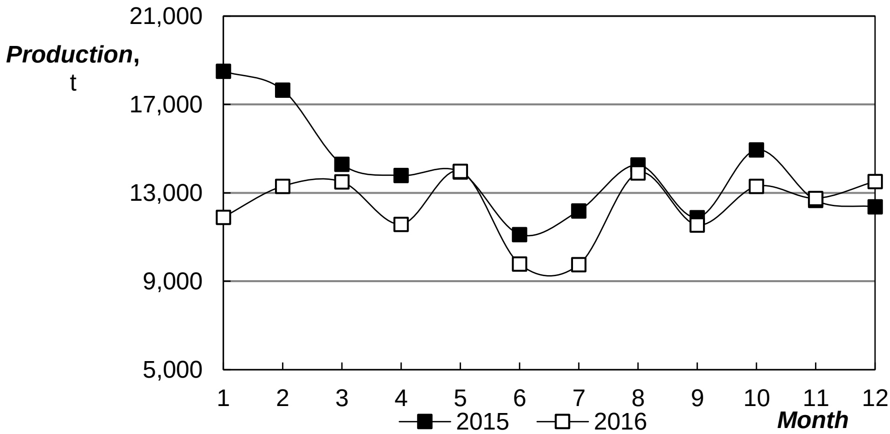

Figure 2. Local biodiesel production in years 2015 and 2016.

Compensation is not equal for all EU countries due to inconsistencies in applied rules. Firstly, local biodiesel production can be related to above mentioned support. Big decrease of production of biodiesel in beginning of 2016 year (Fig. 2) can be explained by decreased support from 2015 to 2016 level (Fig. 1). But, than production level of both years have merged. Production data for 2016 are incomplete.

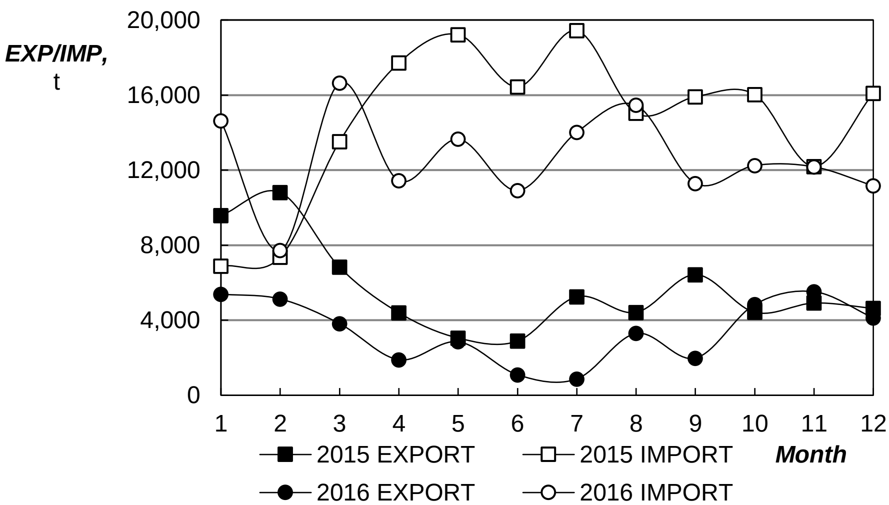

Figure 3. Export and import of biodiesel in years 2015 and 2016.

It would seem that regulation has maintained production. But, closer look at trade shows that importers have gained market from exporters (Fig. 3). It is possible to conclude that decrease of biodiesel exports is saving support compensation and therefore, decrease of exports was intended by regulators. But, it is not so sure if regulators have intended stimulate imports due to negative impact of indirect land use change (ILUC).

Biodiesel consumption was not influenced as it is assessed by minimal blending level by law of air protection (Fig. 4).

Biodiesel stock changes should follow seasonal curve shape according to summer harvest once per year or processing capacities of crushers as biodiesel is made predominantly from oilseed rape in EU countries. But, big changes in storage reserves may show that biodiesel is produced from other raw materials, which are shipped by super tanker boats to refinery oppose to Rotterdam.

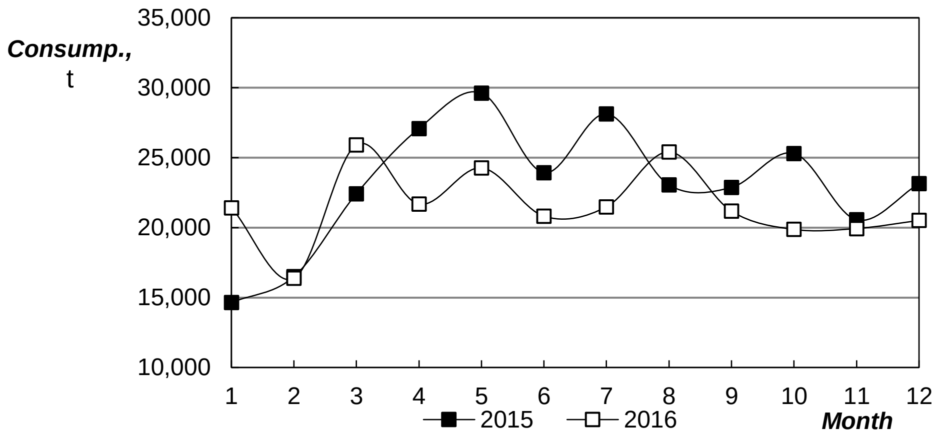

Figure 4. Consumption of biodiesel in Czech Republic in years 2015 and 2016.

Changes of storage reserves (Fig. 5) due to shipped oil or biodiesel originating from palm or soy is negative side effect of regulation as palm oil or biodiesel has more negative impact on climate warming.

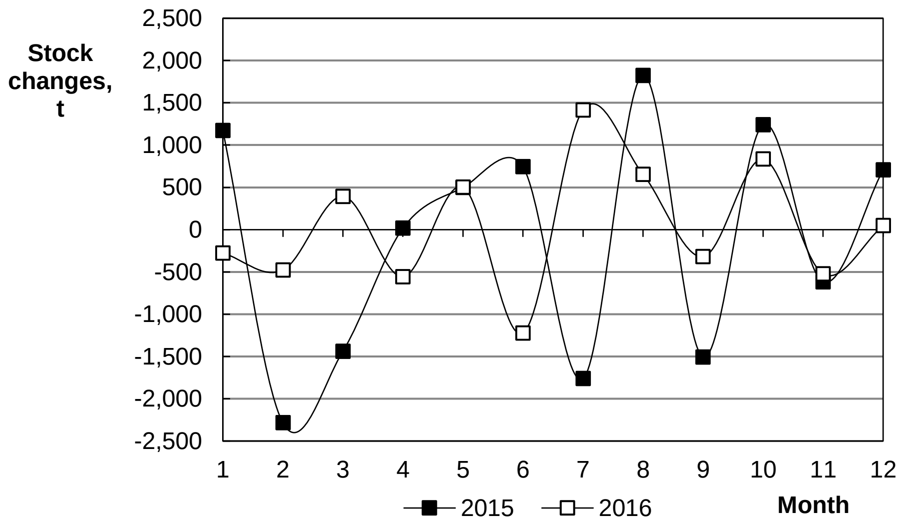

Figure 5. Change of storage reserves of biodiesel in years 2015 and 2016.

The second part of results of this article are patterns for calculation incorporating side effects of production and trade for stability of market support for new products against alternatives or substitutes until they become market ready.

Relatively big attention was given to indices of fuel consumption, which was not deduced from above presented historical data. Literature overview and other articles of authors were used to derive patterns from consumption fuel influencing values. Of course, the fuel consumption may be very different for consumption of other products of biorefinery.

Therefore, consumption part of regulation patterns for stability of market for biorefinery product innovation react on alternatives and substitutes (Fig. 6). Real difference between support about EUR 0.30 (Fig. 1) is bigger than calculated need for support with difference about EUR 0.1 (Fig. 6) because of above mentioned undercompensation.

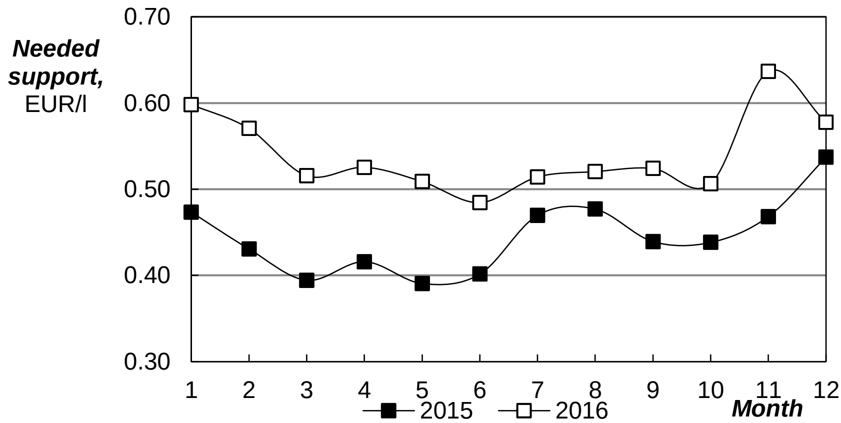

Figure 6. Calculated needed support of biodiesel.

Consequences of market access rules and crude oil price development has collapsed market of high condensed fuels (Fig. 7). This may happen for any biorefinery product, alternative or country.

Fig. 7 shows consequences of above explained market access compensation causing end of biofuel product for ČEPRO Company, which is operating network of EuroOil petrol stations, recently without high condensed biofuels. Fuel distributors apply 6% vol. of biodiesel (FAME) for diesel engines only as it is strictly controlled without any relationship with commodity price development.

Market has reacted on EU fiscal policy by stop of sales of renewable fuels in Czech Republic (Fig. 7). Therefore, EU biofuel competitors could take CZ market over. But, low prices of fossil fuels has reduced turnover of other EU biofuel competitors also. The relationship between uncertainty and risk–taking behaviour towards protection of innovations at Common Market by fiscal measures is neither solving distortions nor collecting taxes at expected level. Photovoltaics and other renewable energy sources, which are also protecting climate warming are not taxed yet, except of biofuels. Therefore, the difference between paid tax and fine for biofuels is uncomparable with support for photovoltaics.

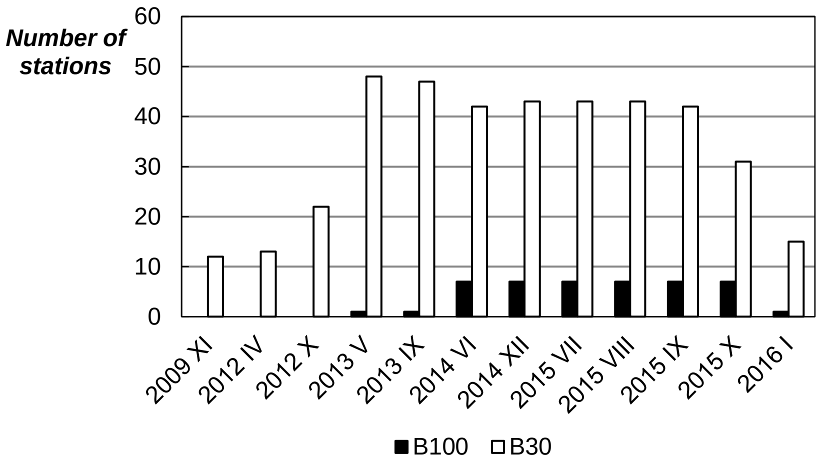

Figure 7. Number of Euro Oil petrol stations offering B100 and B30.

CONCLUSIONS

Used patterns will standardise market access for all involved parties in development of biorefinery alternatives (products). Coefficients and logic of calculation patterns should be validated and extended to other biorefinery products to protect them into market maturity against alternatives and substitutes. The three parts of production, trade and consumption should be kept separate as trade is the most volatile but can recover oppose to production. Consumption patterns are influenced more by political decisions than by regulation. It is enough to issue new norm or support other source, like electric cars and all investments into renewable raw materials are lost. The question is if consumer is enriched? GHG indicators are used for this purpose, which impact on climate warming is not fully justified yet. Therefore, GHG balancing was not included into this article.

We may conclude that equally restrictive rules according to market price development are needed. But, only market access indicators were included in presented patters. Market price development will be verified if market access standardisation patterns will be used and processed in time series for longer time.

Overcompensation of excise duty for biofuels in Czech Republic, which was calculated by presented patterns in this article, was confirmed for 2015 year. High concentrated biofuels went out of the market due to both increased price by overcompensated excise duty and low market price of crude oil, which will affect market share of biofuels also after 30 June 2017 when the excise duty will decrease again. Presented patterns still can forecast reliably rate of excise duty in coming years. Both, forecast level of excise duty and market price of crude oil, is putting biofuels between other biorefinery products if market access is standardised by proposed patters. The proposed market access standardisation of biofuels will deliver lacking energy to developed countries and needed protein to developing countries. The mission of biorefinery will not be solved in one biofuel processing factory, but globally yes, including of contribution of excise duty to state budget.

Limitations and suggestions: Intentions to collect as much taxes as possible and willingness to punish distortive competitors are legitimate but do not comply with economy of company or sector as global market is involved. Therefore, secondary market for innovations should be created besides forex, commodities and stock market exchanges to allow investors to react more frequently than institutions do. Market of alternative renewable and climate warming protecting materials should be supported by crowd funding in future. This projection exceeds framework of this article, but should be developed in future research.

ACKNOWLEDGEMENTS. The paper was created with the grant support project IGA University of Economics, Prague F3/19/2016 – Economic efficiency of biofuels from waste materials.

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Evaluation of the actual sitting position of drivers of passenger vehicles

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Abstract. This paper is concerned with comparing the actual sitting position of drivers of passenger vehicles with the position commonly considered optimal from the viewpoint of active and passive safety, and the long-term effects on the driver's health. The research described herein was conducted on a sample of randomly selected drivers in Czech Republic. All the measurements were conducted in a single, neutral, medium-sized passenger vehicle with which none of the test subjects had any previous experience. For this reason, none of the tested drivers had the advantage of familiarity with the environment. This research came about as an attempt to re-create the common situation wherein a driver adjusts his/her position behind the steering wheel solely on the basis, of intuition. Through a statistical evaluation of the acquired data, it was possible to confirm the initial hypothesis that a substantial portion of tested drivers assume a less than optimal driving position. This fact has a negative effect not only on reducing active and passive safety, but directly impacts upon the health of drivers who cover high annual mileage. The results of this paper can be used when designing cabins and modern interactive systems for passenger vehicles, which will be able to assist the driver in setting the optimal driving position. In this way, it will be possible to directly impact upon traffic safety and positively influence drivers' health.

Key words: Driver, Seat, Position, Sex, Physiological Optimum.

INTRODUCTION

Today the design of the cabin ergonomics of passenger vehicles is considered an ever increasingly important component of the construction process of a new vehicle (Wang et al., 2007). An optimally ergonomically designed driving seat, as well as those of the vehicle's crew, plays a considerable role primarily in the area, of vehicle safety (Reed, 1998). Modern adjustable seats enable the driver to set a whole range of geometric parameters and choose a sitting position which the driver subjectively feels to be comfortable. The optimal positioning of the seat thus directly influences the driver's feelings and overall comfort, and thereby also the safety of operation of the vehicle (Reed, 1998, Matoušek, 1998; Bhise, 2012).

The position of the driver in the seat is important from a number, of perspectives, which in certain respects are contradictory. This for example concerns requirements with regard, to active safety, with regard, to physiological comfort, passive safety and others (Tilley, 2002). This study considers the position of the driver primarily from a physiological and medical perspective, and deals with the influence of angles between the limbs on the burden placed on specific groups of muscles.

A whole range of studies have focused on measurement of the position of the driver in the vehicle (Park et al., 2016), and are described in certain norms (SAE J4004). However, they mostly concern measurement in laboratory conditions and on special measurement seats (Park et al., 2016). This study obtains precise data from a real environment, in which the observed subject is not exposed to stress by a laboratory environment and sits in an actual vehicle.

The primary objective of this work is to describe and quantity the actual position which drivers adopt in the vehicle, and, also to compare these values with the values designated as optimal (Andreoni et al., 2002). With regard, to the question of the optimal values of the individual described angles, there is a considerable lack of consensus among experts, and values very often differ depending on the used method of measurement or the angle of measurement. All the published results of optimal values were summarised in a separate study (Schmidt et al., 2013). For the purposes of this study, the values (Andreoni et al., 2002) which most closely approximate the physiological optimum were chosen (Véle, 1995). Within the framework of certain surveys engaged with ergonomics (Hruška & Jindra, 2016), it was determined that a correlation exists between the sex of the driver and ability to control the vehicle and adapt to its control and communication elements. A secondary objective of this study was to confirm the hypothesis that a correlation exists between sex and correct sitting position of the driver in the vehicle.

MATERIALS AND METHODS

Participants

100 subjects (Table 1) were obtained for the purpose, of measurement (39 women and 61 men), all from a university environment – students or graduates in technical or economic subjects. The number of participants was limited in terms of organizational capabilities. However, the number of participants when compared with other studies on the same subject, however, this number may be described as above average (Schmidt et al., 2013). Participants were selected from the ranks of students and tutors of a technical university as a group that is as uniform and homogenous as possible with respect to the participant's completed education, in order, to avoid various levels of education that would have to be taken as a parameter affecting the overall results. The age of the subjects was within the range of 18 to 65 years (average age 29 years). In all cases, it was requested and confirmed that the subjects had a driving licence authorising driving of passenger vehicles. All the subjects were also in good physical health and had no limitations in terms of their physical motor skills.

Table 1. Numbers of tested persons and their parameters in relation to measurement

	Number	Age			Number of km travelled (thousand km)		
		Average	Minimum	Maximum	Average	Minimum	Maximum
Men	61	30	19	65	192	5	800
Women	39	27	18	52	68	5	400
Total	**100**	**29**	**18**	**65**	**144**	**5**	**800**

Testing environment

The chosen testing vehicle was the Mercedes Benz C220d model range from 2016, with standard interior furnishings. The vehicle was furnished with modern, adjustable seats with mechanical movement in a lengthwise direction and electronic positioning of the height of the seat, incline of the seat and back rest (Fig. 1). The furnishing also included a mechanically configured adjustable steering wheel (Fig. 1). The vehicle can be characterised as a standard medium sized saloon model.

This vehicle was chosen because it is not very widespread type in the Czech Republic and the participants were therefore selected so that the test vehicle had no previous experience. This helped to ensure equal conditions for all participants.

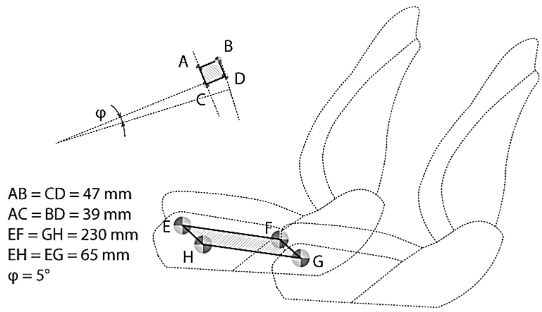

Figure 1. Positional ranges of seat and steering wheel in tested vehicle.

The vehicle was placed in a laboratory in constant conditions and at a constant temperature with a stable noise burden, so that all the subjects were under the same conditions during the test. During the measurement, the driver's door was open to the maximum position in order, to determine the maximum angle of view of the camera.

For manual data gathering a standard digital ER-05141 angle gauge was used. For electronic data gathering in the form of digital photographs, a digital compact Nikon J1 camera was used. This type of camera is equipped with a fixed lens with a focal length of 10 mm. The angle of view of the camera is 65.5°. The camera was placed on a photographic tripod with high capacity for maintaining stability at a precisely defined constant distance from the vehicle (Fig. 2).

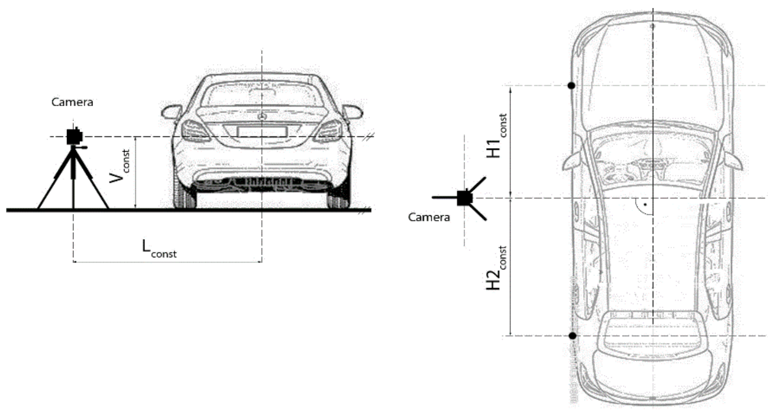

Figure 2. Diagram of measuring station with mutual position of recording camera and seat.

For secondary measurement of the mutual position of the recording device and the vehicle, a digital Bosch PLR 30 C distance gauge was used.

For adjustment of photographs and reading of values, the programs Adobe Photoshop CS6 and Adobe Illustrator CS6 were used.

Data Collection Procedures

None of the tested subjects had any prior experience with the testing vehicle. Each tested subject was thoroughly trained and familiarised with the control systems of the position of the seat and steering wheel before sitting in the measuring vehicle. After sitting in the tested vehicle, each tested subject was given sufficient time to test out and understand all the functions necessary for controlling the position of the seat and steering wheel. Before the actual measurement each tested subject was asked whether they considered their position in the vehicle to be comfortable, and whether this position corresponded to the maximum extent to the position which they usually assumed when driving a vehicle.

Each tested subject was subsequently indicated with tangent points which were placed on the locations of the elbow joint (*articulatio cubiti*), knee (*articulatio genus*), shoulder (*articulatio humeri*) and hip joint (*articulatio coxae*). The tested person was then instructed to place their hands in a neutral position on the steering wheel according, to 9 and 3 on the clock face, with loosely hanging arms without tension (Fig. 3). The measurement took place always on the left side of the body, because the tested position was always laterally symmetrical. Recording and manual measurement always took place on a frontal plane and the individual angles were recorded on a sagittal plane.

Figure 3. Tested subject, photographed in measurement position with designated flowlines of joints.

After a digital photograph has been obtained, each tested subject was manually measured with the aid of the above-stated instruments, always by the same employee, in order to ensure that the measurement method was always the same. The angles *alpha* (*articulatio cubiti*), *beta* (*articulatio genus*) and *gamma* (*articulatio coxae*) were measured manually (Fig. 4), as well as the basic anthropometric data on the tested subjects (Fig. 5), which is recorded in Table 2.

After the end of measurement, all the obtained photographs were digitally analysed and the values of the *delta* (*articulatio humeri*) and *epsilon* angles were determined, which was not possible using the method of manual measurement. For greater precision of data, the values of the angles *alpha, beta* and *gamma* was used, obtained by an averaging of both methods of measurement – manual measurement and digital analysis of photographs. The values of the angles obtained by both methods of measurement differed on average by only 4%, and it is therefore possible to state that both methods of measurement were sufficiently precise.

Some theoretical studies (Schmidt et al., 2013) use a number, of separate points in the area, of the spine, and measure the mutual angle of their flowlines. However, the shape of the spine when sitting and driving a passenger vehicle is predominantly defined by the shape of the backrest of the seat and as, a result the shape of the spine is overlooked for the purposes of this study. Only the overall incline of the torso is measured, defined by the angle *epsilon* (Fig. 4).

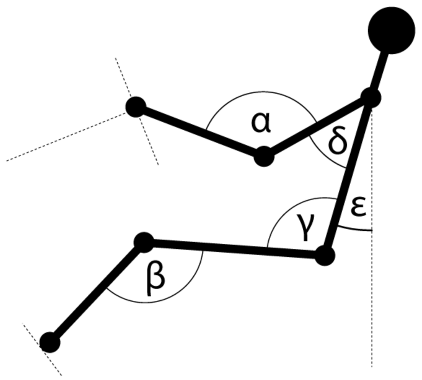

Figure 4. Diagram of measured values.

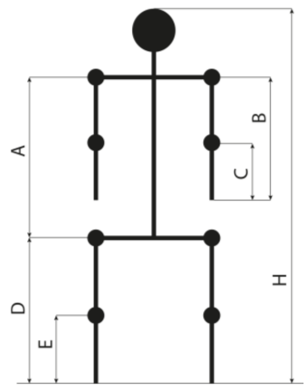

Figure 5. Anthropometric data.

Table 2. Basic measured anthropometric data of tested subjects as illustrated in Fig. 5

Dimension	Women			Men		
	average	min	max	average	min	max
A (cm)	57	51	63	63	57	71
B (cm)	45	39	52	49	40	60
C (cm)	31	26	35	34	29	39
D (cm)	97	83	103	103	92	116
E (cm)	47	39	51	48	40	60
H (cm)	170	159	180	184	171	201

RESULTS AND DISCUSSION

The results obtained during the measurement were statistically processed and evaluated using contingency tables and a Pearson's chi-squared test. The statistical averages and extremes obtained from the measured data are presented in Table 3. The obtained values were classified into three categories according, to whether they were located, in the selected optimal values, or were lower or higher. The contingency table (Table 4) presents the values for men and women separately. Table 5 presents the values of the recalculated frequencies of the individual angles, again separately for men and women.

Table 3. Resulting values of measured data of tested subjects as illustrated in Fig. 4

Angle	Optimum	Women			Men		
		average	min	max	average	min	max
Alpha (°)	105–125	113	89	141	128	101	160
Beta (°)	123–149	124	110	135	125	105	151
Gamma (°)	89–99	101	90	112	99	88	117
Delta (°)	22–42	27	14	36	35	20	51
Epsilon (°)	15–20	21	14	25	21	14	30

Table 4. Contingency tables (processed into row) of measured values for individual angles, divided according to sex

Angle	Women (number of subjects)			Men (number of subjects)		
	below	within optimum	above	below	within optimum	above
Alpha (°)	9	25	5	3	24	34
Beta (°)	18	21	0	28	32	1
Gamma (°)	0	14	25	0	34	27
Delta (°)	2	37	0	2	44	15
Epsilon (°)	1	15	23	4	27	30

Table 5. Difference in frequencies of individual angles according, to zero hypothesis for men and women expressed in percentages

Angle	Women			Men		
	below	within optimum	above	below	within optimum	above
Alpha (°)	92%	31%	-67%	-59%	-20%	43%
Beta (°)	0%	2%	-100%	0%	-1%	64%
Gamma (°)	-	-25%	23%	-	16%	-15%
Delta (°)	28%	17%	-100%	-18%	-11%	64%
Epsilon (°)	-49%	-8%	11%	31%	5%	-7%

In the case of 17 men and 3 women, extreme values of the positioning of the steering wheel were reached, with the tested subjects stating the range of adjustment of the steering wheel as insufficient. This had an influence on the optimal position, which could therefore not be attained. However, from the perspective of these parameters the tested vehicle ranks among the best on the market, and as, a result it is possible to expect that these subjects would have a similar problem in the great majority of vehicles of a similar category. This expectation was also confirmed by all the tested subjects.

From the data stated in Table 4 and in Table 5 it is evident that the greatest deviations from the optimal values are reached by men in the angles *alpha* and *epsilon*. A certain connection exists between these angles, which can be loosely interpreted as meaning that if the angle *epsilon* exceeds the optimal values, these values will most probably also be exceeded by the angle *alpha*. These angles are extremely important from the perspective of the entire postural system of the driver.

From a physiological perspective the values of the *alpha* angle are especially significant if they exceed the values selected as optimum (Table 3). Even a small exceeding of the upper limit (125°) may lead to substantial overloading of the *musculus biceps brachii* (Véle, 1995). In general, it is possible to state that the lesser the angle *alpha*, the more appropriate this position (Véle, 1995). The value of the *delta* angle is connected directly with the *alpha* angle, and here also it applies that if the upper limit of the optimal range (44°) is exceeded, there is an overloading of the *musculus biceps brachii*, with an attendant overloading of the *musculus triceps brachii* and the *musculus levator scapulae*. In the case of the *gamma* angle, exceeding of the upper limit (99°) represents an increased burden on the *musculus iliacus* and *musculus iliopsoas*. In the case of values above 110°, the significance of support for the lumbar section of the spine on the back of the seat is practically annulled, and the entire weight of the body is significantly placed on the *gluteus medius* and *gluteus maximus*.

For testing of the correlation between the sex of the tested subjects and the optimal value of spontaneously chosen angle, a Pearson's chi-squared test was used. This test serves to determine the dependency between various divisions into categories. It measures the standardised difference between actual feelings of objects which fall within the selected combination of categories and the numbers of subjects who would fit into these combinations on the precondition of independence. The sum of the standardised differences is then compared with the critical value of division X^2 on the selected level of significance (as standard 95%). The number of degrees of latitude of division is determined by the product by one reduced number of categories of both selected divisions into categories.

Table 6 summarises the statistical significance of attaining the optimal angles depending on the sex of the tested subjects. For each of the contingency tables the measured value of X^2 is stated and compared with the critical value of division by two degrees of latitude on the level of significance of 0.95. The *gamma* angle reaches only values within the optimum and above, as, a result the table and the critical value of division has one degree of latitude less.

Table 6. Values of Pearson's chi-squared test of dependency of individual angles on sex

Angle	X^2	Critical value	Cramer V	Result
Alpha (°)	20.75	5.99	0.45	Dependency
Beta (°)	0.65	5.99	0.08	No dependency
Gamma (°)	3.75	3.84	0.19	No dependency
Delta (°)	11.31	5.99	0.33	Dependency
Epsilon (°)	1.38	5.99	0.11	No dependency

The level of dependency was also measured by Cramer's V. On the basis, of the calculated values, it is possible to designate the dependency of the *alpha* angle as fundamental and the dependency of the *delta* angle as medium. This can be interpreted to mean that a difference exists between women and men, especially in the configuration of the mutual position of the steering wheel and upper part of the body. In this respect women have a tendency, to sit closer to the steering wheel, with their arms more flexed and relaxed.

Explanation of this situation can be found in generally different anthropometric parameters of men and women. As mentioned above, in the case of 17 men, stating the range of adjustment of the steering wheel as insufficient. Compared to this, on average, shorter female limbs forces women to take a position closer to the dashboard, the space in which it can be sufficiently set and steering wheel position.

The main contribution of this thesis may be regarded in the quantity of tested subjects and the involvement of a gender factor. In comparison with the present thesis, such a large group of tested persons has not been applied in any studies concerned with research in similar themes in the last 20 years. By way of example, Andreoni uses 8 persons (Andreoni et al., 2002), Kyung uses 38 persons (Kyung & Nussbaum, 2002), and Hanson 38 persons (Hanson et al., 2006), or these studies do not analyse the European population, e.g. Park (Park et al., 2016), who uses 43 persons, though all of them were of Korean nationality. The last extensive study on this theme was written in the year 1940, testing as many as 250 persons (Lay & Fischer, 1940). Needless, to say the development of passenger cars never stops and parameters of cars and the interior equipment have changed considerably in the past 20 years. Accordingly, it may be argued that results delineated in this thesis have the potential to improve and update the understanding of problems of optimization of the driver's position in passenger cars.

CONCLUSIONS

Within the framework of this study we succeeded in obtaining a large quantity of valuable primary data from a relatively homogenous group of respondents, which may be statistically relevant from the perspective of applicable comparisons with other statistics which may have been obtained from respondents with other parameters, such as those with different education, age etc. By dividing the data with the aid of contingency tables it was determined that a significant group of respondents assume a position behind the steering wheel which on the basis, of the selected comparative parameters cannot be designated as optimal.

This finding could be used for the development of automatic processes of configuration of the seat, according, to the entered parameters of the driver, into a position which would be defined as optimal. This would bring about an elimination of the human factor, which, as is evident from the above results, is defective in these processes.

On the basis, of the above results, it is further possible to state that the hypothesis stated in the introduction to the study is in large part confirmed. Statistically significant differences exist in the position assumed when driving a passenger vehicle between men and women. The explanation of this phenomenon can be considered, to be the generally more responsible approach of women to driving a passenger vehicle.

The results presented in this study could serve as a basis for further research, which would assist in further specifying the observations stated above. The data and hypotheses presented in this study could serve as factors aiding in the process of designing automobiles, with reference, to the potential target groups of customers.

It is evident that especially within the area of adjustable steering wheels it is necessary to provide a wider range of movement than is currently available in vehicles. A statistically significant proportion of drivers are unable to attain a position which could be designated as optimal due to insufficient adjustment of the steering wheel.

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Agronomy Research **15**(2), 426–434, 2017

Effect of construction shape and materials on indoor microclimatic conditions inside the cowsheds in dairy farms

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Abstract. The aim of this paper is to present the results of microclimatic research focused on the indoor conditions in cowsheds and milking parlours in two dairy farms. The attention is paid mainly to the construction and materials used for buildings, which can influence together with technological equipment and system of ventilation the microclimatic conditions inside the cowsheds. In the frame of this research main parameters of internal and external properties of climate (air temperature, humidity, globe temperature, THI, BGHI and concentration of CO_2) during the hot summer were measured and evaluated. Results of long time and short time measurements show very important role of used materials and shape of buildings. The research results show that the use of principles of passive air conditioning can contribute significantly to the improvement of internal microclimate. Reduced amplitude of temperature oscillation was 42.4% of amplitude of outside air temperature in cowshed with massive construction and 91.7% in modern light building. The average phase shift of temperature oscillations, expressed as a time delay of internal temperature rise behind the external temperature rise was about 2.8 hours and time delay of drop of internal temperature behind external temperatures drop was 3.3 hours in massive cowshed. The same parameters in modern light cowshed were only 1.1 hours and 0.5 hours.

Key words: air temperature, massive construction, solar radiation, temperature oscillations.

INTRODUCTION

Problems of thermal comfort environment of cattle are receiving considerable attention in recent decades, especially in terms of thermoregulatory abilities of cattle. Modern dairy cows are producing very high milk yield; therefore they are under metabolic stress. To enable the milk production to their potential, the housing conditions should reduce any additional stress by microclimate inside the cowsheds.

Thermal state of the indoor environment is characterized by thermal and humidity variables which affect the resulting mental and physical state of an animal in agricultural buildings. As a consequence of the analysis of thermal environment is a formation of optimal conditions for animal organism. There are small differences between recommendations in published articles and books about optimal parameters of indoor environment mainly air temperature and humidity; nevertheless it can be concluded that the required optimal temperatures for cowshed are 10–20 °C (minimum 2 °C, maximum 25 °C). In milking parlour during a winter period is optimum 14–16 °C (minimum

10 °C), in summer period is required optimal temperature in the range of 14–22 °C (maximum 26 °C). These recommended values of temperature are usually completed by recommendation of suitable ventilation systems (Chiumenti, 2004; Choupek & Suchy, 2008; Koznarova & Klabzuba, 2008; Zejdova et al., 2014; Papez & Kic, 2015; Rajaniemi et al., 2015).

Thermal state of the indoor environment is also influenced by relative humidity. High water vapour content in the air reduces the possibility of cooling the body by evaporation. It can cause heat stress already at a relatively low temperature of indoor environment. Relative humidity should by ideally in the range of 40–80%. The maximum allowable value of relative humidity according to Czech standard CSN 73 0543–2 is 85%. Long–term exposure of relative humidity above 85% adversely affects the organism and apparatus and could damage wooden elements of buildings. (Kic & Broz, 1995; Kunc et al., 2007; Pavelek & Stetina, 2007; Papez & Kic, 2013; Zejdova et al., 2014; Papez & Kic, 2015).

Effect of combinations of temperature and humidity is included in the temperature–humidity index (THI). This index is widely used to describe the heat stress. THI value below 70 is considered as comfort for cattle. THI in the range of 70–78 is considered as stressful and values higher than 78 cause extreme suffering (the organism is enable to maintain the thermoregulatory mechanisms or normal body temperature). (Armstrong, 1994; Zejdova et al., 2014). Black globe humidity index (BGHI) is also a good indicator of heat stress. It is based on similar measurement method, associating the use of black globe temperature instead of dry bulb temperature for adding the solar radiation effect to the principal of THI. This method is used in different research works of summer heat stress (Zewdie & Kic, 2015; Dalcin et al., 2016; Zewdie & Kic, 2016).

In summary, cattle thanks to their thermoregulation ability can better adapt to the lower air temperature and harder tolerate high temperatures. Therefore, the aim of this paper is to show the measurement results of main microclimatic parameters in different types of buildings in dairy farms in hot summer period. Measurement results should verify the influence of construction shape and materials on indoor microclimatic conditions.

MATERIALS AND METHODS

This research work and measurements were carried out in two dairy farms situated in the same central part of Czech Republic. Summer season with maximum daily temperatures in the Czech Republic are usually months July and August. The year 2015 was very hot in the Czech Republic and therefore it was very suitable for carrying out the experiments and measurements of microclimate. There are usually 46 summer days (mean temperature over 25 °C) in the Czech Republic, but in 2015 it was 60 days, the number of tropical days (temperature over 30 °C and at night does not drops below 20 °C) is usually 9, but in 2015 it was 35 days. The warmest day of the year was August 8^{th} 2015 (meteoforum.e-pocasi.cz, 2017).

Buildings studied in the first dairy farm are: a modern cowshed CS1 for cows and milking parlour MP1. Buildings studied in the second dairy farm consist from old cowshed CS2 and milking parlour MP2.

The modern cowshed CS1 (Fig. 1) is used for housing of 100 cows in group pens with straw bedding. The non-insulated steel construction (length 40.5 m, width 12 m) with side feed table has a natural ventilation. The roof with central ridge slot (6 m height) is covered by plastic plates, partly completed by translucent fibreglass, gable walls are partly made from wood and partly from PVC mesh; side walls are made from PVC mesh which can be covered by the vertically movable PVC tarpaulin. It creates the protection against rain, snow, sunshine and wind. The herringbone milking parlour MP1 is a traditional brick construction, which is closed, insulated and ventilated by forces ventilation during the milking process.

The cowshed CS2 (Fig. 2) in second dairy farm is very old building, constructed from massive stone and brick walls with vaulted ceiling used for housing of 80 cows in individual cubicles with straw bedding. The herringbone milking parlour MP2 is situated in the same massive building as the cowshed CS2.

Figure 1. The modern cowshed CS1.

Figure 2. The old massive cowshed CS2.

Long-term measurements were carried out during the days of highest summer temperatures since 11th to 14th August 2015 and short-term measurements were carried out on August 11th, during the warmest hours of the day since 10 a.m. to 5 p.m.

Air temperatures and relative humidity were measured by data loggers ZTH65 outside and inside the buildings with registration at intervals of 15 minutes during four days (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 all described animal houses and stored at intervals of one minute to measuring instruments ALMEMO 2590–9, ALMEMO 2690–8 and ALMEMO 5990–2 during approximately one hour (time for stabilization of sensors).

Effect of combinations of temperature and relative humidity is included in the THI. According to (Zejdova et al., 2014) the THI is determined by the equation (1). Calculation of the BGHI is based on the results from short time measurements with the use of black globe temperature instead of dry bulb temperature, according to the Eq. (2).

$$THI = 0.8 \cdot t_i + \frac{(t_i - 14.4) \cdot RH_i}{100} + 46.4 \qquad (1)$$

where: THI – temperature–humidity index, –; t_i – internal temperature of air, °C; RH_i – internal relative humidity of air, %.

$$BGHI = 0.8 \cdot t_g + \frac{(t_g - 14.4) \cdot RH_i}{100} + 46.4 \qquad (2)$$

where: $BGHI$ – black globe–humidity index, –; t_g – globe temperature, °C.
For evaluation of THI are usually used the following limit values. If THI ≤ 65 it means comfort state; if THI is from 66 to 79 it means alert state, prolonged exposure occurs fatigue; and if THI ≥ 80 it means discomfort, if THI ≥ 84 it is dangerous, heat stress is highly probable if the activity continues.

RESULTS AND DISCUSSION

The main objective of this article is a presentation of results of measurement of main microclimatic research focused on the indoor conditions in several agricultural buildings used for housing of cattle in dairy farms, 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.

Problems of ventilation and suitable environment were studied (Naas et al., 1997) in cowsheds with loose housing in Brazil in order to evaluate and determine the influence of environmental and temperature on milk production. Heat stress of dairy cows was reflected in the decrease in milk yield. Reduction of heat stress for the best cow herds is very important. Problems of reduction of energy consumption for ventilation in cowsheds emphasize in their publication (Frorip et al., 2012).

Basic parameters of microclimate in unheated cowshed for cows during the summer period are presented in the publication (Sada et al., 2012). Average outdoor temperature, however, was relatively low (16.33 °C) and therefore the average internal temperature in cowshed was only17.12 °C.

Results of research on relation between the indoor and outdoor climate in uninsulated cowsheds are presented in publication (Reppo & Mikson, 2006). The average summer outside temperatures were from 14.54 to 17.26 °C. But there is not available publication focused on the influence of building mass on the temperature shift in time together with reduction of indoor temperatures in the cowsheds.

The results of long-time measurement of air temperature and relative humidity of the air in cowsheds and milking parlours of two dairy farms described in Materials and Methods are presented in Table 1. The results of this measurement show that the average air temperatures in both cowsheds CS1 and CS2 were lower than average external temperature. Thanks to the lower relative humidity of air in the cowshed CS1 is average calculated THI in this cowshed lower than in cowshed CS2.

Table 1. Average values and standard deviation of the air temperature t, relative humidity RH and THI in cattle houses of two dairy farms (the first dairy farm: CS1 modern cowshed and MP1 milking parlour; the second dairy farm: CS2 old cowshed and MP2 milking parlour) and outside in meteorological station during the long-time measurements

Parameter	t	RH	THI
Building	°C ± SD	% ± SD	- ± SD
External	27.3 ± 3.1	45.9 ± 14.2	73.4 ± 3.3
CS1	26.7 ± 4.0	47.0 ± 19.7	72.5 ± 2.6
MP1	26.7 ± 1.3	58.5 ± 8.2	74.9 ± 1.7
CS2	27.1 ± 1.7	50.5 ± 9.9	74.3 ± 1.3
MP2	27.2 ± 1.9	50.7 ± 10.1	74.4 ± 1.5

SD – Standard deviation.

Rather important are also changes of indoor temperatures during the hot days. The course of the air temperature and relative humidity of air during the whole long-time measurement is in Figs 3 and 4.

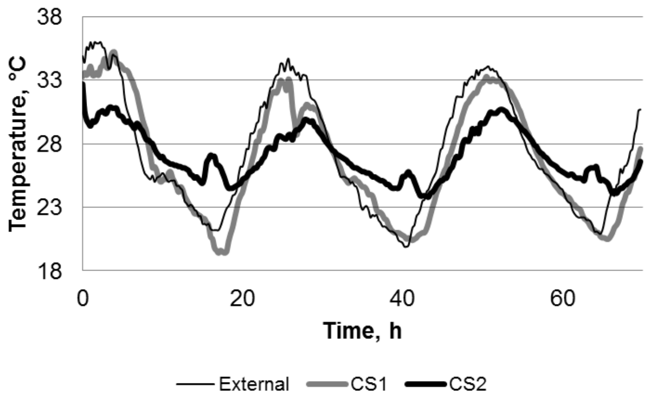

Figure 3. The course of the air temperature outside and inside the cowsheds CS1 and CS2.

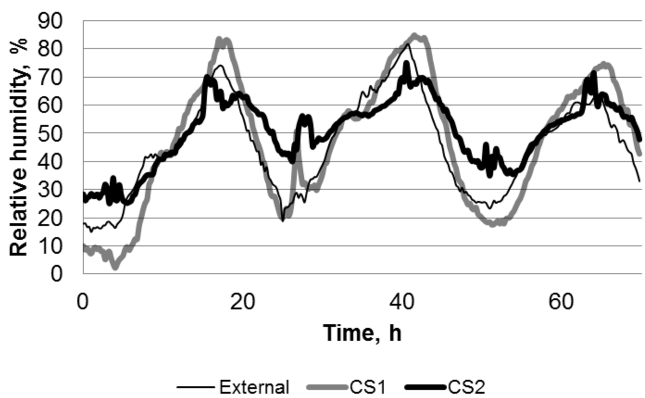

Figure 4. The course of the air relative humidity outside and inside the cowsheds CS1 and CS2.

The courses of relative humidity correspond to the internal temperature 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 during the hot summer. Recommended maximum relative humidity 80% was not exceeded.

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 during the hot summer. Recommended maximum relative humidity 80% was not exceeded.

Results of linear regression expressing dependence of internal temperatures on outside temperatures in the cowsheds CS1 and CS2 are presented in Fig. 5. According to the course of calculated equations of both lines is gradient (slope) of line (tangent line) 0.9164 (cowshed CS1) significantly higher than gradient of line 0.3525 (cowshed CS2). This implies that the internal temperature in the cowshed CS1 is more influenced by the outside air temperature than in the cowshed CS2.

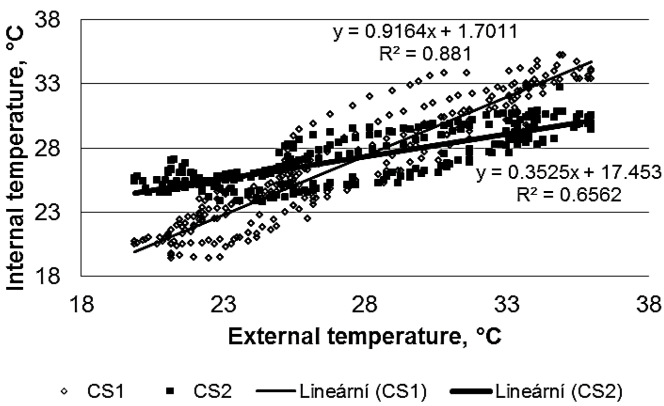

Figure 5. The linear regression of internal temperatures on outside temperatures in the cowsheds CS1 and CS2.

Correlation between internal and external temperatures is lower especially in the case of cowshed CS2 because the indoor air temperature changes are influenced (delayed and reduced) by the mass of constructions. It means that massive construction dampens the size of changes of inside temperature both in terms of amplitude and in terms of response speed to changes of outside temperature.

Rather interesting and important is therefore the comparison of oscillation amplitude A of external and internal air temperatures in Table 2. It also shows a reduction of amplitude of temperature oscillation A_R calculated as a difference between external and internal amplitudes and expressed also as a percentage of amplitude fluctuation A_{RP} of outside air temperature.

Based on the results of registered measurements of external and internal air temperatures a phase shift of the temperature oscillations are calculated, expressed as a time delay ψ_R of rise of the internal temperature behind external temperature rise and time delay of drop of internal temperature ψ_D behind external temperature drop. The results are also shown in Table 2.

Table 2. Average values of oscillation amplitude A of external and internal air temperatures, reduction of amplitude of temperature oscillation A_R and A_{RP}, time delay of rise of internal temperature ψ_R behind external temperature rise and time delay of drop of internal temperature ψ_D behind external temperature drop in the cowshed CS1 and in the cowshed CS2

Parameter	A	A_R	A_{RP}	ψ_R	ψ_D
Building	K	K	%	h	h
External	14.5	-	-	-	-
CS1	13.3	1.2	91.7	1.1	0.5
CS2	6.2	8.3	42.4	2.8	3.3

Average values and standard deviation of the globe temperature, internal air temperature, relative humidity concentration of CO_2, THI and BGHI in cowsheds CS1 and CS2 during the short-time measurements are presented in Table 3.

Table 3. Average values and standard deviation of globe temperature t_g, air temperature t, relative humidity RH, concentration of CO_2, THI and BGHI in cattle houses of two dairy farms (the first dairy farm: CS1 modern cowshed, and the second dairy farm: CS2 old cowshed) and outside in meteorological station during the short-time measurements

Place of measurement	t_g	t	RH	CO_2	THI	BGHI
-	°C ± SD	°C ± SD	% ± SD	% ± SD	- ± SD	- ± SD
External CS1	-	32.4 ± 0.1	21.7 ± 0.1	0.033 ± 0	76.2 ± 0.1	-
CS1	31.3 ± 0	30.7 ± 0.1	27.2 ± 0.1	0.034 ± 0	75.4 ± 0.1	76.1 ± 0.0
External CS2	-	35.8 ± 0.2	16.5 ± 0.2	0.033 ± 0	78.6 ± 0.1	-
CS2	30.6 ± 0	30.7 ± 0.1	30.2 ± 0.4	0.035 ± 0	75.9 ± 0.1	75.7 ± 0.1

SD – Standard deviation.

The results of short-time measurements confirm and develop more the results of long-time measurements just during the very hot period of summer day. There is a very positive effect of massive construction of cowshed CS2, which reduced inside temperatures during the highest outside temperatures. Calculated THI values are in both cowsheds lower than THI calculated from external data.

The external temperatures, under which the cowshed CS2 was measured (t = 35.8 °C) were more difficult than in the cowshed CS1 (t = 32.4 °C), nevertheless, the internal temperatures were the same (t = 30.7 °C) in both cowsheds. The positive influence of massive construction reflects the level of average t_g and therefore also calculated BGHI were lower in massive cowshed CS2 than in the modern cowshed CS1.

The results of CO_2 concentrations in cowsheds CS1 and CS2 presented in Table 3 are not surprising. The recommended maximum concentration of CO_2 of 0.20% was not exceeded in any house, as it was measured in the summer season with completely opened window, doors and other ventilation openings to maximum ventilation. Slightly higher concentrations of CO_2 in the cowshed CS2 is due to smaller volume of the internal space of cowshed and more difficult conditions for natural ventilation.

CONCLUSIONS

The results of measurements in cowsheds show that massive buildings better reduce external heat load by reduction of amplitude variation and by time shift of internal temperature.

Reduced oscillation of internal temperatures is important especially during the shorter-term variations of outdoor temperatures, because the inner part of the building does not warm up significantly. This is reflected primarily in animal houses with smaller biological loads and with lower intensity of ventilation e.g. in buildings for cattle housing.

The time shift caused by heat accumulation in the massive construction helps to overcome the high afternoon temperatures, which reflects a time shift in the increase of indoor air temperature. Due to the reduction in the amplitude of air temperature the indoor air temperature does not reach the maximum temperature of the outside air.

Natural ventilation is reflected with the opposite effect compared to the standard, because in this case the outside temperature is higher than the internal and the direction of air flows in inlets and outlets are opposite.

The principles of heat accumulation in massive constructions should be used in some modern buildings in combination with other principles of passive air conditioning.

ACKNOWLEDGEMENTS. Supported by Internal grant agency of Faculty of Engineering, Czech University of Life Sciences in Prague no: 2015:31170/1312/3114.

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Agronomy Research **15**(2), 435–443, 2017

Land use/land cover change modelling of Ergene River Basin in western Turkey using CORINE land use/land cover data

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Abstract. Land use planning is a useful tool to find a balance among the competing and sometimes contradictory uses in order to achieve food security, economic growth, energy supply, nature conversation and other objectives. In this study, modelling land use/land cover change of Ergene River Basin in Western Turkey between the years of 1990 and 2012 was investigated. The CORINE land use/landcover data and ArcGIS software were used to detect land use/land cover change between the years, 1990–2000, 2000–2006 and 2006–2012. As a results, the artificial area (including settlement area and industrial zone) and water bodies increased by 39.4% and 47.9%, due to industrial development and new reservoirs construction, respectively, while wetlands and agricultural areas decreased by 1.1%, 1.0% and 32.1%, respectively. The change in the agricultural areas into industrial area corresponds to about 13,000 hectares, which is considered threatening not only natural resources but also food security since the basin has the most productive arable land of Turkey.

Key words: Land use/land cover change, CORINE, Ergene, Turkey.

INTRODUCTION

Land is a scarce resource increasingly affected by the competition of mutually exclusive uses. Fertile land in rural areas becomes scarcer due to population growth, pollution, erosion and desertification, effects of climate change, urbanization etc. On the remaining land, local, national and international users with different socioeconomic status and power compete to achieve food security, economic growth, energy supply, nature conversation and other objectives. An integrated land use planning can help to find a balance among these competing and sometimes contradictory uses (Wehrmann, 2011).

The integrated approach to planning the use and management of land resources entails the involvement of all stakeholders in the process of decision making on the future of the land, and the identification and evaluation of all biophysical and socio-economic attributes of land units. This requires the identification and establishment of a use or non-use of each land unit that is technically appropriate, economically viable, socially acceptable and environmentally non-degrading (FAO, 1995). Land-use changes have important implications for future changes in the Earth's climate and, consequently, great implications for subsequent land-use change (Agarwal et al., 1999). Vitousek (1994) notes that 'three of the well-documented global changes are increasing concentrations of carbon dioxide in the atmosphere; alterations in the biochemistry of the global nitrogen cycle; and on-going land-use/land-cover change'.

Land use planning and necessary supporting data are crucial to developing countries that are usually under severe environmental and demographic strains (FAO, 1995). In Ergene River Basin in Western Turkey, land degradation has been exacerbated for the past 30 years with the introduction of industry leading to land use changes. Miss-use and miss-management of the land in the basin are more common than in the other basins of Turkey. While 81.76% of the total basin area is potentially cultivated area, present cultivated area occupies % 65 of the total basin area, which reveals the 22.776% of this area is miss-used and –managed, i.e., used beyond their capability classes (Cangir et al., 1996; Cangir & Boyraz, 2001; Konukcu et al., 2004; Kocaman et al., 2007).

Although land degradation in Ergene River Basin was reported by many authors, land use change has not been studied. The objective of this study was to investigate the land use/land cover change of Ergene River Basin in Western Turkey between the years of 1990 and 2012 using CORINE land cover data.

MATERIALS AND METHODS

Ergene River Basin, located in Marmara Region and in the middle of Trakya, is bordered by Istranca Mountain ranges in the north, Ganos Mountain ranges in the southeast and Koru Mountain ranges in the east (Fig. 1). The total length of the river from Istranca Mountain where it arises to the Aegean Sea in the Saroz Golf where it discharges is 283 km. The basin occupies about 1.4% of Turkey with 11,000 km^2 area and accommodates 1,150,000 people. The northern part of the basin has typical terrestrials climate characterised by hot and dry summers and cold winters whereas the southern part has Mediterranean climate dominated by hot and dry summers and mild and rainy winters. The long-term annual average precipitation is around 600 mm, humidity is about 70% and temperature is mm, 13 °C (Action Plan, 2008; Konukcu et al., 2016a). The basin comprises of two main Rivers, namely, Maritsa and Ergene, and 67 sub watersheds. Corlu Creek, Suluca Creek, Luleburgaz Creek, Babaeski (Seytan) Creek, Teke Creek, Hayrabolu Creek and main stream are the main tributaries of Ergene River basin. The total renewable water water resources of the baisn is around 1.73 billon m^3, one third of which is surface water with 1.33 billion m^3 and the remaining part with about 0.4 billon m^3 is underground water resources (Konukcu et al., 2016a). The hydrology map of the basin is presented in Fig. 2 whreas the elevation, soil and forest maps of the basin are illustrated in Figs 3, 4 respectively.

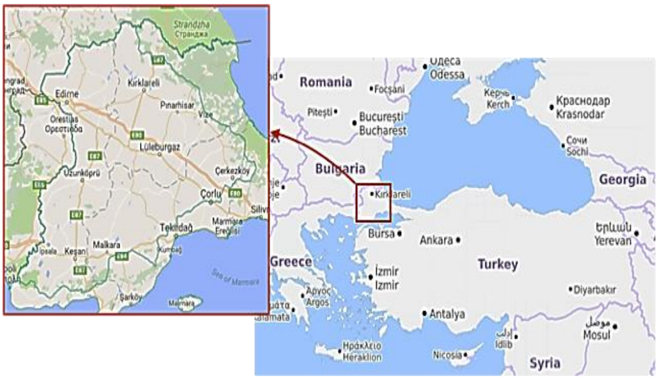

Figure 1. Location of Ergene River Basin.

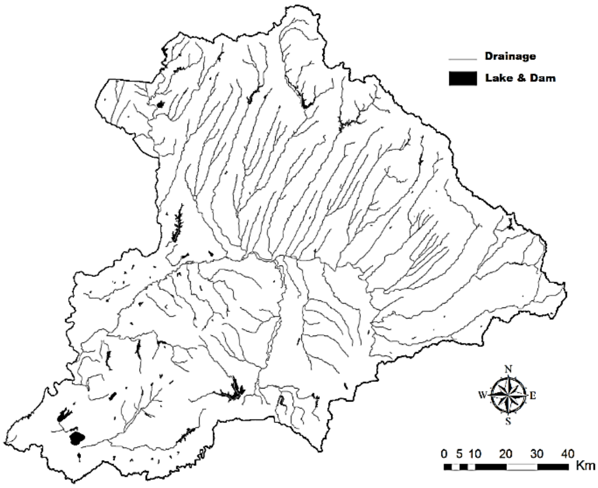

Figure 2. Hydrology map of Ergene River Basin.

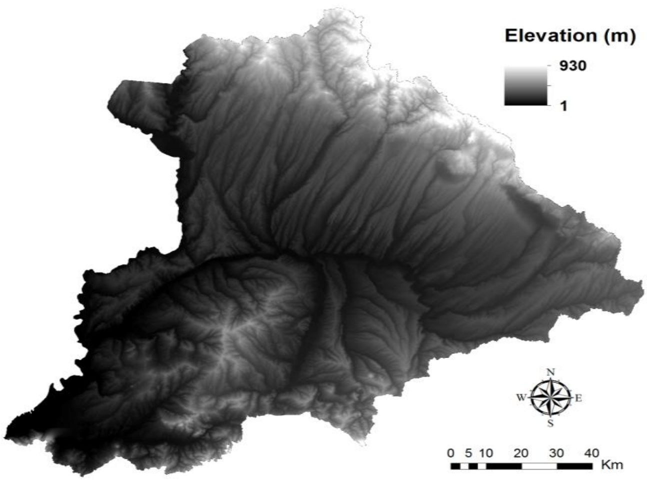

Figure 3. Elevation map of Ergene River Basin.

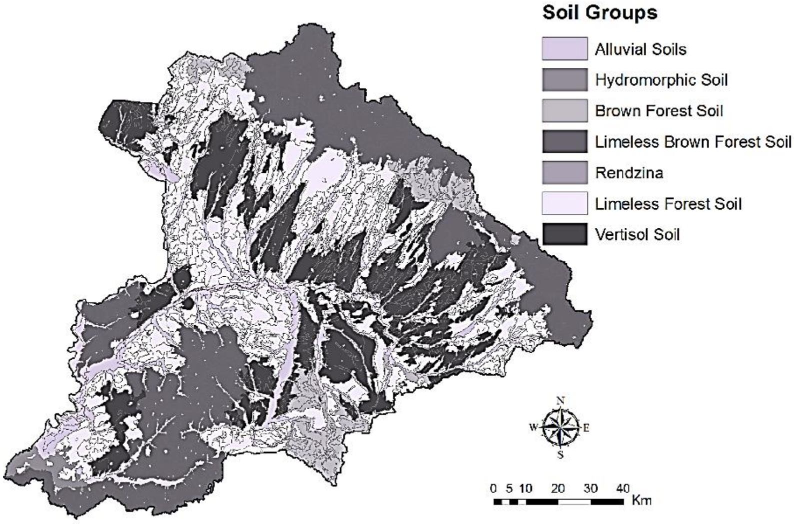

Figure 4. Soil map of Ergene River Basin.

In the modelling of land use/land cover changes, CORINE land use/land cover (CLC) maps of Ergene River basin for the years 1990, 2000, 2006 & 2012 and ArcGIS based model was used.

The CORINE (Co-ORdinated INformation on the Environment) data series was established by the European Community (EC) as a means of compiling geo-spatial environmental information in a standardised and comparable manner across the European continent. The (CLC) inventory is a Pan-European landuse and landcover mapping programme. It supplies spatial data on the state of the European environmental landscape and how it is changing over time. Based on the interpretation of satellite imagery, CLC provides national scale maps of land use and land cover change on a six year basis for thirty nine countries in Europe. The data series are used in a wide range of social and environmental applications by the varioius national environmental agencies, private companies, environmental researchers and academics. The fact that it is a pan-European dataset means it is useful for policy-making and for comparative environmental analysis and assessment throughout Europe. Corine 2012, the fourth instalment in the series is now complete, alongside to base years of 1990, 2000 and 2006. The CORINE land cover nomenclature is hierarchical and distinguishes 44 classes at the third level, 15 classes at the second level and five classes at the first level. The five classes in the first level are atificial surfaces, agricultural areas, forests and semi-natural areas wetlands and water bodies. Additional national levels can be mapped but should be aggregated to level 3 for the European data integration. No unclassified areas should appear in the final version of the data set. (Lydon & Smith, 2014). The land use land/land cover data of Ergene River Basin in 1990, 2000, 2006 & 2012 for the five classes in the first level are presented in Table 1.

Table 1. The land use land/land cover data of Ergene River Basin in 1990, 2000, 2006 & 2012 for the five classes in the first level in CORINE land cover nomenclature

Code Explanation	Area (ha)	Area (%)
Year 1990		
Artificial surfaces	34,764.26	2.40
Agricultural areas	1,154,121.93	79.72
Forests and semi-natural areas	246,875.37	17.05
Wetlands	5,053.15	0.35
Water bodies	6,948.36	0.48
Total	1,447,763.07	100
Year 2000		
Artificial surfaces	45,184.91	3.12
Agricultural areas	1,144,458.65	79.05
Forests and semi-natural areas	245,822.99	16.98
Wetlands	3,684.74	0.25
Water bodies	8,611.78	0.59
Total	1,447,763.07	100
Year 2006		
Artificial surfaces	46,169.25	3.19
Agricultural areas	1,143,562.06	78.99
Forests and semi-natural areas	245,743.62	16.97
Wetlands	3,449.17	0.24
Water bodies	8,838.97	0.61
Total	1,447,763.07	100
Year 2012		
Artificial surfaces	48,463.83	3.35
Agricultural areas	1,141,081.66	78.82
Forests and semi-natural areas	244,509.39	16.89
Wetlands	3,432.98	0.24
Water bodies	10,275.21	0.71
Total	1,447,763.07	100

In addition to EEA CORINE land use/land cover classes 12 additional fourth stage codes developped for Turkey were also used. These codes for Turkey were:

1121. Discontinues urban in cities
1122. Discontinues urban in rural areas
2111. Non-irrigated arable land
2112. Non-irrigated arable land, green houses
2121. Irrigated arable land
2122. Irrigated arable land, green houses
2221. Fruit trees and berry plantations, non-irrigated
2222. Fruit trees and berry plantations, irrigated
2421. Complex cultivation, non-irrigated
2422. Complex cultivation, irrigated
3321. Bare rocks
3322. Bare rocks with very high salt content.

The satellite and ancillary data used in the CLC modelling were Landsat5-TM satellite image with 30 m resolution for the year 1990; Landsat7-ETM satellite image with 30 m resolution for year 2000; satellite image Spot4&5 / IRSP6 satellite image with

20 m resolution for year 2006; satellite image Spot5 with 5 m resolution for the year 2012; 1/25,000 scale raster topographic maps, irrigation data; 1/100,000 scale forest map and 1/25,000 scale soil map.

RESULTS AND DISCUSSION

The land use/land cover changes between 1990 and 2000, between 2000 and 2006, between 2006 and 2012 are shown in Figs 5, 6 & 7, respectively, whereas the land use/land cover changes between 1990 and 2012 is summarised in in Table 2.

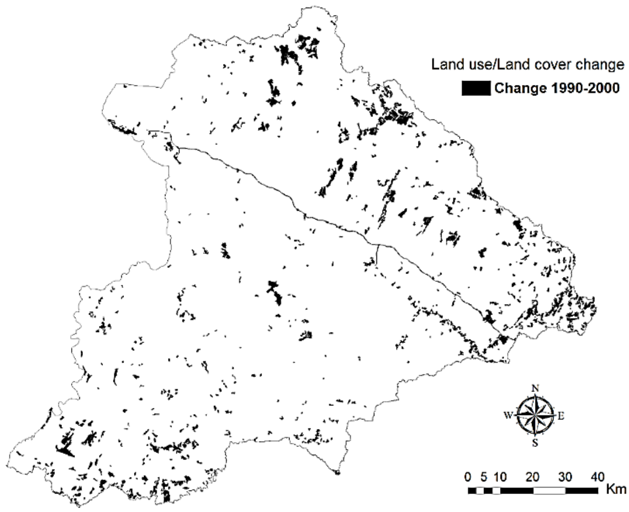

Figure 5. CORINE land use/land cover change between 1990 and 2000.

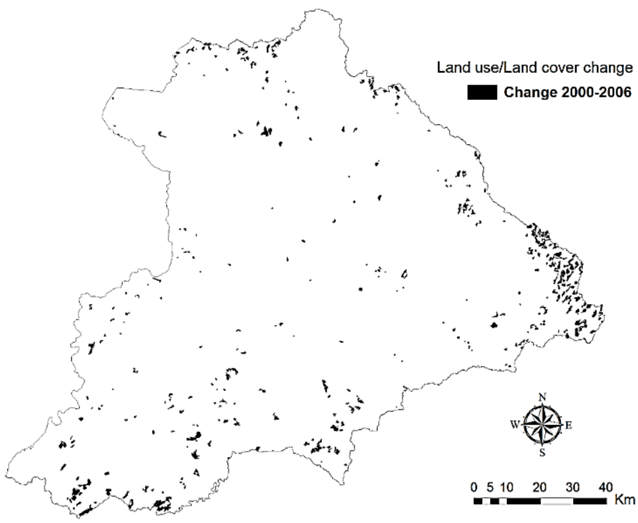

Figure 6. CORINE land use/land cover change between 2000 and 2006.

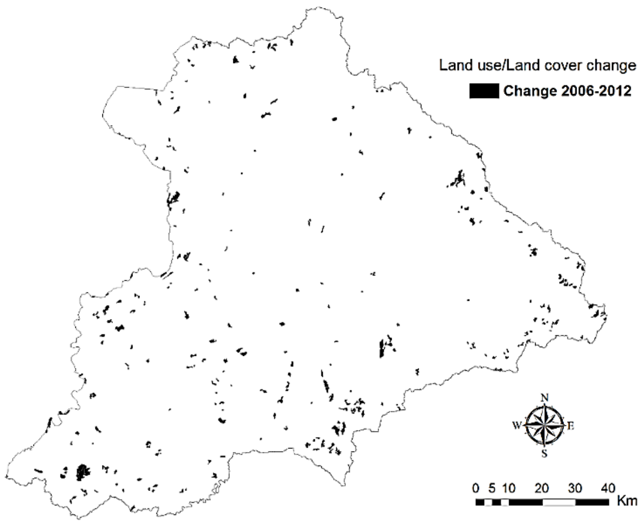

Figure 7. CORINE land use/land cover change between 2006 and 2011.

Table 2. Land use/land cover change of Ergene River Basin between 1990 and 2012

Land Use	1990		2012		Land use/land cover change (%)
	Area (%)	Area (Hectare)	Area (%)	Area (Hectare)	
Artificial area	2.4	34,764.26	3.3	48,460.67	+39.4
Agricultural Area	79.7	1,154,121.93	78.8	1,141,081.66	-1.1
Forests and semi natural areas	17.1	246,875.37	16.9	244,509.39	-1.0
Wetlands	0.3	5,053.15	0.2	3,432.98	-32.1
Water bodies	0.5	6,948.36	0.7	10,275.21	+47.9

Table 1 & 2 show that majority of Ergene River Basin, almost 80%, is occupied by land use class of agricultural area, which is followed by the land use classes of forests and semi natural areas, artificial area, water bodies and wetlands, respectively.

It seems that natural areas were turned into agricultural areas or settlements generally in terms of variations in land use/land cover. Important variations were occurred especially in 231 (pasture) and 2111, 2121, 2421 (different agricultural areas) coded regions. Also, change of agricultural areas into urbanized or industrialized areas was widely observed. Development of both Turkey and Ergene River Basin after 1990 seems also to affect urbanization rate. Rapid increases in industrialization and building industrial areas on agricultural land and pastures are the main problems in Ergene River Basin. Pressure on agricultural areas and pastures and decrease in their sizes can be seen from Table 2. This also means to the increase in contamination. In each time periods, changes towards 512-water bodies can be observed. These changes correspond to the newly constructed dams and ponds. Because of industrial forestry in the northern part of the basin, change of 324 (changes in vegetation) into 311, 312, 313 widely seen in time periods. Afforestation works in the last decade has a big impact on forestry.

The ongoing land use changes from natural area, especially agricultural, forests and semi natural areas, into urban and industrial area are seen as a threat for sustainability of land, water, biodiversity and other natural bodies (Konukcu et al., 2016b). Sonter & Lawrie (2007) stated that land capability is the inherent physical capacity of the land to sustain a range of land uses and management practices in the long term without degradation to soil, land, air and water resources. Using land beyond its capability impacts can include loss of valuable soils by water and wind erosion on agricultural land, soil structure decline, soil acidification.

Most of the Ergene River basin soils are deep, fertile and suitable for agricultural production and mechanization (Eyupoglu et al., 2001). Kocaman et al. (2007) reported that 81.76% of basin is potentially cultivated land, 70% of which is under erosion hazard varying in intensity (0.74 t per haper year at average), namely 25.3% light, 34.6% moderate, 8.6 strong and 1.5% very strong, while the rest has no such problem, which is sourced by land use change and land use beyond their classes.

Similarly, Alturk (2017) indicated that water availability in Ergene River basin for human and nature will be endangered in the future (after 2050) due to combined effects of land use change and climate change, flooding and subsequent erosion hazards.

The basin is of great importance for Turkey in wheat and sunflower production. Deveci (2015) found that, by climate change, sunflower yield will decreased up to 22% while, unlike other region of Turkey, wheat yield will increase up to 50% between the years 2076–2085 when compared to the measured data of 2012. This tells that Thrace Region/Ergene River Basin is vital to ensure food safety of Turkey with this increase in wheat yield. Therefore, land use change, particularly transformation of agricultural areas into other classes, should be prevented.

CONCLUSIONS

As a result, the most important pressure in Ergene River Basin is on 231 (pasture) and 2111 (dryland agricultural) where maximum decrease were observed. While the artificial area (including settlement area and industrial zone) and water bodies due to new reservoirs construction increased by 39.4 and 47.9%, respectively, wetlands and agricultural areas decreased dramatically. This dramatic changes in agricultural areas to industrial area has been threatening not only natural resources but also food security since the basin has the most productive arable land of Turkey.

The decision maker is aiming to increase industrial areas in the region in the future. It is inevitable that this increase in industrial areas will cause urbanization to growth by triggering immigration to the region. It, in particular, will lead to a decrease in cultivated land and pastures. To prevent or decrease the speed of land use/land cover change in a sustainable and manageable ways, the following measures are to be taken:

- development of industrial area should be allowed only in organised industrial zone;
- population growth, migration into the region and subsequent urbanisation should carefully be managed;
- regulations permitting urbanisation on agricultural area, particularly on the land with capability classes of I, II and II, should be banned.

ACKNOWLEDGEMENTS. This research was funded by EU and Turkish Ministry of EU Affairs within the scope of 'ILMM-BSE – Integrated Land Use Management Modelling of Black Sea Estuaries' Project. The contents of this publication are the sole responsibility the authors and can in no way reflect the views of the European Union.

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Agronomy Research **15**(2), 444–455, 2017

Soil fertility and productivity of apple orchard under a long-term use of different fertilizer systems

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Abstract. An apple should be planted on suitable soils which can be used for growing two or more generations of gardens for decades. This can be reached by creating and supporting an optimum level of mineral nutrients for fruit trees. The aim of this study was to compare the long-term effect of mineral or organic fertilization on apple tree growth and yield and soil fertility. The research has been conducted since 1931, when an apple orchard of Winter-Calville on seedlings was established on dark-grey heavy loam soil of Uman National University of Horticulture. The non-irrigated trees were subjected to the following treatments: 1. Unfertilized (control); 2. Application of cattle manure 40 t ha^{-1} (organic); 3. N_{120} P_{120} K_{120} (mineral); 4. 20 t ha^{-1} of humus N_{60} P_{60} K_{60} (organic-mineral). In 1982 the first orchard was removed and 2 year later another one was re-planted on the same soil. The second orchard, that included, beside the same variety also Idared grafted on seedling and on M4, was subjected to the same treatments.
Soil fertility and apple tree productivity increased under the use of organic fertilizer system. Organic-mineral fertilizer system provided almost the same response, while mineral fertilizer system provided the lowest one.
During the study a decreased uptake of nutrients applied with fertilizers was often related to insufficient soil moisture supply. Soluble nitrogen was washed out of root layer into ground water, while phosphorus and potassium were transformed into compounds and forms inaccessible for plant nutrition. Thus it is necessary to apply those rates of fertilizers that are insufficient in the soil to reach the optimal levels of content of corresponding nutrients which should be determined by agrochemical analysis.
It is possible to maintain an optimal fertility of soil in orchards by applying only organic fertilizers. Alkalization of inter-row spacing with regular grass mowing (turf and humus soil management system) provided the same humus content in soil as application of 40 t of humus per ha in a year after the use of fallow system.

Key words: apple tree, soil fertility, fertilizer system, nutrition elements, yielding capacity, long-term research.

INTRODUCTION

The yielding capacity and quality fruit of an apple tree, the most important horticultural crop in Ukraine, depends on natural factors: such as soil and climate conditions that influence processes of plant nutrition depending on the level of soil fertility and water supply and create favourable or stressful conditions of external influence on plant bodies and biological properties of cultivated rootstock variety combinations, as well as technological factors: soil management (pre-planting, fertilization, tillage, irrigation) and plant care measures (canopy training depending on tree spacing, pruning, fruit bearing control, nutrition, disease and pest management, etc.).

As to the efficient use of natural factors it is very important to place industrial apple plantations on the most suitable soils with optimal physical and chemical parameters of fertility (Atucha et al., 2011; Zuoping et al., 2014; Wang et al., 2015; Wang et al., 2016), that are evaluated by the previous soil and agrochemical examination of plots of land where orchards are laid out and cultivated (Fura, 2009). To improve the properties of soil that are not optimal enough it is essential to carry out its pre-planting preparation with relevant cultivation and fertilization (Wawrzynczczak et al., 2012).

In the process of a long-term cultivation of apple orchards it is necessary to maintain high level of soil fertility over many decades for functioning plantings even for several generations of plantations on the same areas that were selected according to suitability of soil and water supply (for the irrigation of intensive plantings) and take into account the established horticultural infrastructure. There is no point to relocate new plantings on less fertile soils as they will be less productive while the expenses on the improvement and maintenance of the necessary level of soil fertility will be considerably higher. The refore it is more profitable to cultivate trees on the same areas where the old ones had been grown. With such a change of generations of fruit plantations, old and less productive rootstock variety combinations are replaced by more productive, gardens with better progressive constructions with cultivars that have better parameters of yielding capacity and quality of fruits are laid out. To ensure high productivity of apple trees it is essential for the soil to remain fertile for sufficient nutrition of new fruitful trees according to their productivity potential. Under such conditions a negative impact of soil fatigue caused by a long-term growing of a previous orchard is less tangible.

If it becomes necessary to decrease a negative influence of soil fatigue before planting new trees the soil should be specially prepared: it is required to enrich the soil with organic substances for enhancing biological activity and with elements of mineral nutrition insufficient for optimal levels, to optimize acidity of the soil, to loosen the soil deeply for the improvement of water-air regime, etc (Gasparatos et al., 2011; Vliegen-Verschure, 2013).

In this regard the objective of the research was to substantiate the results of a long-term experiment with different fertilizer systems applied in apple orchard, which has been carried out during 85-year period at Uman National University of Horticulture and according to the state executive order was included into State Register of scientific objects of national asset as ‘Unique research agroecosystem of apple tree orchard of National University of Horticulture’. The study was also aimed at working out recommendations for optimal fertilization of an orchard with the purpose of obtaining maximal productivity. The authors directly participated in obtaining, analyzing and interpreting experimental data.

MATERIALS AND METHODS

The experiment was started in the autumn of 1931 by professor S.S. Rubin in the orchard planted in the spring of the same year on plot of land of dark-grey heavy loam soil. The experiment scheme included three systems of fertilization: organic – the application of cattle manure 40 t ha^{-1}, mineral – $N_{120}P_{120}K_{120}$, organic-mineral –

20 t ha^{-1} of humus + $N_{60} P_{60} K_{60}$ and also the unfertilized control. All mentioned rates of fertilizers were introduced into the soil once in two years at the time of autumn re-ploughing at the depth of 18−20 cm within 10 meters wide inter-row spacing (trees of Winter-Calville apple variety on seedling rootstock were planted at a distance of 10 m x10 m).

The research had been conducted for 50 years till the orchard was removed in 1982. Experimental plots of all experimental variants were marked out and preserved for the following study of the newly re-planted orchard in spring of 1984. The new orchard included, beside Winter-Calville on seedling rootstock, also Idared on both vigorous seedling and medium-growth vegetative rootstock M.4, planted at a distance of 7 m x 5 m. Within the period of 1982−1984 the soil of the uprooted orchard was cleared of residual root pieces and ploughed at the depth of 50 cm.

During the growth period of the old orchard as well as the new experimental orchard without irrigation, the soil was maintained under fallow. During spring-summer period the soil was cultivated for weed killing and loosening, while in spring it was ploughed in inter-row spacing at the depth of 18–20 cm.

Nitrogenous fertilizers have been applied half-dose annually according to the scheme of the experiment in the newly cultivated orchard since 1984. They have been applied within rows during spring soil cultivation to reduce unproductive losses of nitrogen.

To evaluate soil conditions in the experimental garden the following methods were used: Tiurin method to determine the humus content; Kappen method to identify reaction of soil solution (pH) – in extraction 0.1 n KCl; hydrolytic soil acidity; Kappen-Hilkovitz method to define the sum of absorbed bases (Ca and Mg); Kjeldahl method to determine nitrogen and distillation method to determine mineral compounds; organic nitrogen was defined by the difference between total content and mineral compounds content; Ginsburg-Lebedeva method to find out phosphorus compounds of different solubility; Vozhenin method to determine potassium of different level of solubility and fixation by soil minerals; Kravkov method in modification of Bolotina, Abramova to determine the forms of main macroelements of nitrogen, phosphorus and potassium available for fruit trees nutrition under 14-day composting of soil samples in thermostat (NO_3) and Egner-Riehm-Domingo method (P_2O_5 and K_2O) (above mentioned techniques were described by Z.M. Hrytsayenko et al., 2003).

The productivity of apple plantings was evaluated by measurements of annual increment of all above ground tree organs (trunks, shoots, leaves) and periodically roots (under digging) and by direct weighing of fruit crop from every registered tree (in the orchard of the 1st generation) and from registered plots (in the orchard of the 2d generation).

Validity of the research and substantiality of differences among productivity indexes in the experimental studies were assessed according to the results of dispersion analysis of mathematical statistics (Ehrmantraut et al., 2000).

RESULTS AND DISCUSSION

The long-term experiment proved that under fallow the processes of mineralization of organic substances prevail over the processes of their humification. To maintain sufficient level of humification of soil, it is necessary to enrich it regularly with organic substances by application of appropriate fertilizers. This is confirmed by the results of the research into dynamics of humus (Fig. 1). The results show that during the initial period of growth of young apple trees, when the soil in wide inter-row spacing was under tillage systematically and too little organic matter came into it from plants, the level of humus in the root layer of 0−60 cm reduced significantly by 1956 in all experimental plots compared to the initial level (2.04%).

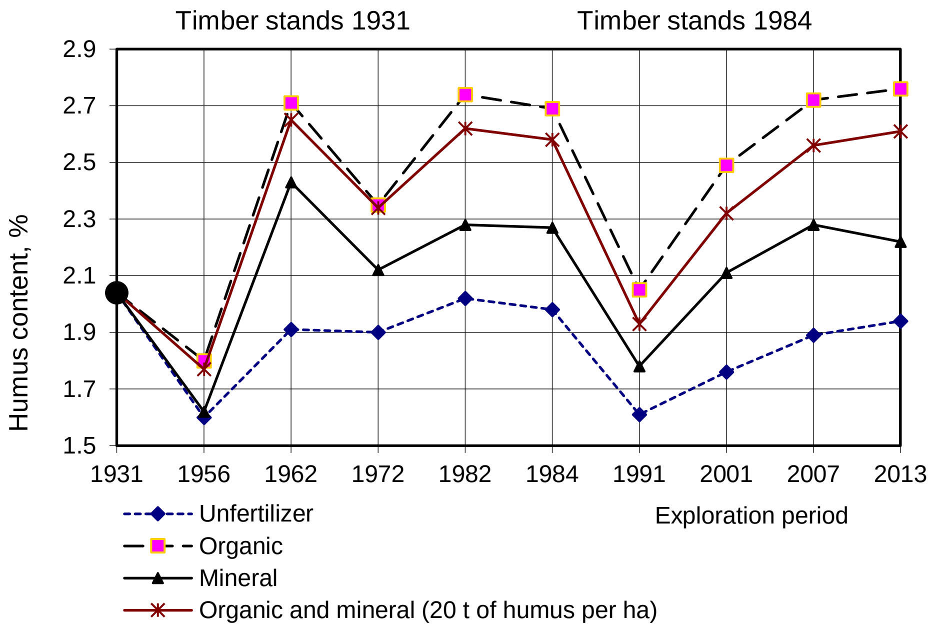


Figure 1. The dynamics of humus content in the soil layer of 0−60 cm under a long-term use of different fertilizer systems in the apple orchard, %.

Under organic and to a lesser extent under organic-mineral fertilizer system the humus content exceeded the indexes of its level in the control variant.

In the following period, till 1962, the humification of soil increased on fertilized plots and exceeded the initial level of 1931 especially under organic, organic-mineral fertilizer system. The reduction of humus concentration by 1972 was caused by the rejuvenation of the experimental orchard; in 1965, perennial branches were pruned and the canopies were considerably reduced. As a result in the following years less organic matter came into soil from plant residues.

The soil humification rate increased significantly under the intensive growth of tree canopy and corresponding leaf shedding in 1982, which occurred rather intensively in a manured soil.

The same dynamics of humus substances in soil was observed during the period of 1984–2013, when new apple trees were planted. At first humus concentration decreased by 0.37% up to 1991 in unfertilized soil and by 0.49–0.65% in fertilized soil, and later it increased till 2007 upon which the balance of soil humification was established. It was the highest level under organic fertilizer system (2.72−2.76%), slightly lower under organic-mineral fertilizer system (2.56−2.61%), and it was significantly lower under mineral fertilizer system (2.22−2.28%). During the research period, the lowest level of soil humification was on control unfertilized plots. The highest content of humus in the soil was in 1982 (2.02%) and in 2013 (1.94%), i.e. the content of humus in the soil was lower throughout 83-year period of research compared to the initial period in 1931.

Physicochemical and biological indicators of soil fertility are closely related to organic matter and humic substances in particular. Research data (Table 1) show changes in a number of physicochemical indicators under long-term fertilization. If organic fertilization scheme fostered the shifting of exchange soil acidity in the direction to neutral (up to pH 5.5), then mineral fertilization system acidified the reaction of the medium (up to pH 4.4). Hydrolytic acidity has changed in the same direction. The increase of calcium and magnesium concentration in soil was revealed under the use of organic fertilizer system, while the use of mineral fertilizer system led to its decrease. This was due to the fact that mineral fertilizers stimulated soil disturbance processes. As a result, more soluble mineral compounds of these elements were formed and washed out into deeper layers of the soil profile.

Table 1. Physicochemical parameters of dark-grey heavy loam soil in 0−60 cm-layer after a 50-year use of different fertilizer systems

Fertilizer systems	pH_{KCl}	Hydrolytic acidity, mg-eq (100 g)$^{-1}$ soil	Soil absorption complex, mg (100 g)$^{-1}$ of soil		Degree of saturation with soil absorbing complex,%
			Ca	Mg	
Unfertilized (control)	5.1	2.5	19.5	4.1	90.4
Organic (humus 40 t ha^{-1})	5.5	1.9	20.5	4.7	93.0
Mineral ($N_{120}P_{120}K_{120}$)	4.7	3.6	18.0	3.8	86.0
Organic-mineral (humus 20 t ha^{-1} +$N_{60}P_{60}K_{60}$)	5.2	2.4	19.8	4.3	90.7

Microbiological processes were more active in systematically fertilized soil (Styła et al., 2010). As a result cellulose decomposed rather intensively (by 4−11%), CO_2 liberation from the soil surface increased by 19–28% and the production of nitrate nitrogen increased by 116–160% under optimal hydrothermal conditions for nitrification in thermostat. Organic fertilizer system promoted these processes to a greater extent due to the best provision of soil with organic substances as energetic material for enhancing vital activity of microbiota.

Long-term regular fertilization in the orchard provided constant maintaining of the content of mobile compounds and forms of mineral nutrition elements within optimal levels or their exceeding. The concentration of nitrate nitrogen ($N-NO_3$), produced under optimum hydrothermal conditions, in the unfertilized soil layer (0−40 cm) of the control variant was always within 14−20 mg kg^{-1}, which is lower than the optimum level for an apple tree on a dark-grey heavy loam podzolic soil that makes up 22−25 mg kg^{-1}. The content of nitrate nitrogen on fertilized plots was 27−33 mg kg^{-1}, under the use of mineral fertilizer system was 22–24 and under the use of organic-mineral fertilizer system was 26–29 mg kg^{-1}. There was a sufficient amount of phosphorus mobile compounds determined in the layer of soil of 0−60 cm in all experimental variants: in the soil of control variant it was 80–140 mg kg^{-1}, under organic fertilizer system, 160–260 mg kg^{-1}, under mineral fertilizer system, 130–220 mg kg^{-1} and under organic-mineral fertilizer system, 150–270 mg kg^{-1} (optimum content is 70–100 mg $kg^{-1}$of soil). The concentration of potassium mobile compounds in the soil of control variant was within optimum level 230−280 mg kg^{-1} in certain years (230−260 mg kg^{-1}), but in most cases it was lower than optimal level and accounted for 130−220 mg kg^{-1}. Under the use of all fertilizer systems the concentration of potassium mobile compounds sometimes corresponded to the optimum level and exceeded the upper limit (280 mg kg^{-1}) more frequently under organic fertilizer system.

The research results confirm that mobilization of nitrogen into soluble compounds from soil supplies was stimulated by fertilization as well as its possible non-symbiotic fixation from atmosphere by soil microorganisms. Data mentioned above show significant unproductive nitrogen losses because of washing out outside root layer of the soil and possibility of ground waters contamination with nitrate and other compounds of this element.

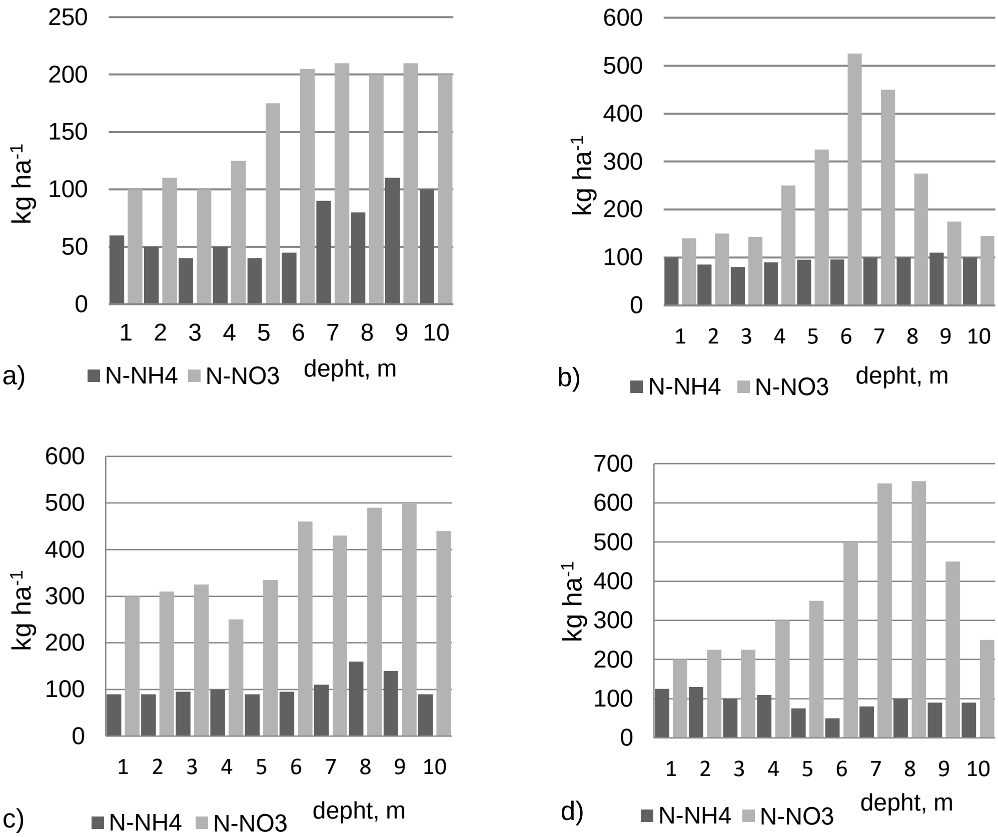
All amounts of P introduced with fertilizers and not used by trees remained in 1 meter soil stratum in different compounds with Ca, Al and Fe as well as in the composition of organic substances. In more humified 60 cm soil layer, potassium was found mainly in soil solution and in absorbed state on the surface of fine particles of colloidal fraction of soil (exchange potassium). At the depth of 60–100 cm potassium ions were found in the lattices of clay minerals enriching the content of exchange hydrolyzed and fixed potassium.

Under the conditions of percolative regime in the soil in the orchard over the first 50-year period on the plots under experimental fertilizer systems the soil was enriched with phosphorus and potassium to the depth of 1 meter while nitrogen moved 10 meters deeper (up to 13 m) reaching ground waters (Fig. 2).

The greatest amount of nitrogen migrated as nitrate compounds and certain number as soluble organic matter (Fig. 3).

The total accumulation of nitrogen in the soil stratum deeper than 1m profile exceeded its amounts introduced with fertilizers over the whole 50-year period. Thus on a per hectar basis N was introduced together with humus – 3,520 kg and together with N P K – 2,760 kg, of which it 2,360 kg or 67,0% and 980 kg or 35.5% were found in 1m layer respectively. Fertilized trees used 160 and 141kg additionally. In total it accounted for 2,520 and 1,121 kg that is why 1,000 and 1,639 kg of nitrogen were lost respectively. But supplementary amounts of nitrogen 8,200 and 5,880 kg were found in the soil stratum deeper than 1m and up to 10 m which is 2.3 and 2.1 times more than introduced amounts.

These research results confirm that mobilization of nitrogen into soluble compounds from soil supplies was stimulated by fertilization as well as its possible non-symbiotic fixation from atmosphere by soil microorganisms. Data mentioned above show significant unproductive nitrogen losses because of washing out outside root layer of the soil and possibility of ground waters contamination with nitrate and other compounds of this element.



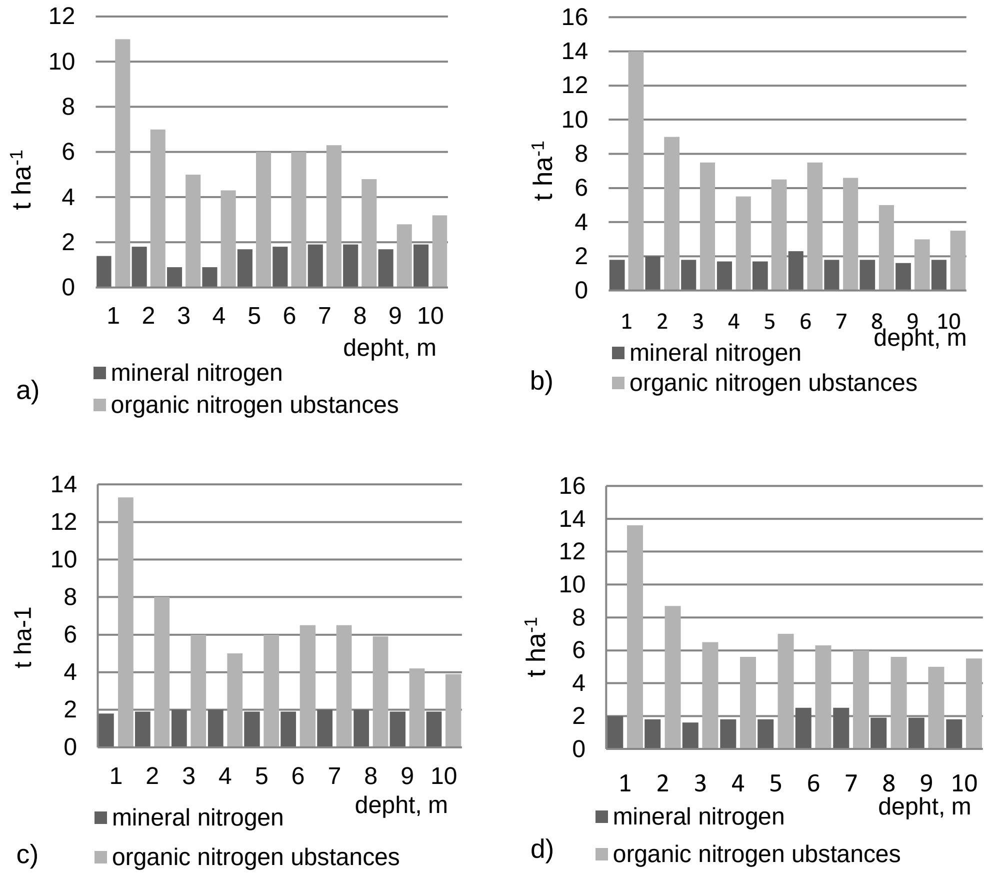
a) − Unfertilized (control); b) − Organic (humus 40 t ha^{-1}); c) − Mineral N_{120} P_{120} K_{120}; d) –Organic-mineral (humus 20 t ha^{-1} + $N_{60}P_{60}K_{60}$)

Figure 2. Mineral nitrogen in 10-meter soil profile after a 50-year period of fertilization of dark-grey podzolic soil in the experimental garden.

All amounts of P introduced with fertilizers and not used by trees remained in 1 meter soil stratum in different compounds with Ca, Al and Fe as well as in the composition of organic substances. In more humified 60 cm soil layer, potassium was found mainly in soil solution and in absorbed state on the surface of fine particles of colloidal fraction of soil (exchange potassium). At the depth of 60–100 cm potassium ions were found in the lattices of clay minerals enriching the content of exchange hydrolyzed and fixed potassium.

Thus under systematic long-term soil fertilization of an orchard higher levels of fertility were created and maintained and mineral nutrition of fruit plants in particular.

Better nitrogenous nutrition was provided mainly by enriching the soil with organic substances, which is proved by the indexes of its higher humus content. Phosphorus and potassium nutrition was provided by increasing content of their mobile compounds and forms in the root layer of the soil. Higher levels of soil nutrition were created under the use of organic and organic-mineral fertilizer systems, compared to the mineral system. Other indicators of soil fertility (physicochemical and biological in particular) were more optimal under the use of organic and organic-mineral fertilizer systems. Moreover, under the application of organic fertilizer the soil was enriched not only with main nutrition elements (N, P, K), but also with the other micro- and macro-elements.



a) − Without fertilization (control); b) − Organic (humus 40 t ha^{-1}); c) − Mineral $N_{120} P_{120} K_{120}$;
d) − Organic-mineral (humus 20 t ha^{-1} + $N_{60} P_{60} K_{60}$)

Figure 3. Organic and mineral nitrogen in 10-meter soil profile after a 50-year period of fertilization of dark-grey podzolic soil in the experimental garden.

According to soil fertility, changes of apple tree productivity in the experimental orchard increased. The productivity was determined by the level of supply of fruit trees with water, which depended in non-irrigated orchard on regional climatic and weather conditions in certain years. Practically the level of available water supply was the main limiting factor for the growth and productivity of experimental apple trees in the zone of unstable moistening. Over the entire 42-year period of fruit-bearing (1940–1981) of experimental variety Winter Calville in the plantation of 1931 the average productivity was higher under organic, organic-mineral fertilizer systems and made up 13.2 t ha^{-1} and 13.4 t ha^{-1} respectively which is higher than productivity on non-fertilized plots of control variant (10.6 t ha^{-1}) by 2.6 t ha^{-1} and 2.8 t ha^{-1}and under mineral fertilizer system – by 2.8 t ha^{-1}.

Similar difference in the intensity of fruit-bearing found in Winter Calville in the first plantation, was observed in the second orchard re-planted in 1984 which had been grown on the same experimental plots (Table 2).

Table 2. The yielding capacity of Winter-Calville apple variety under the long-term use of different fertilizer systems, t ha^{-1}

Fertilizer systems	Plantations 1931 year		Plantations 1984 year	
	Growth and fruit-bearing period (1940−1946)	Fruiting period (1947−1963)	Growth and fruiting period (1990−1996)	Fruiting period (1997−2013)
Unfertilized (control)	2.5	7.5	3.5	12.1
Organic (humus 40 t ha^{-1})	3.2	10.6	4.8	16.7
Mineral ($N_{120}P_{120}K_{120}$)	2.8	9.1	4.5	14.9
Organic-mineral (humus 20 t ha^{-1} + $N_{60}P_{60}K_{60}$)	2.9	10.5	4.7	16.2
LSD_{05}	0.7	1.5	0.8	1.1

The initial period of fruiting of the trees planted in 1931 (1940−1946) was characterized by low yields, gain in weight of vegetative organs and decrease in soil humus content under the use of all fertilizer systems. As a result, fertility level on experimental plots as well as yielding capacity were slightly different, compared to the next fruiting season (1947−1963). Compared to non-fertilized plots (2.5 t ha^{-1}), yield was higher on fertilized plots by 12–28% and during the fruit-bearing period of well-formed trees it was higher by 21–41%. During the last period of fruit-bearing, the difference in yielding capacity under organic and organic-mineral fertilizer systems compared to the mineral system was rather noticeable, which was caused by unequal levels of soil fertility created over the years. Similar dependence of fruit-bearing results under various levels of soil fertility is confirmed by the indexes of yielding capacity of a subsequent plantation of 1984 during both growth and fruit-bearing periods. The indexes of fertilized plots exceeded the indexes of unfertilized plots (control) by 23–38% and were higher under organic and organic-mineral fertilizer systems by 34–38%, and lower under mineral fertilizer system – by 23–29%.

Depending on fertilizer systems the similar difference in yielding capacity was found in Idared apple variety on both rootstocks grown in a subsequent plantation of 1984 (Table 3). The highest yields were recorded under the use of organic fertilizer system that exceeded control indexes of yielding capacity of trees on seedlings by 33–36% and on vegetative M.4 rootstock by 21–31% and under organic-mineral fertilizer system – by 27–31% and by 23–31% respectively. Under mineral fertilizers application the corresponding exceeding in yielding capacity reached 19–20% and 14–19%. Considering fruit-bearing peculiarities of experimental trees it should be noted that Idared variety had better yielding capacity compared to Winter Calville.

Table 3. The productivity of Idared apple variety, planted in 1984, under the long-term use of different fertilizer systems, t ha^{-1}

Fertilizer systems	The period of growth and fruiting (1990−1996)		Fruiting season (1997−2013)	
	Seedling rootstock	Vegetative rootstock M.4	Seedling rootstock	Vegetative rootstock M.4
Unfertilized (control)	4.8	4.4	13.8	12.4
Organic (humus40 t ha^{-1})	6.4	5.3	18.7	16.2
Mineral ($N_{120}P_{120}K_{120}$)	5.7	5.0	16.5	14.8
Organo-mineral (humus 20 t ha^{-1} + $N_{60}P_{60}K_{60}$)	6.1	5.4	18.1	16.3
LSD_{05}	1.2	0.8	0.9	0.8

Considerably higher crop yield indexes of Winter-Calville were obtained in subsequent plantation of 1984 compared to the old plantation of 1931 as a result of high tree density in a new garden and improved plant care measures (except fertilization) which provided more stable fruiting every year. In the old garden the fruit-bearing was regular, but in the years (1952, 1953, 1954, 1960) the trees didn't bear fruit because of dry weather conditions during vegetation or because of damaged flowers by spring frosts (last year). The refore the average yielding capacity in the old garden only in bumper-crop years was twice as much as it was over all years. Sometimes the yielding capacity reached 20 t ha^{-1} on fertilized plots (1963) and was even higher 30 t ha^{-1} (1957). But in subsequent years after such heavy fruit-bearing the yielding capacity dropped sharply (1964) or the garden didn't bear fruit at all (1958).

Long-term study of different fertilizer systems for the plantations of apple trees enabled to establish that the highest level of soil fertility in the orchard is provided by systematic enrichment of the soil with organic substances applying organic fertilizers or its combination with mineral fertilizers.

Introducing mineral fertilizers only in inter-row spacing under fallow does not provide optimum soil fertility for fruit trees and to a great extent it causes losses of nutrients from root layer as a result of washing out soluble compounds and nitrate nitrogen in particular.

A great loss was recorded on all the fertilized plots, because under relatively low productivity caused by insufficient moisture supply trees didn't use all amounts of nutrient elements applied with fertilizations and a number of them was washed into deeper soil layers or was fixed by soil absorbing complex into insoluble compounds and forms inaccessible for plant nutrition. Being created in fruit tree plantings by pre-planting fertilization the optimum levels of content of fertilizer elements in soil should be maintained due to the introduction of fertilizers at the rates calculated according to the results of agrochemical analyses. These analyses should be carried out periodically (in 2–3) years and determine the content of compounds and forms of corresponding mineral elements available for nutrition of plants in a root layer. In other words, it is essential to apply only those fertilizers and in such quantities that are not sufficient to reach optimum levels. This fertilization ensures optimum nutrition of trees and under sufficient water supply they can produce a required yield of high-quality fruits.

In this case if there is need to enhance certain growth and generative processes (blossoming, fruit setting, increase in their weight and formation of better quality, differentiation of buds or shoot growth etc.) during vegetation it is worth applying special fertilizing – either outside root fertilizing or with irrigation water by fertigation. Under such integrated fertilization system applied in the garden fertilizers are used in the most cost-efficient way without considerable unproductive losses.

The results of the research in a long-term experiment have shown the optimum levels of nitric nitrogen concentration in dark-grey heavy loam soil for apple trees which is determined by 14-days composting of soil samples in thermostat under optimum hydro-thermal conditions for nitrification which are considered to be potential abilities of soil to produce $N\text{-}NO_3$ for the whole vegetation of plants and mobile compounds of phosphorus and potassium forms.

The possibility to constantly maintain optimum levels of all main indexes of soil fertility in a garden with the introduction of organic fertilizers only without mineral ones has been substantiated. It is important for organic gardening which is more environmentally friendly than traditional. In the experiment such soil fertility was provided by the introduction of 40 t ha^{-1} of humus in a year.

Additional study has showed that the same soil humification is provided by alkalization of inter-row spacing with periodical grass mowing during vegetation period (turf and humus system of soil maintaining). In this case the mass of dry substance of grass (the amount of above-ground part of roots) accumulates every year and is bigger than that one which is applied with 20 t ha^{-1} of humus per year. As a result physical, agrochemical and biological indexes of soil fertility improve. Therefore there is no need to introduce organic fertilizers as it is done under fallow system but feed grasses and trees with multiple-nutrient fertilizers.

CONCLUSIONS

1. Application of organic fertilizer system ensures the highest level of soil humification – at the end of 83-year period of growing experimental garden the exceeding over the initial level of humus content makes up 31% and under mineral fertilizer system – only 7%. Organic-mineral fertilizer system ensures intermediate level of humus content closer to organic fertilizer system.

2. Under organic fertilizer system other indexes of soil productivity improve to the fullest extent: reaction of soil solution, saturation of soil complex with bases, the level of hydrolytic acidity, biological activity of soil medium, provision of root soil layer with mobile compounds and minor plant nutrients (N, P_2O_2 i K_2O).

1. Under mineral fertilizer system the soil noticeably acidifies, exchangeable and hydrolytic acidity increases and saturation of soil absorbing complex with bases dicreases.

2. According to the increase in soil productivity under a long-term fertilization in the period of apple fruit bearing the yielding capacity increases the most – 31−41% under organic fertilizer system and it is the lowest under mineral fertilizer system – 21–23%. However, under climate conditions of unstable moisturizing the productivity of non-irrigated apple plantation is quite low – average yielding capacity doesn’t exceed 16–19 t ha^{-1} on well fertilized plots because of insufficient moisturizing. That is why a

considerable part of nutrients mobilized in the soil, nitrogen in particular, isn't used by trees and is lost because of washing out into the deep subsoil horizons.

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Agronomy Research **15**(2), 456–467, 2017

The use of maize stalks for energy purposes and emissions measurement during their combustion

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Abstract. Biomass is an ideal renewable energy with advantages of abundance resources and neutral in greenhouse gas circulation. Majority of this energy could have been used directly in agriculture itself. The rest of the biomass for other parts of industry or even communal parts could be made available as a refined and densified biomass available for direct combustion in form of bales. The objective of the work was a monitoring of possibilities of maize cortical use for energy purposes during combustion. Emissions measurement from the combustion of maize phytomass was performed by measuring device TESTO 350 M/XL. During the combustion of packages with the moisture of 18% and 38% was monitored and the effect of moisture on the content of gas emissions of CO, CO_2, NO, NO_2 as well as the percentage of residual O_2 in the flue gas after combustion. All values of monitored emission limits were in current normative limits defined in Collection of Laws no. 356/2010. All emissions limits are in accordance to monitored standards for CO, CO_2, NO, NO_2, but on the other hand it should be noted that the more favourable results are based on combustion of cortical with moisture of 18% than at 38%. The issue of maize cortical harvesting considering machinery, technological and economical viewpoint within the Slovak republic but also worldwide is poorly understood and therefore these issues should be the subject of further research.

Key words: maize cortical, renewable energy, emission limits, maize cortical harvesting, maize cortical combustion.

INTRODUCTION

Biomass is an ideal renewable energy with advantages of abundance resources and neutral in greenhouse gas circulation (Krištof et al., 2011; Fei et al., 2014).

Maize is one of the agricultural crops, which have wide use from the view of phytomass production and is considered the third millennium crop. Why? Because the human and animal nutrition is impossible without utilization of maize. Alcohol, oil and biogas, also plastics, thermal insulation and other materials can be produced from maize, even electric energy by means of biogas cogeneration. Maize is primarily an economically profitable crop.

Considering combustion, characteristics of biomass are important; main indicators of quality are values of water content in biofuel, chemical composition of combustible fuel, content of volatile matter, biofuel heat value (Findura et al., 2006; Maga & Piszczalka, 2006; Jobbágy et al., 2011). Maize stalks have a heat value of 14.4 MJ kg^{-1} at moisture level of 10%, at the volumetric weight of 100 k gm^{-3} in packages. However, Straw, Miscanthus, maize, and horse manure were reviewed in terms of fuel characteristics by Carvalho et al. (2008) with conclusion that all the fuels showed problems with ash lumping and slag formation. Different boiler technologies showed different operational performances. Maize and horse manure are problematic fuels regarding NOx and particulate emissions. Miscanthus was the best fuel tested. It was also empathised that due to the big variation of fuel properties and therefore combustion behaviour of agricultural biomass, further R&D is required to adapt the existing boilers for these fuels.

Theoretically, in agricultural industry at Slovakia is possible to produce about 46,500 TJ (46.5 PJ) of energy from biomass without it even affect negatively on animal production (feeding, litter) or replacement of organic matter into soils. Majority of this energy could have been used directly in agriculture itself. The rest of the biomass for other parts of industry or even communal parts could be made available as a refined and densified biomass available for direct combustion in form of bales (selected types of fytomass) or wooden chips. From the maize biomass itself, with average annual production for energy purpose about 667,880 tons, is possible to be counted with production of equivalent amount of energy about 2,610 GWh or 9,400 TJ, respectively. This amount of relatively clean energy is therefore not insignificant while biomass is considered as carbon free fuel. Zhang et al., 2011 studied particle size distribution and polycyclic aromatic hydrocarbons (PAHs) emissions from the burning of rice, wheat, and corn straws, three major agricultural crop residues in China. He concluded that the total PAHs emissions from the burning of three agricultural crop residues in China were estimated to be 1.09 Gg for the year 2004 which is a great amount of emissions without energy production despite of the potential if studied biomass.

At the same time it needs to be noted that treatment of biomass is required for its use improvement. Moreover, biomass material pressing at very high pressure is aworking process, which we refer to as compaction in the final phase (Pepich, 2006).

Traditional multi-operational maize straw harvesting is performed in the following steps, which are defined by primary method of grain maize harvesting, it means what type of machine was used to harvest maize crop (Jandačka & Mikulík, 2008).

Grain harvest is performed by conventional combine harvesters with adapter for grain maize harvesting with crushing maize stalks under combine-harvester. After that, maize straw crushing is performed. This is followed by maize straw and stubble grinding by means of hammer and knife mulching machine (Birrell, 2006; Collection of Laws, 2010).

The objective of the study was a monitoring of possibilities of maize cortical harvesting by combine harvesters and its subsequent use for energy purposes during combustion. We monitored the combustion of packages with the moisture of 18% and 38% and the effect of moisture on the content of gas emissions of CO, CO_2, NO, NO_2 as well as the percentage of residual O_2 in the flue gas after combustion.

MATERIALS AND METHODS

Maize cortical was cultivated on farm in Rastislavice on the area of 34.62 hectare. Biological grain and maize stalks yield were evaluated from the selected area as well. The methodology of sampling and evaluation was performed according to recommendation by Jobbágy et al. (2011). Samples were manually harvested from area

10 m^2 from 5 different places of the field before complete harvest by harvester. Despite of the biological yields of maize, only around 60% of maize residues were collected due to complicated post-harvest treatment. For grain harvesting was used altered combine harvester JD assembled with corn adapter Olimac.

The pressing of maize cortical was performed by pressing machine KUHN LSD 1270 for large-volume; square packages. Packages have been removed from the territory and stored.

We chose incineration of Menert-Therm in Šaľa, Slovakia which provides heating of several residential buildings, for packages from maize cortical combustion. The combustion unit is characterised by following parameters: Combustion unit CHP JUTSEN (Datatherm, ltd., Slovakia); Nominal power output of boiler (1.5 MW); Nominal power output of steam (13 t h^{-1}); Nominal working pressure (38 bar); Nominal working temperature (400 °C); Power output of generator (2,775 kVA) with Turbine produced by SIEMENS. The combustion unit is designed for combustions of various biomass materials with relative moisture content up to 30% (straw, wood chips, densified pellets and briquettes, and maize straw as well as it was observed in the study). The combustion units works on the principal of continuous feeding of material into combustion chamber while the dimension of the combusted material is among the most important parameters. The combustion chamber is filled by gravimetric principle where chopped piece of whole package is delivered to the combustion process in time intervals controlled by control units which observe and adapt the speed of feeding at the basis of evaluation of combustion processes.

Compressed packages of maize cortical with dimensions of 2,200 x 1,200 x 900 mm, with a weight of 400 kg, with a moisture content of 18% and 38% (Fig. 1) were used as combustion material.

Figure 1. Package of maize cortical inserted into the dosing device of incinerator.

Emissions measurement from the combustion of phytomass was performed by measuring device TESTO 350 M/XL, which is used by the Department of machines and production systems. Modular system TESTO 350 M/XL is composed of three main parts (Fig. 2). This device is calibrated for accurate emissions measurement, while the evaluations of the measured values are based on emission limits defined by the Clean Air Act no. 137/10 and by the Decree Ministry of Environment of the Slovak Republic no. 356/2010.

A B C

Figure 2. Modular system TESTO 350 M/XL for the analysis of flue gases: A – control unit; B – analyzer box; C – sampling probe.

From a variety of values, which could be measured by TESTO 350 M/XL, for analysis, we chose O_2, CO, CO_2, NO, NO_2 gases, as well as control values: flue gas temperature, qA, lambda and efficiency.

Ultimate analyses for the carbon (C) and nitrogen (N) content in dry mass, as well as proximate analyses for the moisture, ash, volatile matter, and fixed C content as received (Liao et al., 2004). When studying the effect of different moisture contents on emissions, we rehydrated the crop residues by adding ultrapure water to obtain fuels with different moisture levels (~10%, 18% and 38%), and then sealed the wet fuel in plastic bags for 1–2 days before combustion (Chen et al., 2010). The moisture content was tested before each burn.

RESULTS AND DISCUSSION

Considering opportunities of PD Rastislavice, Slovakia and incineration of Menert-Therm in Šaľa, Slovakia we proceeded with maize cortical utilization as a source of energy for heating of residential buildings.

Monitored values of biological yield of maize phytomass

Based on measured and graphically evaluated values we can conclude that the phytomass yield is very variable. Biological yield of grains on monitored parcel ranged from 8.36 to 12.05 t ha^{-1} and yield of maize material was in the range of 11.34 to 15.8 t ha^{-1}.

Comparison of measured characteristics parameters of combustion and emissions at different moisture level

Results of experimental measurements are shown in Fig. 6. (CO emissions) and Table 1 (all parameters). Some values are presented in internationally recognized units of ppm (parts per million). Results of the average values of experimentally monitored emissions are more favourable for combustion of maize cortical at moisture of 18% than at 38% moisture.

Utilization of the maize straw as a source of energy was also studied by Carvalho et al. (2013). In their study, maize straw was also considered as satisfactory due to its energy potential, however, their emphasis that boiler controls should be improved to better adapt the combustion conditions to the different properties of the agricultural fuels. Additionally, there is a need for a frequent cleaning of the heat exchangers in boilers operated with agricultural fuels to avoid efficiency drops after short term operation.

However, biomass burning emissions, including carbon dioxide (CO_2), carbon monoxide (CO), elemental carbon (EC), organic carbon (OC), particulate matter (PM) and others (Andreae & Merlet, 2001; Jenkins et al., 1992), still have significant impacts on the local and regional environment (Huang et al., 2012a; 2012b; 2014). Emission factors (EFs), defined as the mass of a pollutant emitted per unit of fuel consumed, are used to compile emission inventories, as inputs to dispersion models, and to evaluate the effectiveness of pollutant control strategies. EFs strongly depend on the type of crop, and burning conditions, such as fuel load and moisture content (Reid et al., 2005; McMeeking et al., 2009; Chen et al., 2010) as it was indicated in our study (see Table 1).

Table 1 Descriptive statistic of measured parameters of emissions

Moisture, %	PARAMETERS	O_2, %	CO, ppm	CO_2, %	NO, ppm	NO_2, ppm
18	MEAN	**15.63***	**479.01***	**5.86***	**42.69***	**1.27***
	Median	20.33	493.55	3.57	7.75	0.99
	s.d.	6.24	225.10	3.04	47.84	0.72
	Kurtosis	-1.74	0.00	-1.55	-1.51	2.73
	Skewness	-0.55	-0.25	0.64	0.62	1.91
	Minimum	6.43	40.75	3.06	3.15	0.56
	Maximum	20.69	970.20	10.69	131.15	3.29
	Count	28	28	28	28	28
38	MEAN	**11.13**	**384.96**	**7.24**	**88.63**	**14.83**
	Median	13.33	409.85	5.62	88.05	10.24
	s.d.	3.54	183.91	2.60	14.75	9.96
	Kurtosis	-1.76	-1.27	-1.76	-1.03	-1.17
	Skewness	-0.47	-0.05	0.47	0.39	0.27
	Minimum	5.71	110.19	4.70	68.00	0.48
	Maximum	14.60	702.15	11.21	115.00	32.37
	Count	33	33	33	33	33

*denotes statistical significant difference; *Duncan's test*; $n = 28$; $\alpha = 0.05$ (for CO $p = 0.07$; for CO_2 $p = 0.06$; for other means $p < 0.05$).

Measurement of percentage values of residual oxygen in the flue gases

Measured and evaluated results are shown graphically in Fig. 3.

Previous studies have obtained many EFs for open burning of crop residue worldwide as summarized in Supplemental (e.g. Nguyen et al., 1994; Yokelson et al., 1996; Turn et al., 1997; Andreae & Merlet, 2001; Hays et al., 2005; Dhammapala et al., 2006; Kim Oanh et al., 2011), but few of these studies have considered the effect of moisture content on EFs (Kim Oanh et al., 2011). A more recent study by Hayashi et al. (2014) determined EFs for open burning of rice straw, wheat straw and barley straw in Japan using a portable combustion hood, and evaluated the effects of fuel moisture content on the EFs. Hayashi et al. (2014) found that increased moisture content enhanced the emissions of CO, CH_4 and particulate organic matter.

As it was indicated by Ni et al. (2015), fuel moisture decreased the CO_2 EF but increased the EFs of incomplete combustion products (e.g. CO, $PM_{2.5}$ and OC). This may be caused by the enhanced smouldering burn of wet fuels. The increased OC emissions due to an increase in moisture (from Level I to II, and from Level II to III) accounted for ~50% of the increase in $PM_{2.5}$ emissions. Hence, the increased emission of $PM_{2.5}$ could partly be attributed to the increased OC emission. Even though the EFs of EC did not decrease with increased moisture content, the EC fraction in total carbon (TC) displayed a decreasing trend with increasing moisture content: 0.05, 0.04 and 0.03, respectively. This corresponds to EC being generated from a flaming phase that is intensified when the fuel is dry (Lobert & Warnatz, 1993).

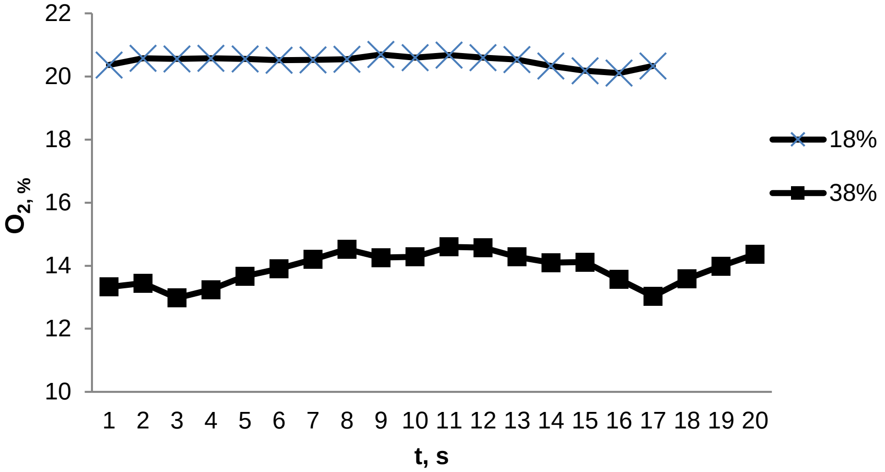

Figure 3. Comparison of percentage state of residual oxygen.

Based on measured values, we can allege that time-scale percentage state of oxygen in the flue gas has an average value of 15.12% with a maximum value of 21% and a minimum value of 5.37%. As presented in graphical form, at the start of combustion (inserting the tapered part of the package to the boiler) oxygen conditions are very different but after stabilization of combustion oxygen conditions are stable in the range from 10 to 15%.

As it shown in Fig. 3, in case of maize straw bale with lower moisture content (18%) resulted in increased mean value of oxygen at level 20% while in case of bale with greater moisture (38%) resulted in decreased mean value of 13.89% of oxygen in gas emissions. More importantly, the lowest value of oxygen was recorded at the beginning of bale combustion (12.97%) while later on values starts to increase by roughly linear trend up to 8^{th} second of measurement to value 14.52% and then decrease slowly again down to value 13.02% in 17^{th} second of measurement while then starts to increase roughly by linear trend.

He et al. (2009) studied reaction heat of agro-stalks smouldering, wheat straw, corn stalk, cotton stalk, millet straw, sorghum stalk and sweet potato rattan powder were smouldered and pyrolyzed in a simultaneous thermal analyzer (STA). This study showed that the oxidative polymer degradation heat of the agro-stalks is more than 6.92 MJ kg^{-1} consumed matters, higher than that of cellulose paper. And char oxidation heat is around 23 MJ kg^{-1} consumed matters, similar to that of cellulose paper, but higher than that of cigarette.

Measurement of CO_2 content in the flue gases

Process of CO_2 content in the timeframe is shown in Fig. 4. Based on measurement results, we detected very different values of CO_2 emissions when inserting the package into the boiler and subsequent stabilization of values in the range of 0.6 to 11.4 ppm.

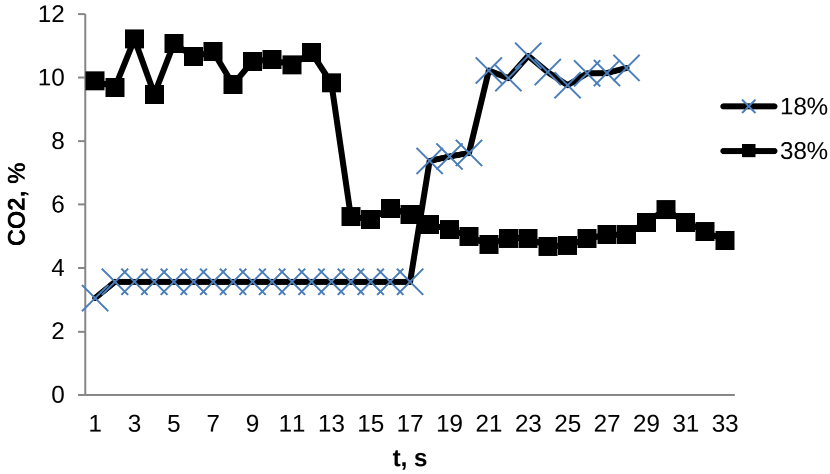

Figure 4. Comparison of state of CO_2 emissions.

The results again shown reasonable different values of CO_2 emissions during combustion of bales made of maize straw with overall moisture 18% and 38%. As is is possible to see at the Fig. 8, the beginning of combustion in case of bale with 18% moisture was characterized by values of 3.05% and 3.57% until the 17th second when the increase was recorded up to value 10.68% in 23th second when it starts decreasing in slow rate. Despite of that, mean value of CO_2 emissions 5.85% was recorded. In contrast, bale with greater moisture (38%) caused greater amount of CO_2 emissions at the beginning of combustion process and values ranged from 9.47% to 11.21% until 13th second when it reach dramatically value 5.53%. Rest of the combustion was characterized by relatively stable measured value of CO_2 emissions until 30th second when it increased to 5.84% and then decrease roughly by linear trend while mean value of emissions were observed at level of 7.23%.

Big jumps in values at 17th second of burning process were observed in the measurement of all types of emissions. These jumps are probably caused by opening and closing the combustion chamber which take place each time when fuelling the combustion chamber. Opening and closing caused an additional supply of oxygen to the chamber and thus incomplete combustion of materials. In such cases, it tends to increase the emission flow (Shen et al., 2013). Despite this fact, were not recorded exceeding emission limits.

Measurement of NO content in the flue gases

Process of measured values of NO emissions is shown in Fig. 5. State of NO emission from the combustion of cortical is very variable at the start of combustion, but after stabilization of combustion, values are within acceptable numbers around 43.56 ppm. The production of NO emissions during combustion of maize straw bale with 18%

of moisture at the beginning of measurement indicated as a relatively stable where the values ranged from 3.15 ppm to 8.3 ppm. Later on (about 18 seconds) production rapidly raised even at the level of 118.35 ppm while continuous trend was characterized by a great variability and values ranged from 78 ppm up to 131.15 ppm. In contrast, emission production in case of greater bale moisture (38%) varies a lot (from 68.45 ppm to 115 ppm) until 16 seconds of combustion time. The values fluctuated until it reached 109 ppm where it starts decrease linearly until 29 seconds of combustion to value of 106 ppm and the again linearly decrease to the minimum of measured emissions.

According to Qian et al. 2011, temperature and excess air ratio are the major operating parameters for NO emission. For biomass with high nitrogen content, NO emission decreases with excess air, and increases with bed temperature.Compared with char-N, volatile-N is the more dominant reactant source for NO emission. Therefore, according to our study, moisture content of biomass may be considered also as one of the affecting parameter even only at the beginning of combustion process as it is shown at Fig. 5.

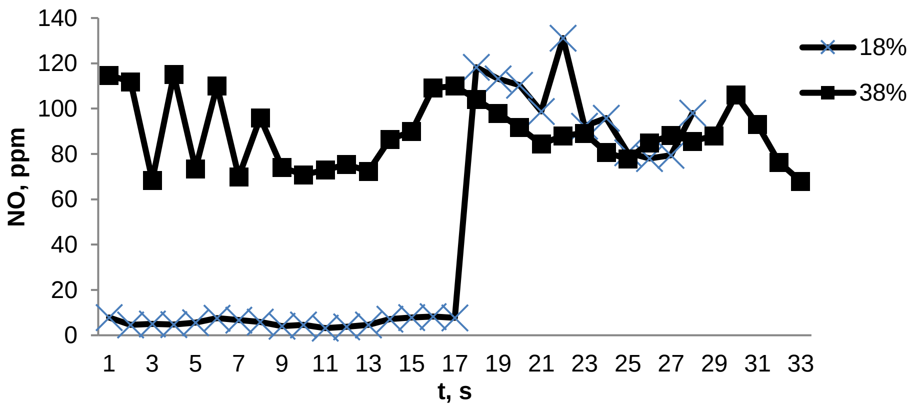

Figure 5. Comparison of state of NO emissions.

Measurement of NO_2 content in the flue gases

The results of measurements of NO_2 emissions by modular system TESTO 350 M/XL are shown in Fig. 6. State of NO_2 emissions from the combustion throughout the time horizon is circulating around the value of 0.99 ppm, but combustion of dumpy cortical after the chamber closing caused an increase of value to 43.8 ppm.

Brunner et al. (2013) focused on relevant combustion characteristics of biomass fuels in grate combustion systems. In this study it was comprised a wide variation of different fuels, including conventional wood fuels (beech, spruce, and softwood pellets), bark, wood from short rotation coppice (SRC) (poplar and willow), waste wood, torrefied softwood, agricultural biomass (straw, Miscanthus, maize cobs, and grass pellets), and peat and sewage sludge. Study showed that that the thermal decomposition behavior and the combustion behavior of different biomass fuels vary considerably. It was concluded that the conversion rate from N in the fuel to N in NOx precursors varies between 20 and 95% depending upon the fuel and generally decreases with an increasing N content of the fuel. Moreover, as it was stated, the release of ash-forming vapors also considerably depends upon the fuel used. In general, more than 91% of Cl, more than

71% of S, 1–51% of K, and 1–50% of Na are released to the gas phase. Study also reveal that the potential for aerosol emissions can be estimated, which varies between 18 mg Nm^3 (softwood pellets) and 320 mg N m^3 (straw) (dry flue gas at 13% O_2). Moreover, these results also provide first indications regarding the deposit formation risks associated with a certain biomass fuel.

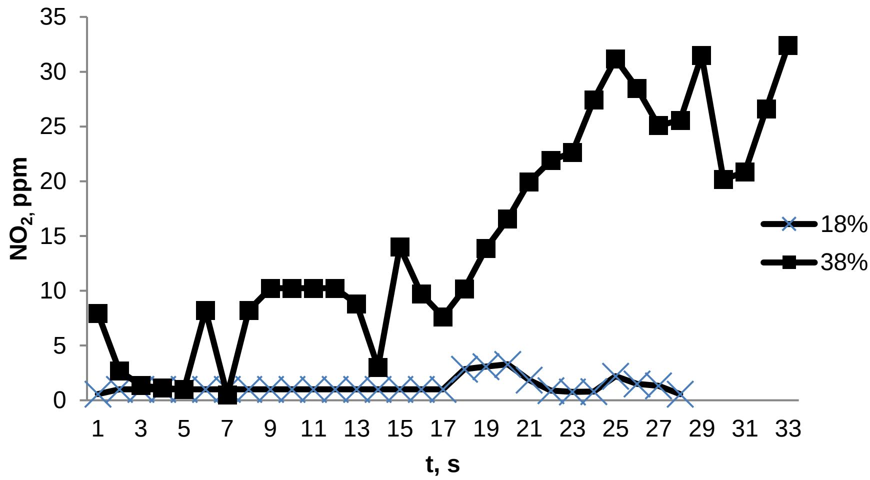

Figure 6. Comparison of state of NO_2 emissions.

Shen et al. (2013) conducted a study to investigate the influences of fuel mass load, air supply and burning rate on the emissions and size distributions of carbonaceous particulate matter (PM) from indoor corn straw burning in a cooking stove. Among other conclusions it was also suggested that special attention should be paid to the use of CO as a surrogate for other incomplete combustion pollutants due to the observation that emission factor of organic matter, particulate matter and elemental carbon were found to be positively correlated with each other but they were not significantly correlated with the emission factor of co-emitted CO (Fig. 7).

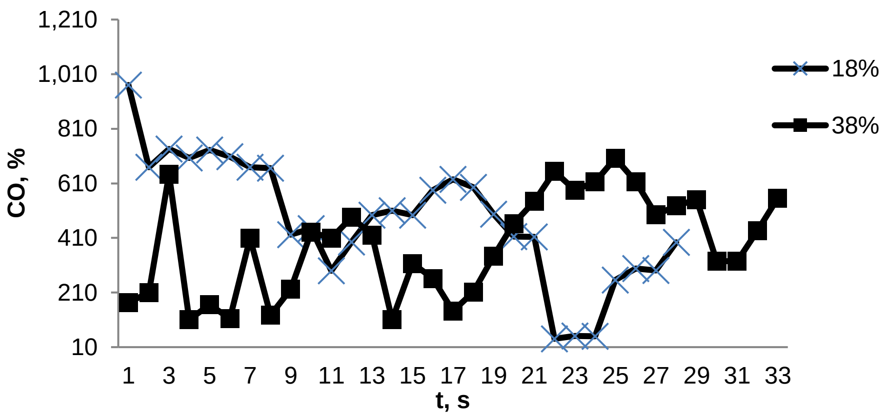

Figure 7. Comparison of state of CO emissions.

The use of corn straw as a source of energy is important also in conjunctions with conclusions made by Ni et al. (2015) while it was concluded that open burning of crop residue is an important source of carbonaceous pollutants, and has a large impact on the regional environment and global climate change. In addition, the effect of fuel moisture was investigated through the controlled burning of wheat straw. Increasing the moisture content decreased the CO_2 emission factor, and increased the emissions factors of CO and organic carbon.

Moreover, the gasification of straw stalk in CO_2 environment was studied by isothermal thermogravimetric analysis. The characteristics of rice straw and maize stalk gasification at different temperatures were examined under CO_2 atmosphere. The relationship between reaction time and carbon conversion of two biomass chars was analyzed by the random pore model (RPM), and compared with the simulation of the shrinking core reaction model (SCRM). The results show that the random pore model is better to predict the experimental data at different temperatures. This means that the characteristics of pore structure for the influence of biomass chars gasification is well reflected by parameter ψ used in RPM. It indicates that the RPM can be applied to the comprehensive simulation of biomass chars gasification in CO_2 environment (Fei et al., 2014).

CONCLUSIONS

Based on measured experimental results and their assessment it can be concluded that the use of maize cortical for energy purposes during combustion is real and, considering climate gas emissions, measured values are within emissions limits defined in Collection of Laws no. 356/2010, page 2,955, article 1.9. Stationary equipment for combustion of fuel with a total nominal power of 0.3 MW to 50 MW. All emissions limits are in accordance to monitored standards for CO, CO_2, NO, NO_2, but on the other hand it should be noted that the more favourable results are based on combustion of cortical with moisture of 18% than at 38%. This observation is even more interesting while the combustion unit was designed to utilize only few biomaterials and as limited value was set the moisture of this material to 30%. The issue of maize cortical harvesting considering machinery, technological and economical viewpoint within the Slovak republic is poorly understood, therefore, these issues will be the subject of further research at the Department of machines and production systems.

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Agronomy Research **15**(2), 468–477, 2017

Wood ash – green energy production side product as fertilizer for vigorous forest plantations

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Abstract. Notable amounts of wood ash containing plant macro and micronutrient elements in balanced proportions are produced in Latvia. If bioenergy production source product is plant material, and facilities are operating well, then 'side product' fermentation residues or wood ashes should not contain elements in toxic concentrations. Wood ash contains P and K which are lacking in acidic organic soils and could work as fertiliser as well as a long term liming agent, besides that, all micronutrient elements necessary for physiological processes are present in wood ash. Wood ash could also be used as 'revitalization agents' – fertilisers to improve the growth of plantation forests. The aim of this research is to find and describe the positive effect of wood ash fertilisers on Norway spruce (*Picea abies*) and other economically valuable tree species. Research results show positive wood ash application effect on tree growth and vitality within the first 4 years when used for recultivation and revitalization purposes. Recycling of wood ash (0.5–3 t ha^{-1} before planting) for fertilisation of and *Picea abies* forest plantations are a sustainable and effective solution for the improvement of tree growth as well as an environmentally safe method of utilization of bioenergy production residues.

Key words: wood ash, fertiliser, regeneration, recultivation, revitalization, soil amendment, Norway spruce.

INTRODUCTION

Wood energy is continuously increasing as a renewable natural resource. Mainly wood biomass is used as burning material in heat plants. In Latvia heat plants continue to increase the amount of fuelwood burned each year (Table 1). Ash is produced as a by-product of the burning process (Fig. 1).

Table 1. Tonnes of fuelwood burned each year by Latvian companies (LEGMC)

	2012	2013	2014	2015
Pellets	21,609	23,742	15,538	45,230
Wood	497,846	641,191	753,385	907,451
Fire wood	186,747	179,472	154,764	144,795
Woodchip	690,774	978,922	1,182,330	1,305,062
Total	1,396,975	1,823,326	2,106,016	2,402,537

Wood ash is typically deposited as waste material. Given the significant amount of ash produced (Fig. 1), more rational ash disposal options should be evaluated.

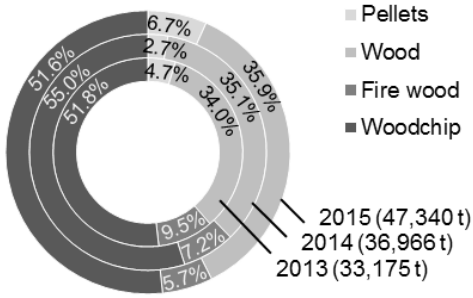

Figure 1. Ash produced in Latvia, tonnes depending on source material in 2013, 2014 and 2015 (LEGMC).

One of the obstacles for forest regeneration and recultivation is a lack of nutrients in the soil, increasing soil acidity is another typical problem in Northern Europe (EEA, 2000; Kikamägi et al., 2013). Acidity is especially problematic when recultivating cut-away peatlands (Lazdiņa et al., 2011). Ash contains bioavailable potassium, calcium, magnesium, phosphorous and other macro and micro nutrients (Augusto et al., 2008; Libiete et al., 2016). This suggests that it can be used as a fertilising substance. In previous studies, if applied on topsoil, ash has shown potential to increase tree increment by both altering pH levels of soil and increasing bioavailable nutrient amount in soil as a direct addition and by boosting biochemical soil processes (Augusto et al., 2008; Lazdiņa et al., 2011). The positive effects of ash treatment are not visible immediately but rather start to show gradually and effectiveness is long lasting in organic soils (Augusto et al., 2008; Okmanis et al., 2016; Silvan & Hytönen, 2016). Compared to mineral fertiliser ash is an environmentally friendlier alternative that also promotes circular economy and sustainability (Ingerslev et al., 2014; Huotari et al., 2015). This leads to the conclusion that wood ash should be managed as a resource instead of waste. Since ash chemical properties vary greatly depending on source material, it is safer to be used in forestry instead of agriculture.

In forestry, there are three main applications for wood ash. It can be used as soil amendment in order to improve forest regeneration, to condition recultivated lands and to revitalize both young and mature stands. Descriptive statistical data of measurements were calculated and shown in graphs and tables as a mean and standard error of mean (SE). Data following to normal distribution, to compare how significant the differences are between mean values of tree parameters after two T-test treatments. The aim of this research is to analyse wood ash utilisation options and possible use in forestry based on experience in recultivation, regeneration and revitalization in three study sites with different background and management practices.

MATERIALS AND METHODS

In this research results acquired at three different study sites in Latvia are discussed (Fig. 2). Each study site is set to represent different forestry practises and potential way of ash use. In all instances data was collected within 4 year period after ash treatment application. All tests were carried out on organic soils.

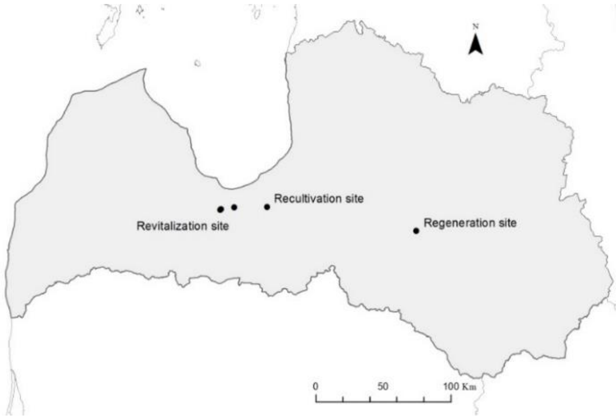

Figure 2. Study site location.

Forest regeneration

Forest regeneration with economically valuable trees species is studied in Latvia, Kalsnava parish (56°40′11″ N 25°54′36″ E). Plantation field has been established in a continuous clear-cut area, where previously stood a Norway spruce (*Picea abies*) forest of high productivity (up to 20 m^3 ha^{-1} annual increment at the age of 20), that died of unknown causes at the age of 40 years. The experiment is set as a long term study site in order to understand the requirements for the successful regeneration and management of ameliorated peatlands. The study area was then divided into multiple rectangular plots and enclosed with a fence to protect the trees from browsing. Soil chemistry originally was varying in this site (Table 3). In 2015 spring 8,207 seedlings of spruce were planted in rows of different density (2,000 trees per ha or 4,000 trees per ha). The study area consists of:

- control – only early tending or cleaning (15 plots)
- wood ash – wood ash and early tending or cleaning (9 plots)
- PK fertiliser – mineral fertiliser and early tending or cleaning (6 plots).

To evaluate the growth and survival rate of different species in this area, 1,296 birches (*Betula pendula* Roth), black alders (*Alnus glutinosa*) – each in 6 plots and 2,932 poplar (*Poplus sp.*) cuttings 20 cm length in 15 plots were also planted. Tree species were planted in rows both separately and interchangeably with spruce. Poplar plantation was restored in 2016 using planting material of the same origin but in two lengths – 20 cm long cuttings and 165 cm long cuttings (576 of each). Soil liming was carried out for poplar plantation and in nine plots wood ash was also applied.

Table 2. Soil chemistry properties in regeneration site prior treatment

	Soil pH_{CaCl_2}	Exchangeable K mg kg^{-1}	Available P mg kg^{-1}	Total P g kg^{-1}
Average ± SE	3.9 ± 0.1	55.7 ± 14.7	55.7 ± 22.2	2.3 ± 0.2
Min – Max	3.3–4.3	24.1–148.0	10.6–170.6	1.4–3.4

Data of survival rate and causes for dieback was collected for all planted species. In addition height of trees and annual growth increment for 2015 and 2016 were measured for spruce plantations in this study site. However, observation continues at this study site in order to evaluate longterm effects.

Recultivation

Recultivation possibilities of cut-away peatlands were studied in Latvia, Ķekavas parish (56°50′41″ N 24°6′30″ E), mainly focusing on use of mineral fertiliser and wood ash as soil amendment. Initially reed canary grass *Phalaris arundinacea* (RCG) was sown in this site as a short rotation energy crop. To stimulate the growth of RCG, the area was treated beforehand with wood ash applied on topsoil (10 t per ha) or PK mineral fertiliser applied on topsoil (0.5 t per ha). The control plot was left untreated.

RCG could not survive regardless of treatment type, but natural forest regeneration successfully took place instead. Self-sowing of aspen (*Populus tremula*), birch (*Betula pendula* Roth and *Betula pubescens*), spruce (*Picea abies*) and pine (*Pinus sylvestris*) occurred naturally in this study site. Data was collected in 2011 by selecting representative sampling plots in wood ash and mineral fertiliser treated areas. Self-sowing had not occurred in control plot. The trees in the plots were counted to determine the density of developing forest stands and tree height was measured.

Revitalization

Mature Norway spruce stand was treated with wood ash and mineral fertiliser in order to revitalize the stand after spruce bud scale (*Physokermes piceae*) invasion. Study area is located in Latvia, Līvbērzes and Klīves parishes (56° 50′ 31″ N 23° 42′ 33″ E, and 56° 49′ 45″ N 23° 33′ 9″ E and 56° 49′ 25″ N 23° 32′ 27″ E). This area consists of three plots that are each further divided into 9 sub-plots (400 m^2 each) with an 11 m buffer zone between them. These 9 plots were then treated with wood ash (2.5 tonnes per ha applied on topsoil) or potassium sulphate (K_2SO_4) mineral fertiliser (145 kg per ha applied on topsoil). Control plot was left untreated.

The diameter at breast height (DBH) was measured. Height was measured for 10 trees in each sub-plot using a hypsometer. Increment core data was collected using the Pressler borer. Cores then were glued to a flat surface and grinded for better visual identification of each increment. Cores were scanned with an Epson Expression 10000 XL high resolution scanner and t measurements of increment ring width were made with WinDENDRO software (0.001 mm accuracy).

RESULTS AND DISCUSSION

In Kalsnava study site birch showed the highest survival rate of 91.74 ± 0.14% in 2015 and 88.19 ± 0.36% in 2016. Spruce survival was 59.21 ± 0.19% 30.07 ± 0.20% respectively. Black alder showed worse results – 52.16 ± 0.17% in 2015 and only 17.36 ± 0.32% of initially planted trees were left in 2016. Poplar plantation was renewed in 2016 and later on showed survival rate of 62.67 ± 0.30%, but only for 165 cm cuttings. All of 20 cm cutting poplars had dried out completely in both years (Fig. 3). Such survival rate distribution might be due to natural succession. In boreal forests of Northern Europe regeneration after natural disturbance (for example forest fires, wind falls or flooding) begins with birch, followed by spruce and later pine (Engelmark, 1993).

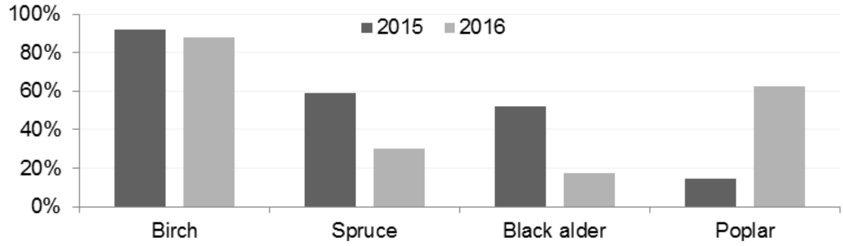

Figure 3. Survival rate of trees in year 2015 and 2016.

Later in 2015 pine (*Pinus sylvestris*) was also planted in this site. Three types of plants were selected – 960 trees from seedlings grown in mineral soil, 960 trees from seedlings grow in organic soil and 480 trees of mixed origin. Trees from organic soil seedlings showed the best survival rate (> 70%) in 2016 while others had just ~40%. The factor of soil used for seedlings is mostly neglected when regenerating a forest.

Main cause of tree death in the regeneration study site was drying out. The best vitality (62.4% healthy trees) in 2015 was achieved in with the application of mineral fertiliser. 40.3% high rate of drying out due to natural causes is present for spruces that were treated with wood ash (Fig. 4).

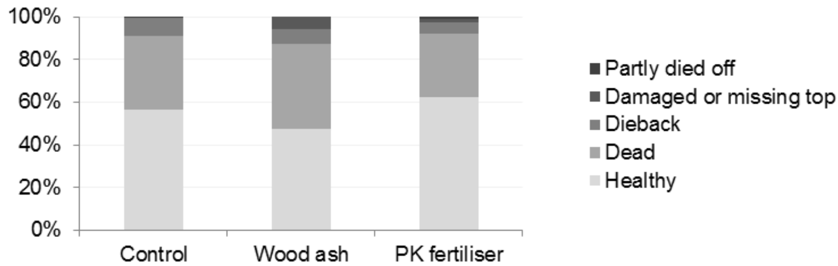

Figure 4. Vitality of 2 year old spruce in 2015 treated with wood ash or PK fertilisers and control.

In 2016 wood ash treated spruce plantations still showed the highest death rate – 63.8% of trees that were healthy in 2015 (Fig. 5).

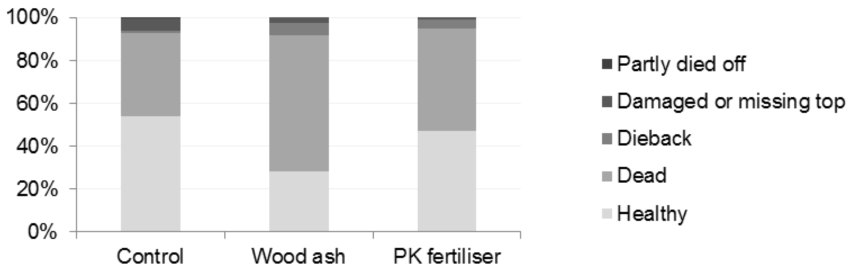

Figure 5. Vitality of 3 year old spruce in 2016 treated with wood ash or PK fertilisers and control.

Between of all treatments control had least amount of trees dying in 2016 – 39.3%. It must be taken into consideration that previous studies show some negative short term effects on tree root development if young seedlings are treated with wood ash (Gaitnieks et al., 2005; Kļaviņa et al., 2016). Therefore the acquired results might not be enough to draw conclusion of wood ash effectiveness on plant spruce plantation regeneration. Dieback was more notable in 2015 for all treatments. Control had 5.1% dieback, ash – 6.7% and fertiliser 8.7%. Damaged trees did not recover in 2016 and died off completely. In both years there are also some cases of undeveloped top.

In 2016 the shortest average spruce trees were in control plantations. In plantations treated with fertiliser spruces showed the highest average total height. Plantations treated with fertiliser showed the lowest increase in height. Ash treatment results are not significantly different from either control or fertiliser (*two-way t-test*). Control plantations had grown the most both in 2015 and 2016 (8.4 ± 0.1 cm and 8.3 ± 0.1 cm respectively). Initial planting material height was the highest in fertiliser treated plantation, but control had the lowest initial plant height (Fig. 6).

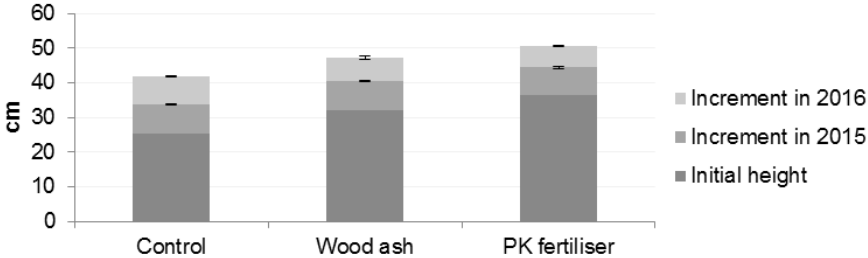

Figure 6. Average spruce height and annual growth in 2015 and 2016 treated with wood ash or PK fertiliser and control (± SE).

In order to evaluate these results more accurately, only trees of equal or similar initial planting height were compared further. In this case ash shows the highest average total height of 47.0 ± 1.0 cm followed by fertiliser 44.8 ± 0.9 cm and control 44.4 ± 0.4 cm. Control and fertiliser fields had no significant difference in height. There is also no significant difference of annual increment in 2015 between fertiliser and control or fertiliser and ash. In 2016 there is significant difference between control trees that had most average increment, and fertilised, but not between wood ash and control or wood ash and PK fertiliser treated (Figs 7 & 8).

Figure 7. Average spruce initial height and annual growth in 2015 and 2016 treated with wood ash or PK fertiliser and control (data inequality showed with dashed lines).

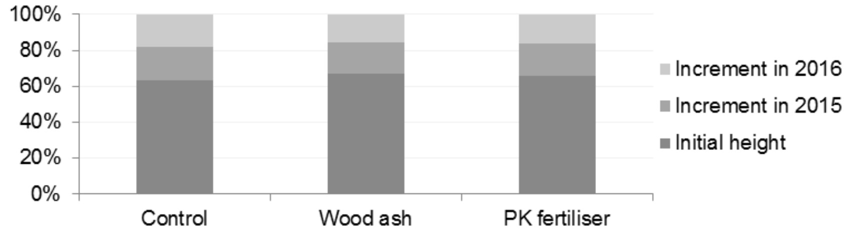

Figure 8. Initial average height and annual average growth in 2015 and 2016 from total average tree height of spruces with equal or similar initial height treated with wood ash or PK fertiliser and control.

In 2008 soil samples were taken in the natural recultivation study area after wood ash and mineral fertiliser application (prior to sowing of RCG). Upper soil horizons contain more exchangeable potassium in plots that have been treated with wood ash compared to PK fertiliser (Fig. 9). Potassium is also one of main lacking elements in peat soils (Kļaviņa et al., 2016).

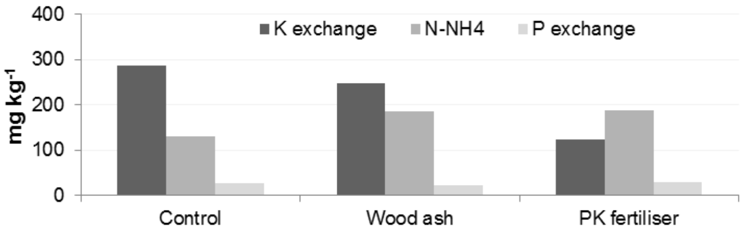

Figure 9. Available nutrients in soil in control, wood ash and mineral fertiliser treated recultivation plots in 2008.

It was concluded that self-sown forest regeneration occurs dominantly with both species of birch (*Betula pubescens* and *Betula pendula* Roth) (Fig. 10) regardless of studied treatment cases. This fits with the natural succession principles. In the control plot natural regeneration did not occur.

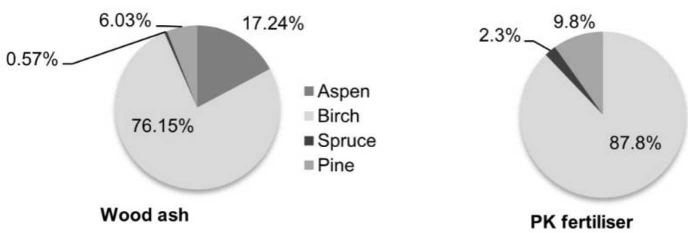

Figure 10. Tree species distribution in plantation with wood ash and mineral fertilisers application.

In mineral-fertilised area naturally regenerated aspen was not found (Table 3). However, it was present in small numbers in previous years (Table 4). This withering away might be due to soil pH value decrease or browsing. Data from 2008 shows no significant difference in soil pH_{CaCl2} for control and both treatment types (control

2.93 ± 0.07, wood ash – 2.92 ± 0.04 and PK fertilizer – 2.94 ± 0.06). Spruce is scarce in both instances despite the fact that there are mature spruces around the area that could provide seed material, spruce overall is not a common species in peatland forests (Jansons & Zālītis, 2013).

Plots with ash treatment have most naturally regenerated trees per m^2, but trees in plots with mineral fertiliser on average are taller and sturdier/thicker (Table 3). From studied tree species, pine has the strongest correlation between tree height and treatment type. Pine is 44% taller in the case of mineral fertiliser compared to ash.

Table 3. Average height and root collar of trees in wood ash and mineral fertiliser treated plots in 2008 and 2011 (± SE)

Species	2008				2011	
	Average stem diameter (mm)		Average tree height (m)		Average tree height (m)	
	wood ash	PK fertiliser	wood ash	PK fertiliser	wood ash	PK fertiliser
Birch	3.48	14.14	29.53	34.06	1.25 ± 0.04	1.53 ± 0.03
Aspen	3.60	9.48	25.89	44.42	0.66 ± 0.04	-
Pine	2.36	5.61	8.75	17.21	0.73 ± 0.08	1.31 ± 0.10
Spruce		5.01		15.75	0.30 ± 0.10	0.49 ± 0.07
Total	3.15	8.56	21.39	27.86	1.11 ± 0.03	1.49 ± 0.03

Compared to fertiliser treated plots, ash impact is less notable. However, both ash and fertiliser treatments have significant impact compared to control area that did not show any signs of natural tree ingrowing. Therefore it is valid to conclude that ash is suitable for recultivaton purposes of cut-away peatlands.

In revitalization study area pH_{CaCl2} of soil was similar in all plots and treatment types, but phosphorus content (determined using aqua regia) and exchangeable potassium differs between plots, showing higher concentration of phosphorous when fertiliser is applied (except for plot 1) (Table 4, Fig. 12.)

Table 4. Soil pH in control, wood ash and PK fertilizer treated revitalization plots (± SE)

Treatmet	Plot 1			Plot 2			Plot 3		
	Control	Wood ash	PK fertiliser	Control	Wood ash	PK fertiliser	Control	Wood ash	PK fertiliser
pH_{CaCl_2}	4.32 ± 0.37	4.40 ± 0.31	4.39 ± 0.31	4.60 ± 0.40	4.53 ± 0.34	4.56 ± 0.33	3.60 ± 0.37	3.62 ± 0.40	3.84 ± 037

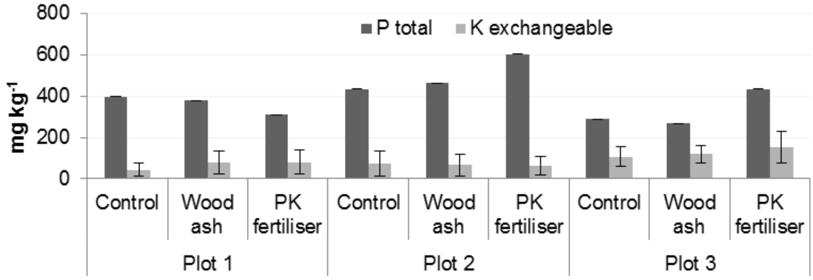

Figure 11. Soil total phosphorous and exchangeable potassium content in control, wood ash and PK fertilizer treated revitalization plots (± SE).

Both mineral fertiliser and wood ash showed significant increase in radial increment of spruce in first year and next years after application. Positive effect of wood ash continued in the following four years of observation (Fig. 12). This supports long term effects of ash treatment noted in other studies (Saarsalmi et al., 2014; Jansons et al., 2016).

2 t ha^{-1} wood as per ha applied

60 kg ha^{-1} K_2SO_4

Control

Figure 12. Spruce increment and revitalization four years after wood ash application.

CONCLUSIONS

1. Wood ash application improves revitalization of mature Norway spruce stands and aids recultivation in drained organic soils.
2. Wood ash treatment for regeneration purposes in this study showed similar results as fertiliser treatment and untreated plots.
3. Wood ash or mineral fertiliser application aids natural recultivation by selfsowing of trees. In this case, the forest regenerates according to succession principles.
4. Birch shows higher survival and self-sowing rate compared to other tree species in the case of both recultivation and regeneration.
5. Positive effects of wood ash is already evident within first 1–2 years after application when used for revitalizing and recultivation.

ACKNOWLEDGEMENTS. The acknowledgements to the field team, and National research program No 2014.10-4/VPP-6/6 that have helped to achieve the goals of the research.

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Evaluation of soil compaction caused by passages of farm tractor in a forest in southern Italy

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Abstract. In recent decades, the use of heavy machinery in forest management has significantly increased, causing the compaction, that often remains for many years and may contribute to a decline in long-term site productivity. Severity of the damage depends on vehicle mass, weight of the carried loads, ground morphology, and soil properties, such as moisture. In Southern Italy, timber extraction is mainly done by farm tractors and the study was carried out in a conifer stand to evaluate the changes in penetration resistance, the water content, the bulk density and the porosity, after different numbers passes 0 (control), 1, 5, 10 and 15 respectively, of one farm tractor (Landini – Landpower 135 TDI). The results indicated that all parameters were significantly higher in the trafficked soil portions rather than in the undisturbed ones. We can conclude that a significant relationship was observed between compaction degree and traffic intensity. In fact, the passage of forestry machines causes soil compaction, leading to significant changes in the soil structure and moisture conditions.

Key words: Forest Soil, Tractor Farm, Extraction, Machine traffic, Compaction.

INTRODUCTION

Soil plays a crucial role in forest ecosystems by mediating the nutrient, water and energy flows that maintain forest productivity and sustain biodiversity (Dominati et al., 2010). Soil, however, is highly sensitive to improper forest management practices, and to large-scale logging activities in particular. Soil compaction reduces the pore space volume, especially that of the intercrumb pore space (macropores), thereby altering the habitat of soil organisms both directly (Van Der Linden et al., 1989; Kaiser et al.,1991) and indirectly by changing the physical properties of soil. Furthermore, soil compaction entails lower water infiltration and hydraulic conductivity, which contribute to more water logging on flat terrain, and more runoff and erosion on slopes (Jansson & Johansson, 1998; Grace et al., 2006).

Logging is perceived as one of the major causes of damage to forest vegetation (Alexander, 2012). Generally, the effects of timber harvesting include changes in vegetation, nutrient availability, soil microclimate and structure, and litter quantity and quality (Keenan & Kimmins 1993; Jurgensen et al., 1997; Proto et al., 2016a). For this region it is important minimize any damage to the ground that is likely caused by heavy machine use during forest operations (Edlund et al., 2013). When harvesting timber, the extent of soil compaction that occurs will depend on various site factors, which are not limited to just the characteristics of soil (e.g. its texture) (Ampoorter et al., 2007). Along with soil moisture and organic matter (Greacen & Sands, 1980; Rohand et al., 2003), one must also consider the frequency of machine passes (Wang et al., 2007), the harvesting system (Froehlich et al., 1985), and the type of machine and its characteristics (Krag et al., 1986; Nugent et al., 2003), mass of the vehicles and their loads (Susnjar et al., 2006), including those types that are 5–40 Mg and number of wheels and their tire inflation pressure (Eliasson, 2005) as well as the amount residual logging slash (Eliasson & Wasterlund, 2007).

The current trend in forestry is to increase the size, power, and load of the logging machines, which can weigh from 12 to 16 Mg in an unloaded state (Ampoorter et al., 2007). Much, if not all, of the soil compaction during timber harvesting will occur during the first 10 passes of a vehicle, but the impact is concentrated in first three passes (Froehlich et al., 1985). These initial passes cause the greatest soil compaction relative to subsequent passes; nevertheless, the latter may further disturb the soil by deepening the ruts. Ruts form through the vertical and horizontal displacement of soil, to either the middle or to the sides of the skid trail, and they are associated with shearing stresses and soil compression in moist or wet soil (Horn et al., 2007). Subsequent vehicle passes generally have little additional impact (Ampoorter et al., 2007; Bolding et al., 2009), but soil bulk density can still increase significantly after more than three passes (Gayoso & Iroume, 1991).

This experimental study was performed in Calabria, in southern Italy. In this region, the forest area has expanded by 40.6% (nationwide, forests have expanded by 34.7%), and its average annual increase in wood volume exceeds, and occasionally doubles, the estimated increase seen in other Italian production forests (Proto & Zimbalatti, 2015). In Calabria, the most common method to harvest trees is referred to as 'traditional', because it exemplifies an early stage of mechanization (Zimbalatti, 2005). This method relies primarily on agricultural tractors, which are sometimes equipped with specific forest-related machinery (e.g., winches, hydraulic cranes, log grapples), and uses animals for gathering and yarding purposes (Macrì et al., 2016). Unfortunately, the current level of mechanization is fairly low (Zimbalatti & Proto, 2009). In Southern Italy, as in many regions of the world, farm tractors serve as a multipurpose vehicle with many applications, particularly in forestry activities. For example, such modified farm tractors may be used to skid the logs from stumps to the landings, to transport the logs in 'tractor-trailer', and to load and unload the logging trucks (Ozturk & Akay, 2007). This low-level of mechanization to extract forest resources is driven by the features of the forest sites, the characteristics of the forest properties, and the small dimensions of many of the forest enterprises (Negri et al., 2016). Within this context, this study aimed to evaluate the impact on soil from a farm tractor (Landpower 135 TDI) as a function of its traffic intensity. Specifically, we were interested in the changes in penetration resistance, water content, and bulk density and porosity of soil that resulted after five different number of passes: 0 (i.e., control), 1, 5, 10, and 15, respectively. The overall objective is to provide useful scientific and technical information, such as the threshold levels of machine traffic intensity, for the development of best management practices for forestry operations in southern Italy with a view to soil preservation and, by extension, enhancing forest productivity and ecosystem functionality.

MATERIALS AND METHODS

Site description

The study was conducted in September 2016 in the Massif Serre Vibonesi region. The forest here is located at 587406 E – 4235438N (WGS_84 – Fuso 33). Elevation is approximately 1080 m above sea level, with a northern aspect. Average annual rainfall in this area amounts to 1,000 mm, with the lowest monthly average precipitation occurring in July (20 mm) and the highest in December (150 mm). Mean annual temperature is 12.8°C, with the lowest values in January. The soils in this area developed from igneous and metamorphic rocks and are classified as Umbrisols, with an udic soil regime moisture. The forest here is dominated by Silver fir (*Abies alba)* trees and it covers 33 ha with a slope of 0%–30%. Canopy cover is estimated at 90%, the average tree stem diameter is 46 cm, average tree height is 25.7 m, and the stand density is 580 trees ha^{-1}.

The machine used in this study is the Landini 135–Landpower TDI, which is powered by a 6-L Perkins 1106-E60TA turbo diesel six-cylinder engine (Fig. 1). The rear tires were larger than the front tires in width and in diameter and the air pressure of all the tires was fixed was fixe at 15 psi. The main technical features of the tractor are shown in Table 1.

Figure 1. Machine used in the experiments.

Table 1. Technical characteristic Landini 135 – Landpower

Parameters	Unit	Value
Power	kW	98.4
Weight	Mg	5,787
Wheelbase	Cm	279
Length	Cm	514
Width	Cm	220
Height	Cm	276
Front tires	-	420/70 R 20
Rear tires	-	520/70 R 38

All logs (of various dimensions) were extracted from the stump area to the roadside landing by using a ground-based extraction system. The study forest area has a reliable main road network that is flanked by a provincial road; the trails that were opened during tree felling were then used as the secondary road network (Cavalli & Grigolato, 2010).

Soil texture along the trails was determined to be sandy loam (following analysis that used the Bouyoucos hydrometer method) (Kalra et al., 1991).

Experimental design and data collection

A skid trail 3.5-m wide and 280-m long, with upslope skidding direction, was selected for the experiments. The longitudinal profile showed that the slope of the skid trail ranged from 2% to 20%. In this study, the impact of skidding on the surface soil layer (0–10 cm depth) of the skid trail were examined by quantifying the penetration resistance, water content, bulk density and the porosity as a function of traffic intensity, and comparing these results with the respective values of samples taken from an undisturbed area. Buffer zones of at least 5 m in length were created between plots to avoid confounding interactions. Our experimental design had four levels of traffic intensity: 1, 5, 10, and 15 passes; each level was replicated five times for a total of 20 plots. Each plot was 10-m long and 3.5-m wide and divided into four equal parts (Fig. 2). In total 450 samples were collected: 100 for each level of traffic and 50 for the areas undisturbed. Furthermore, in these plots we also measured the rut depth made by the passes; however as the ground was not completely flat, this could have been slightly mall overestimated where in those spots of uneven ground. During the harvesting operation and data collection, values of soil moisture content were relatively stable, ranging from 28% to 31% at a 10-cm soil depth.

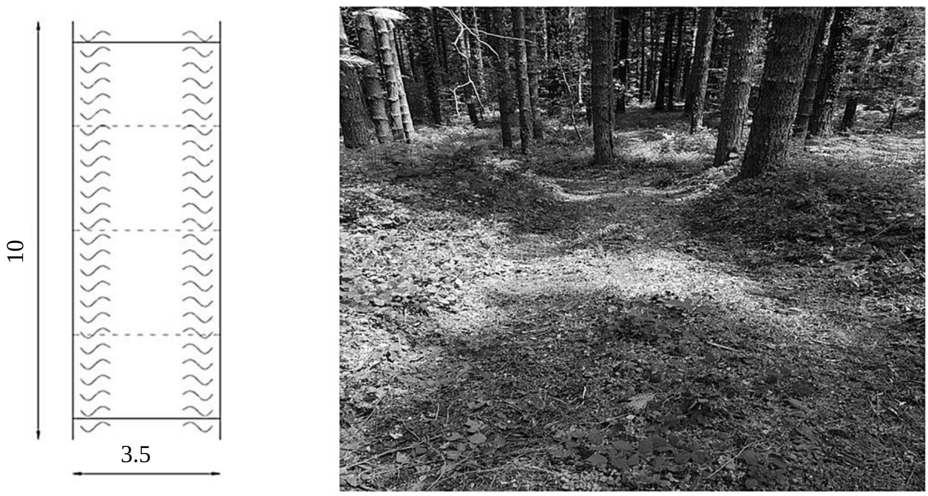

Figure 2. Sample scheme of a trail.

The soil samples were collected using a rigid metallic cylinder (250 cm^3) after first removing any litter on the soil surface. When extracting the steel cylinder from the soil, care was taken to minimize disturbance to the soil content, which were put into a plastic bag and transported to the laboratory. There, the samples were weighed and oven-dried to determine their water content and bulk density. The water content (WC) was determined according to the 'Official Methods of Chemical Soil Analysis' (G.U., 13/09/1999). In this method, the soil moisture content is determined and expressed as a percentage of its oven-dried (constant) weight. Soil bulk density (*Db*) is calculated by the following equation (Naghdi & Solgi, 2014) and expressed in units of g cm^{-3} (1):

$$Db = \frac{Wd}{VC} \quad (1)$$

where *Wd* = weight of the dry soil, and *Vc* = volume of the soil cores (250 cm^3).

Porosity (*P*) is a value that expresses the relative amount of pore space in the soil sample. It is not measured directly, but instead calculated from using the derived bulk density and the particle density (Brady & Weil, 1996; Tanveera et al., 2016) by the following equation:

$$P = 1 - \frac{Db}{dp}\ 100 \quad (2)$$

where *Db* = bulk density, and dp = particle density; this value was 2.65 g cm^{-3}.

To measure penetration resistance as a proxy for soil compaction, we used a portable penetrometer (SC900 Soil, Compaction Meter, Field Scout) that had a 1/2" diameter cone tip. The penetrometer was manually pressed into the soil to a depth of 10 cm to measure the penetration resistance data which it directly stores.

Statistical Analisys

Separate one-way ANOVA in SPSS software v.20 tested for any significant differences in average bulk density, total porosity, penetration resistance, and moisture among the five traffic levels (including control). For a given soil response variable, the Tukey multiple range test was used to see which level means differed significantly ($p < 0.05$).

RESULTS AND DISCUSSION

Soil disturbances in skid trails during a log-skidding operation by a farm tractor were measured by considering soil compaction and rut depth formation. Field measurements were made at five cross sections along the skid road. The study showed that the vehicle passes had a significant effect on soil compaction; in fact, the results indicated that soil compaction and rutting both increased as the number of passes increased. The analysis revealed that key soil characteristics (moisture, bulk density, porosity and penetration resistance) of the timber harvesting plots were all significantly different from those of the non-harvested plots (i.e. control) (Table 2). The post-hoc Tukey test detected significant differences in all parameters studied between the different traffic levels and the control ($p < 0.05$).

Table 2. Soil characteristics (Soil Moisture %; Bulk Density g cm^{-1}; Total Porosity %; Penetration Resistance kPa)

Number of passes	Number of samples	Moisture		Bulk density		Total porosity		Penetration resistance	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
0	50	30.34^a	2.02	0.92^a	0.03	65.2^a	2.99	525.6^a	9.14
1	100	28.36^b	1.29	0.94^b	0.03	64.4^b	3.44	1,632.4^b	4.76
5	100	26.76^c	1.14	0.966^c	0.02	64.6^c	4.96	1,813.9^c	96.87
10	100	14.32^d	0.92	1.046^d	0.05	61.4^d	5.68	2,358.5^d	166.38
15	100	11.47^e	1.34	1.162^e	0.04	56.2^e	3.49	2,504.6^e	186.16

Table 3 shows the results of the ANOVAs for the four soil response variables. The ANOVA suggest there was much random variation in the data, which is perhaps expected in a diffused sampling approach. Sampling points are likely to hit trafficked as well as intact areas within the same sample plot, and this coincidence may explain the high random variation. At the same time, the sampling intensity was sufficient to capture a significant difference among the treatment levels, as indicated by the very low *p*-values.

The effect of soil compaction on the soil moisture content was significant ($p < 0.01$). Specifically, the results show a reduction in water content in the skid trail. This decrease was directly proportional to the number of passes; in fact, the average moisture content was 11.47% on the tractor trail (after 15 passes) versus 30.34% in the undisturbed area (Fig. 3). Previous studies (Raghavan et al., 1977; Davies et al., 1973) have identified wheel slip on agricultural tractors as culprits that cause significant soil compaction, and wheel slip from forest vehicles can presumably also contribute to such compaction.

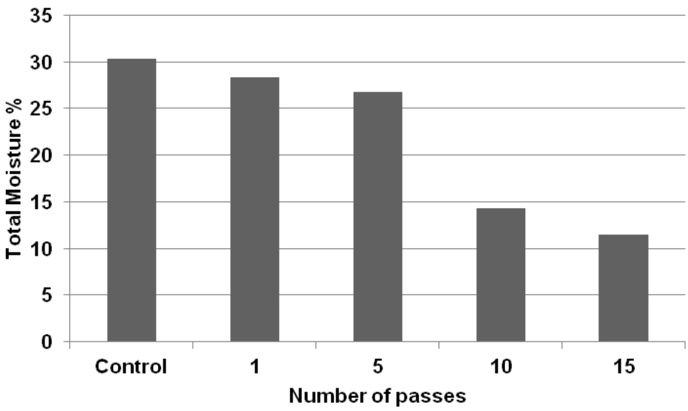

Figure 3. Soil moisture (%) compared to the previous number of machine passes.

Soil compaction caused by skidding reduced the average moisture content in the skid road. In the tracks of the tractor, soil moisture content were low because of less pore space available for water infiltration and retention at elevated bulk density levels. This could be due to the forest floor removal and consequences of a reduced water infiltration rate. Our findings agree with those of Tan et al. (2005), who reported that soil compaction reduced soil moisture content by 11% after forest floor removal. Carter & Shaw (2002) reported that the moisture content decreased with an increase in soil bulk density due to a decrease in soil porosity and the infiltration rate.

Average soil bulk density in the tractor trail ranged from 0.94 g cm^{-3} to 1.16 g cm^{-3}, while it was 0.92 g cm^{-3} in the undisturbed plot. Soil compaction increased with more passes made; indeed, the bulk density was influenced significantly by the traffic frequency ($p < 0.01$). Carter & Shaw (2002) reported significant negative correlations between soil bulk density and soil moisture content. A negative correlation between bulk density and soil moisture content would suggest a potential decrease in soil moisture at higher bulk densities, presumably due to soil compaction. Total porosity was considerably lower than the total porosity in the undisturbed plot, and this response variable decreased with the tractor traffic frequency. Porosity is inversely related to bulk density; this means that a decrease in porosity entails an increase in bulk density after the tractor passes. The total porosity was influenced significantly by the number of passes ($p < 0.01$).

In a highly productive Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) stand in northwest USA. Ares et al. (2005) found that ground-based logging caused, on average, a 27% increase in the soil bulk density and 10% –13% reduction in the soil porosity. At our forest site in Italy, the recorded values for penetration resistance were greatest after 10 and 15 passes as compared to the 1 and 5 passes and the control ($p < 0.01$). The mean values of penetration resistance in the tractor trail range from 1,632.4 kPa to 2,504.6 kPa, with a value of 525.6 kPa in the undisturbed plot (Fig. 4).

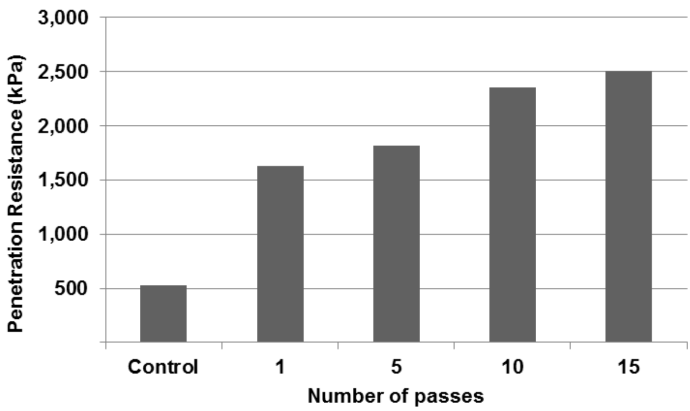

Figure 4. Penetration Resistance (kPa) compared to the previous number of machine passes.

Table 3. ANOVA for Moisture, Bulk Density, Porosity and Penetration Resistance

Moisture					
	Sum of squares	df	Mean square	F	Sig.
Between groups	1,510.906	4	377.727	155.979	0.000
Within groups	48.433	20	2.422		
Total	1,559.339	24			
Bulk Density					
	Sum of squares	df	Mean square	F	Sig.
Between groups	0.196	4	0.049	32.607	0.000
Within groups	0.030	20	0.002		
Total	0.227	24			
Porosity					
	Sum of squares	df	Mean square	F	Sig.
Between groups	280.560	4	70.140	3.123	0.038
Within groups	449.200	20	22.460		
Total	729.760	24			
Penetration Resistance					
	Sum of squares	df	Mean square	F	Sig.
Between groups	12,276,069.952	4	3,069,017,488	170.907	0.000
Within groups	359,144.829	20	17,957.241		
Total	12,635,214.780	24			

Root growth is typically restricted following compaction due to the increased penetration resistance of soil (Wasterlund, 1985; Taylor & Brar, 1991). For many tree species, their root growth is limited when the soil penetration resistance exceeds 2.5 MPa (Greacen & Sands, 1980; Whalley et al., 1995), a threshold that is often reached during forest timber harvesting. Our data show that after 15 passes this value was in fact reached.

Hence, it is clear that the number of machine passes is a key factor that significantly influences the degree of soil damage. Many (e.g. Froehlich, 1978; Brais, 2001) have studied the impact of the frequency of vehicle passes on soil compaction, finding that it occurs mostly during the first few passes of a vehicle. Subsequent passes have a smaller effect, but they may nonetheless increase bulk density levels and reduce porosity to levels critical for absolute tree growth (McNabb et al., 1997). Reduction in soil porosity as implied by compaction imposed by machine traffic in forest soilsmay amount to 50%–60% (Ares, et al.; 2005; Demir et al., 2007; Frey et al., 2009; Proto, et al., 2016b; Solgi & Najafi, 2014). Such a reduction chiefly occurs at the expense of macropores, which function in promoting soil drainage Seixas & McDonald, 1997; Ampoorter et al., 2007). Several studies (Williamson & Neilsen, 2000) have reported than ta reduction of total porosity after machine traffic typically occurs at the expense of the large air-filled pores in the soil surface layers due to a conversion of soil macropores to micropores.

Our results indicated that the ruts deepened after 1, 5, 10, and 15 passes for skid road, reaching maximum depths of 2.2, 2.8, 3.6, 4.1, and 4.7 cm, respectively. In a similar study to ours, Ozturk (2016) reported an average rut depth of 3.5–4.6 cm after 8–16 tractor passes during a log skidding operation. The weight of a loaded vehicle and the number of passes are major factors influencing the rut formation (Jansson & Johansson, 1998; Bygdén et al., 2004; Eliasson, 2005). Ruts are usually more marked by wheeled vehicles than by tracked vehicles, due to the higher pressure on the soil, and for moist soil than for dry soil, due to the lubricating action of water on soil particles (Marchi et al., 2014). When they occur, abundant rains may saturate the soil contiguous to ruts, thus hastening the risk of mud-flows or landslides. As ruts are preferential paths for surface runoff, in steep terrain they may become dangerous foci for erosion (i.e., gullies) (Startsev and McNabb, 2000; Christopher & Visser, 2007). When air-filled porosity falls below 10% of the total soil volume, microbial activity and plant growth can be severely limited in such most soils (Brady & Weil, 2002). The negative impacts of wheeling tracks in forest soils upon soil aeration that control the respiration processes of microorganisms have been documented by Schaffer et al. (2001).

These above effects of soil disturbance may well persist for several decades because of very slow forest recovery rates (Corns, 1988; Shepperd, 1993; Grigal, 2000). In fact, the time necessary for impacted soils to recover to their original physical state is variable, and also will depend on their depth.

The starting point for limiting impact of machinery traffic on a forest ecosystem is a good knowledge of the area involved to better calibrate interventions based on the susceptibility of the environment to damage, as well as its resilience. In particular, the decision of whether or not to use heavy vehicles should rely on an accurate site-level risk assessment for soil aided by a geographic information system. Furthermore, the skidding operations should be thoughtfully planned and carried out when soil conditions are dry, to minimize rutting; but if skidding must be done under wet conditions, the operations should be stopped once deep ruts are evident from machine traffic.

CONCLUSION

This research investigated the conventional factors impacting soil during forest logging operations that rely on a farm tractor. Nevertheless, this study was conducted with the overall objective of characterizing the effects of tractor farm passes – the primary extraction method 'traditional' in the forests of the Southern Italy – on soil disturbance at different levels of traffic intensity. The results clearly show that soil moisture content, bulk density, total porosity, and penetration resistance could all be used as robust indicators for monitoring harvesting impacts upon susceptible soils. The ensuing soil disturbance and rutting from skidding operations in forestry are prime examples of damage to soil on skid roads. The consequences of soil disturbance by the traffic of harvest machinery can persist for several years, or even decades. The most options to limit the negative effects of heavy logging machinery on susceptible soils appear to be:

- ✓ leaving more woody residue on the ground for topsoil reinforcement;
- ✓ reducing as much as possible the contact pressure between moving machines and the soil beneath them;
- ✓ waiting for relatively dry soil conditions when the load-bearing capacity of the soil is higher, and planning the logging design accordingly;
- ✓ avoid generating traffic whenever the soil water content is very high.

Finally, it is worthwhile to remember that designated skid trails should be used to reduce potential soil compaction in logging operations, and to thus preserve the rest of the forest area.

ACKNOWLEDGEMENTS. This study is a part of the project Project 'ALForLab' (PON03PE_00024_1) co-funded by the National Operational Programme for Research and Competitiveness (PON R&C) 2007-2013 through the European Regional Development Fund (ERDF) and national resource (Revolving Fund -Cohesion Action Plan (CAP) MIUR)

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Agronomy Research **15**(2), 490–500, 2017

Human urine as an efficient fertilizer product in agriculture

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Abstract. Flush toilet based water infrastructure, which handles blackwater and greywater together, causes a lot of environmental problems. Among these, the loss of valuable organic material and nutrient content of human excreta (faeces and urine) is not sufficiently emphasized yet. Utilization of human excreta for agricultural purposes is based on the separate collection of greywater and human excreta. As urine contains most of the nutrients of human excreta, researches focus mainly on urine's treatment and utilization for agricultural purposes. We reviewed the data in literature about the nutrient content of human excreta. In this paper we present the content of macro and microelements of human urine to show its potential value as a fertilizer. To confirm the necessity of urine's utilization in agriculture instead of treated it by traditional waste water treatment methods, we have collected and compared the most important advantages and disadvantages of traditional wastewater treatment, separated handling of greywater and excreta as well as human urine's agricultural utilization.

Key words: human urine, human excreta, agriculture, wastewater treatment, dry toilets, urine-diversion dry toilets, sustainable development.

INTRODUCTION

Nowadays one of the most important topic in environmental protection is sustainable development and environment, and part of that are the problems of wastewater treatment and the inappropriate treatment of human excreta.

Distribution of pollution load of urban wastewater shows that 99% of bacteria originates from faeces; 11% of N-content originates from faeces, 87% from urine and 2% from greywater (GW); 40% of P-content originates from faeces, 50% from urine, 10% from GW; 47% of organic matter content originates from faeces, 12% from urine, 41% from GW (Toilettes du Monde, 2009). So 99% of bacteria, 98% of N-content, 90% of P-content and the total amount of drug residues and hormones are in the human excreta, which is less than 2% of the total wastewater volume. We dilute these 2% human excreta to 15–20% black water because of flush toilets, and after this, the 15–20% blackwater is mixed with 80–85% of greywater (exact proportion of greywater and blackwater depend on the types of toilet tanks and household water consumption habits).

Because of these dilutions, the total amount of wastewater needs to be treated by the well-known treatment technologies. Greywater would not require this degree of purification. Qualitative characterization (total solids, biochemical oxygen demand, dissolved organic carbon, nitrate, phosphate, potassium, calcium, sodium, microelements etc.) of household-generated GW streams (collected from bathing, laundry and cooking) of Hungary showed high variability for the analysed parameters (Bodnar et al., 2014), but have much more lower content than blackwater has. Nevertheless, black water and greywater are together in the sewer systems and in wastewater treatment plants.

We got into a vicious circle discharging human excreta to freshwater: waste water treatment converts human excreta to water pollutant, while we replace missing nutrients to soils artificially, which leads to the exploitation of soils in the long run.

Annual amount of urine and faeces of one person consists equal amount of nutrients than what is needed to grow grain for one person’s annual food requirements (Malkki, 1995).

The solution should base on the separation of waste water at the source. Greywater contains soap, washing liquids etc., while blackwater contains human excreta. Using traditional wastewater collection and treatment methods, these two wastewater types are mixed. The key of sustainable water management is that we have to separate the handling of grey water to human excreta. To reach this goal, a wide variety of dry toilets or even urine-diversion dry toilets can be used, latter in the case if we would like to separate also human urine and faeces.

We presented segments of these problems and possible solutions in our previous works (Zseni, 2014; Nagy & Zseni, 2015; Zseni, 2015a; 2015b; Zseni & Nagy, 2015a; Nagy & Zseni, 2016; Zseni & Nagy, 2016a; 2016c). In this paper we would like to focus on urine, as an efficient fertilizer product in agriculture.

With the application of dry toilets, human faeces and urine do not get to the sewer system, so they can be used as a natural fertilizer. According to the newest research and experiments in Sweden and Finland, the most suitable method to substitute the artificial fertilizer is the usage of human urine in agriculture. Human urine as a crop fertilizer is studied for the first time in Finland on a large scale. As a natural circle, human nutrient circle was previously a closed system and the nutrients of excreta were utilized in cultivation. We just have to return back to ancient times, and recover the human nutrient circle (Huuhtanen & Laukkanen, 2009).

We would like to draw attention how much valuable material is lost if we regard human excreta as a waste. We make comparison between traditional wastewater treatment and separated handling of greywater and human excreta. Our aim is to confirm the necessity of utilization of human excreta and especially urine in the agriculture.

MATERIALS AND METHODS

To know, how much valuable material is lost when we regard human excreta as a waste, we have to know its nutrient content. There are several data concerning with quantity and composition of excreta. Therefore we collected, methodized and reviewed the data in literature (Tanguay, 1990; Malkii, 1995; Schouw et al., 2002; Jöhnsson et al., 2005; Vinnerås et al., 2006; Niwagaba, 2009). In this paper we present only the data of urine’s macro and microelement content and we use the Scandinavian data representing the eating habits of developed world and literature which gives extremes according to the different eating habits. For better comparison of data we have calculated all of them in the same unit (g person^{-1} year^{-1} and mg person^{-1} year^{-1}), in the form of elemental C, N, P, K, S, Ca, Zn, Cu, Ni, Cr, Pb, Cd and Hg. Based on the calculations we have estimated the material content of urine of the 10 million Hungarian people.

To confirm our previous opinion about the necessity of agricultural utilization of urine instead of being treated in waste water treatment plants, we have collected and compared the most important advantages and disadvantages of traditional wastewater treatment, separated handling of greywater and human excreta and human urine's utilization in agriculture.

RESULTS AND DISCUSSION

Our conviction is that it would be more reasonable to use human excreta for agricultural purposes not only because of the harmful effects of inappropriate waste water treatment on freshwater bodies, but also because the basic materials of the artificial fertilizer will be exhausted in the future. It is not a new idea to use human excreta for agricultural purposes, rather it was – some place now still is – the part of everyday life. The method of utilization basically can be two types: faeces and urine are collected and used together, or they are separated. The requirement of proper use is to separate the collected excreta from the water supply network. Many solutions exist, prevalent or spread for reaching this goal, for instance traditional latrines, modern dry toilets or separating toilets.

Human urine as a nutrient source

Amount, appearance, physical and chemical features of human excreta heavily depend on human health, the quality and quantity of food and fluid consumed, the sweat, even climate. Faeces encompass water, indigestible materials passing through the intestinal track (e.g. fibres), gland secretion (e.g. gall), as well as pathogenic viruses, bacteria, helminth eggs. Urine mostly contains water and also plant nutrients in water-soluble form.

As this paper focuses on urine, only the results which are concerned in urine are presented here. Data about faeces can be found in our previous works (Zseni & Nagy, 2015b; Zseni & Nagy, 2016b; Zseni & Nagy, 2016d).

The amount of urine is about 1–1.3 l person^{-1} day^{-1}, whose moisture content is 93–96%, dry matter content is 50–70 g person^{-1} day^{-1} depending on meal habits (Feachem et al., 1983; Tanguay, 1990). Other literature data on the amount of urine (total liquid) present 1,500 g person^{-1} day^{-1} (Vinnerås et al., 2006), 610–1,090 g person^{-1} day^{-1} in Switzerland (Jönsson et al., 1999), 600–1,200 ml person^{-1} day^{-1} in Thailand (Schouw et al., 2002). There are 15–19% nitrogen (N), 2.5–5% phosphorous (P_2O_5), 3.0–4.5% potassium (K_2O), 11–17% carbon (C), 4.5–6% calcium (Ca) in the dry matter content of urine, depending on meal habits (Tanguay, 1990). According to Swedish data, urine contains 3,700–3,830 g person^{-1} year^{-1} N, 250–340 g person^{-1} year^{-1} P, 820–1,190 g person^{-1} year^{-1} K (Vinnerås et al., 2006). Jönsson et al. (2005) had processed several literature data and recommended 11 g person^{-1} day^{-1} N, 0.9 g person^{-1} day^{-1} P, 2.4 g person^{-1} day^{-1} K in urine of Swedish people. According to Malkki (1995), the amount of urine is 500 l person^{-1} year^{-1} and it contains 5.6 kg person^{-1} nitrogen, 0.4 kg person^{-1} phosphorus and 1.0 kg person^{-1} potassium annually.

For the comparability of the above presented data we have calculated and converted them into the unit of g person^{-1} year^{-1}, for elemental carbon (C), nitrogen (N), phosphorous (P), potassium (K), sulphur (S) and calcium (Ca). Urine contains microelements such as heavy metals, too, but the quantity of them is negligible (Jönsson et al., 2005; Vinnerås et al., 2006; WHO, 2006). Pharmaceuticals are also present in urine, but at extremely low levels (Rich Earth Institute, 2016). In Tables 1, 2 our calculations are summarised.

Table 1. Calculated average macro element content of urine (g person^{-1} year^{-1})

Urine	Based on Tanguay (1990)	Based on Jönsson et al. (2005)	Based on Vinnerås et al. (2006)	Based on Malkki (1995)
C	2,008–4,344	no data	no data	no data
N	2,738–4,855	4,015	3,687–3,833	5,600
P	201–559	329	248–339	400
K	453–953	876	821–1,190	1,000
S	no data	256	no data	no data
Ca	588–1,095	no data	no data	no data

Table 2. Calculated average microelement content of urine (mg person^{-1} year^{-1})

Urine	Based on Jönsson et al. (2005)	Based on Vinnerås et al. (2006)
Zn	110	14.6
Cu	36.5	36.5
Ni	4.02	3.65
Cr	3.65	3.65
Pb	4.38	0.73
Cd	0.18	0.37
Hg	0.30	0.37

As there is no measured and published Hungarian data for the exact nutrient content of excreta of Hungarian people, we used our calculated data based on Tanguay (1990). According to our conviction the extremes express better the various eating habits of people. The maximum value is characteristic for a meat eater who eats a lot, while the minimum value indicates the nutrient content of excreta of a little eater, vegetarian people. Population of Hungary is almost 10 million people. It means, that urine of Hungarian people contains about 20–43 thousand tons of carbon (C), 27–49 thousand tons of nitrogen (N), 2–5.6 thousand tons of phosphorous (P), 4.5–9.5 thousand tons of potassium (K) and 6–10 thousand tons of Ca in a year. For comparison, the active ingredient content of fertilizers sold in Hungary in a year is: 358 thousand tons of N, 81 thousand tons of P and 80 thousand tons of K (Central Statistical Office, 2016). In the case of microelements, according to data in Table 2, urine of 10 million people contains about 150–1,100 kg Zn, 365 kg Cu, 36–40 kg Ni, 36 kg Cr, 7–44 kg Pb, 2–4 kg Cd and 3–3.7 kg Hg in a year.

Utilization of human urine in agriculture

As urine contains the greater part of excreted nitrogen, phosphorus and potassium, and its handling seems to be easier than faeces, researches on practical treatment and utilization of excreta pay attention mainly to urine. There are substantial amount of literature dealing with treatment and utilization of urine for agricultural purposes (Jöhnsson et al., 2004; Maurer et al., 2006; Niwagaba, 2009; Pradhan et al., 2010; Richert et al., 2010; Wohlsager et al., 2010; Semalulu et al., 2011; Anderson, 2015).

Because of many factors, separate collection of urine is favourable according to some literature. Separation of urine from the solid excrement makes handling of excrement easier and reduces the load derived from excreta by e.g. reducing the volume of excreta, reducing the odour problems and decreasing the runoffs of pathogens and nutrients (e.g. nitrates) to soil, ground water and surface waters (Malkki, 1995; Höglund, 2001; Schönning & Stenström, 2004).

Solid excrement is easier to treat if it is dry and pathogens can die faster than in the wet mixture of urine and faeces. Urine can be considered as almost perfect nutrient solution: nitrogen is mainly in the form of urea, phosphorous as superphosphate and potassium in ionic form what is useful for plants. In addition urine contains micronutrients in a well-balanced way. Using separate collection, nutritional value of urine is directly recovered. If urine is not separated, its nutritional value is partly lost due to runoffs and evaporation and furthermore the nutrients can end up in water bodies (Malkki, 1995; Höglund, 2001; Schönning & Stenström, 2004).

Urine can be utilised either undiluted or diluted, depending on the target. Although, diluted form is more favourable because it has more advantages (Huuhtanen & Laukkanen, 2009).

Urine contains most of the excreta's nutrients and is normally bacteria less. If microorganisms are found in urine, they usually die rather quickly and do not pose any threat to further utilisation of urine as soil fertilizer. Usually the problem is not urine itself but solid excrement that has accidentally mixed with urine (Malkki, 1995; Schönning & Stenström, 2004; Vinnerås et al., 2008; Chandran et al., 2009).

However, there are some problems with the application of urine as well. To eradicate possible pathogens from urine it needs to be stored in closed containers before utilization. If urine is used in household's own purposes e.g. in garden or is added to the compost, it can be used already after a couple of days of storage. If urine is not utilized in own household, the storage should be at least one month when used for food and fodder plants that are not consumed untreated and even six months when used for all plants. Because after six months storage the rotavirus infection and viral infection will be reduced. Also, a total inactivation of *Ascaris* (parasitic worm) was recorded within six months. While storing urine, special attention needs to be paid on the tightness of the containers, because the nitrogen in urine is volatile and due to evaporation valuable nutrients are lost (Höglund, 2001; Schönning & Stenström, 2004).

Therefore storage is an important factor when we are using human urine. Another problem is the large volume of urine. An adult usually produces even 500–570 litres of urine annually. This large volume makes it difficult to store and transport to farms where it can be used, particularly if urine is collected in cities far from agricultural areas. A variety of strategies (distillation, evaporation, freeze/thaw and reverse osmosis) have been tried for removing water from urine and reducing its volume to create a concentrated product. The most energy efficient is reverse osmosis, some newest ongoing research focuses on new techniques to increase the effectiveness of reverse osmosis (Rich Earth Institute, 2016).

Another problem is, that if we focus only on the utilization of urine, than the environmental problem is not totally solved, as faeces has high organic and nutrient content as well, and it is also a very good fertilizer after composting. In our opinion, either we separate faeces to urine, or we collect and treat them together, the main goal has to be the agricultural utilization of both. We have to seek after the best solution, which can differ in different situations (e.g. urban or rural areas, arid or wet climate).

Comparison of different waste water treatment methods

We have collected the advantages and disadvantages of the traditional wastewater treatment and the advantages and disadvantages of separate handling of grey water and human excreta. Our summarised opinion can be found in Tables 3, 4.

Table 3. Advantages and disadvantages of traditional wastewater treatment when greywater and blackwater are treated together

Advantages	Disadvantages
An existing, established system	Expensive to build, operate and maintain
We have a lot of knowledge and information about the system	Great energy demand, which may create great co_2 emission
Old, well known waste water treatment methods / technologies	Water consumption for flushing the toilet
Sewage sludge can be utilised	Soil pollution
Existing technological devices (decantation machines, filters, chemicals), specialists	Underground water pollution
People are comfortable with using the flush toilets	Carbon content of excreta as co_2 gets released to the atmosphere to some degree according to the wastewater and sewage sludge treatment methods used
	Freshwater pollution, which may cause eutrophication
	Changes in natural water cycle
	Household-generated greywater must be treated like blackwater, unnecessarily
	Hormones and medicines are not degraded during wastewater treatment processes
	Non sustainable use of natural resources (water, human excreta)
	The nutrient and organic matter content of human excreta is wasted
	There is no way of humus forming from the organic matter content of the human excreta
	Natural cycles are upset
	Use of artificial fertilizer is needed to enhance soil productivity and this generates negative impacts on the environment and demands energy and mineral resources
	The future food production is threatened

* In developed countries the electrical consumption of the waste water treatment plant is about 20% of the communal electrical consumption, if we are not calculate the waste water treatment plant’s own electrical production (Christ & Mistsdoerffer, 2008).

Table 4. Advantages and disadvantages of separate treatment of greywater and human excreta

Advantages	Disadvantages
Wastewater treatment becomes more simple if we just treat the greywater itself	The idea is hard to implement in urban areas
Less energy demand, less CO_2 emission	It takes more time to take care about the system
Water consumption decreases	We have to be more educated to know why and how we have to use the system
Soil pollution, water pollution and eutrophication decrease significantly	
Amount of waste water sludge decreases significantly	
There is a possibility of humus forming from the organic matter content of the human excreta	
Nutrients in human excreta is not wasted as natural fertilizer can be made of human excreta	
Nutrient content of human excreta goes back to the natural biological cycles	
Low costs of maintaining and operation	
Use of artificial fertilizer may decreases, so its unfavourable environmental effects and use of energy and mineral resources also decrease	
Food production becomes more sustainable	
High variety of techniques, adaptable for different conditions (types of dry toilets, composting methods etc.)	

Separate treatment of grey water and human excreta has a lot more advantages, than disadvantages. Technical solution for utilization of excreta can be the composting of human excreta after collection. It offers appropriate and suitable technology to take back our excreta into the natural cycles and the well-known environmental problems caused by flush toilet based infrastructure can be reduced or even eliminated (PereiraNeto et al., 1987; Schönning & Stenström, 2004; Bracken et al., 2007; Wichuk & McCartney, 2007; Niwagaba, 2009; Országh 2014; Cameron et al., 2015; Polprasert, 2016).

Another question is that faeces and urine has to be used together or just human urine itself as a fertilizer in the agriculture. In Table 5 the advantages and disadvantages of separate using of urine is presented.

Table 5. Advantages and disadvantages of separate utilization of human urine

Advantages	Disadvantages
In fresh excrement many kind of bacteria, viruses and worm eggs may be found*, but urine is normally bacteria less	While storing urine, special attention needs to be paid on the tightness of the containers because the nitrogen in urine is volatile and due to evaporation valuable nutrients are lost
Reducing the odour problems	Treatment and utilization of separately collected faeces has to be solved, too
Nitrogen is mainly in the form of urea Phosphorous as superphosphate and potassium in ionic form in urine what is useful for plants	

* One gram of fresh excreta contains ca 100 million bacteria where among the most common are *Escheria coli* and *faecal streptococci* (*Streptococcus faecalis* etc.), *Shigella-*, *Salmonella-*, *Clostridium-* and *Campylo-species* and especially in the developing countries *Vibrio cholera* (causes cholera). In addition e.g. protozoa and helminths can spread through excreta (Malkki, 1995; Schönning & Stenström, 2004).

CONCLUSIONS

Operation and maintain of flush toilet based water infrastructure has high environmental load. However, the remediation of harmful environmental effects is still concentrated to water pollution. During waste water treatment the valuable organic components of the human excreta are transformed into water loading inorganic N and P compounds. The improvement of end of pipe – waste water treatment – technologies is believed for perfect solution in solving this problem. However, this loading is not the most harmful environmental effect of flush toilets. The greatest environmental harm of flush toilets is the withdrawal of the very valuable organic matter and nutrient content of human excreta from the cycle of biosphere.

More widespread agricultural utilization of human excreta is needed in any case in the future, regarding the annually loss of soil mass and soil fertility on the Earth, and the cost, material and energy demand of fertilizer production and utilization. In this paper we have presented the human urine as a possible and usable natural fertilizer in agriculture.

To sum up, we can say that we have to change our traditional wastewater collection and treatment methods, have to demonstrate the problems and solutions and have to introduce these problems and solutions to as many people as we can. The main goal should be to have an effect on people thinking, so they could realize how important is to make changes in our own life, to make our environment more liveable and to build a sustainable environment. Separately collected grey water and excreta has a lot of favourable advantages, for example: soil and water pollution may reduce, the nutrients in human excreta would not be wasted, natural fertilizer could be made of human urine, and wastewater treatment methods would be simpler if only grey water has to be treated. Using of human urine in the agriculture has a lot of advantages but for the spreading use of urine as fertilizer in the future, it would be important to find the best and cost effective method how to concentrate the different nutrients in urine and how to reduce the volume of urine.

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Agronomy Research **15**(2), 501–514, 2017

Seed priming improves seedling emergence time, root characteristics and yield of canola in the conditions of late sowing

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Abstract. In central zones of Iran, late sowing of canola is the major reason of low yield. This yield reduction is principally due to poor crop establishment and root development dynamics because of low temperature prevailing. The present study was conducted to explore the possibility of improving late sown canola performance by seed priming techniques. A field experiment was conducted using five sowing dates (SD) at 10-day intervals from 5-September to 15-October during 2014–2015 and 2015–2016 seasons, three canola cultivars (Okpai, Zarfam and Talayeh) and seed priming strategies were: hydropriming and osmopriming with $ZnSO_4$ for 10 h. Results showed that minimum time to incipient emergence (T_0) and time to 50% emergence (T_{50}) was recorded from osmopriming of the optimal SD (5-Sep) by Okapi, Talayeh and Zarfam cultivars, respectively. The maximum root length (RL) was on the 5-Sep, so at that this date under the osmopriming and hydropriming, RL increased by 82 and 61 percent in Okapi, 47 and 43 percent in Zarfam and 58 and 44 percent in Talayeh in both growth seasons compared to control, respectively. Also, maximum root diameter (RD), root surface area density (RSAD) and grain yield (GY) was recorded in Okapi, Zarfam and Talayeh cultivars on the 5-Sep under hydropriming and osmopriming, respectively. Delay sowing significantly affected root dry weight (RDW) and root volume (RV). Maximums of RDW and RV at both seasons were recorded from osmopriming on 5-Sep in Okapi cultivar followed by hydropriming.

Key words: Hydropriming, Osmopriming, Root length.

INTRODUCTION

Canola is one of the world's four largest oil crops, and is the sixth largest crop in Iran with an annual planting area of 160,000 hectares (FAO, 2014). Canola yield is very low as compared to its production potential. Out of many constraints regarding low production of canola, low seedling establishment is of prime importance. Iran has arid or semiarid climates mostly characterized by low rainfall and high potential evapotranspiration. The annual precipitation varies from about 1,800 mm over the Western Caspian Sea coast and Western highlands to less than 50 mm over the uninhabitable Eastern deserts. The average annual precipitation over the country was estimated to be around 250 mm, occurring mostly from October to March (Eslamian et al., 2009). Additionally, the annual average temperatures for the entire time period ranged between 9 °C and 27 °C. In central zones of Iran, the optimum time of canola sowing date (SD) is the first week of September, but often sowing is late until mid-October because of late harvesting of the preceding crop. Only strong and vigorous canola seedlings can cope with cold and wet weather conditions, frequently observed in central zones of Iran. Well-developed shoot and root systems are key features for genotypic differences in cold tolerance (Lee et al., 2002; Hund et al., 2007). Low temperature at late sown is a major yield-limiting factor for canola grown in this zone. Low temperature reduces growth of shoots and roots and the mineral nutrition of plants (Cooper, 1973; Bowen, 1991). The root is an important organ that plays a significant role in the growth and development of plants. Seed priming techniques can be effectively used to improve the performance of late sown in crops (Rehman et al., 2015a). Seed priming improves the increasing growth of root and shoot under less than optimum field conditions (Lee & Kim, 2000; Kant et al., 2006).

Zinc (Zn) is one of the vital micronutrients for plants as it has many critical functions. Zn deficiency is common throughout the developed and developing world (Takkar &Walker, 1993) and lack of Zn can limit the growth and productivity of a wide range of crops (Khattak & Parveen, 1986). In most of the Iranian soils pH is high and they are also calcareous, in this type of soils solvability of micronutrient is less and cause decline uptake these elements and finally requirement of plants to this elements is increasing (Mousavi, 2011). Since this nutrients are significantly involved in reproduction process and their deficiency may occur simultaneously in calcareous soils of Iran (Ziaeyan & Rajaie, 2009). It acts as a co-factor for more than 300 enzymes and is also required for the production of tryptophan which is a precursor of auxin (Aravind & Prasad, 2003). Seed priming with Zn can improve crop emergence, stand establishment, and subsequent growth. For example, priming *Echinacea purpurea* (L.) seed with 0.05% $ZnSO_4$ solution increased root development (Babaeva et al., 1999). In barley (*Hordeum vulgare* L.), seed priming with Zn improved 50% reduced germination time (Ajouri et al., 2004). Priming seeds in Zn solution enhanced dry weight of root in rice (Prom-u-thai et al., 2012). The present study was designed to evaluate the potential of osmopriming agent in comparison with hydropriming technique on seedling development and root morphological characteristics of late sown three canola cultivars under the climatic conditions in central zones of Iran during two growing seasons.

MATERIALS AND METHODS

Site description

The present study was conducted during the two growing seasons of 2014–2015 and 2015–2016 under field at the experimental farm of Islamic Azad University, Karaj Branch, Iran. The site is located at latitude of 35˚45′ N, longitude of 51˚6′ E and 1,313 m above the sea level in a semi-arid climate experimental field (Fig. 1). The soil type was a silty clay (10.33% sand, 46.33% silt, 43.34% clay), with 0.98% organic matter and pH of 7.4. Daily rainfall and temperature were obtained from a meteorology station located 7 km away from the experimental field (Fig. 1).

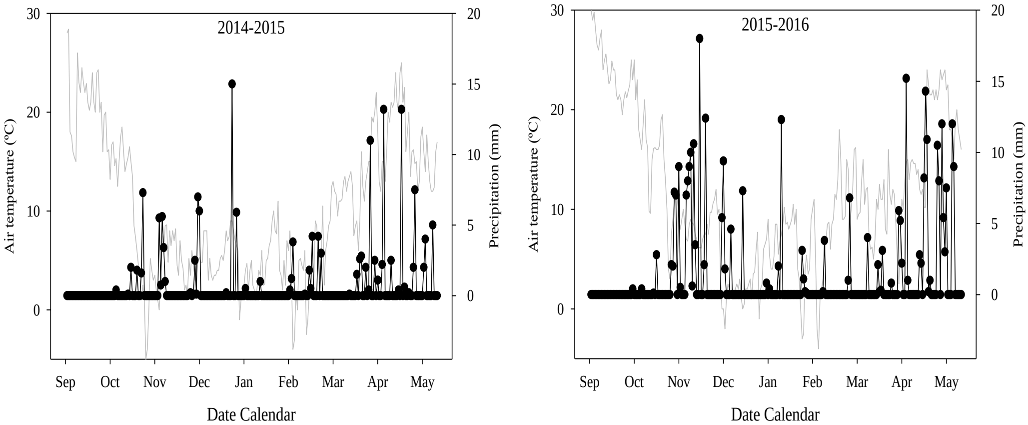

Figure 1. Daily mean temperatures (solid line) and daily total precipitation (●) during the experimental years.

Experimental details

To prepare the field, it was irrigated before conducting the experiment and after the field got wet enough, it was a 30-cm deeply by moldboard plowing in a few days before sowing in August, followed by a disking to slice plant residue and incorporate fertilizers into the soil. Canola seeds were obtained from Seed and Plant Improvement Institute (SPII), Karaj, Iran. NPK fertilizers were applied at rates of 150:80:80 kg ha^{-1}, respectively. P, K and 1/3 of N were applied before sowing and incorporated. Other portions of N were used at the end of rosette stage and beginning of the flowering. Each experimental plot included 6 sowing rows with 6 m in length and 30 cm in width. Average density was 80 plants m^{-2}. The fields were irrigated five times in two growing seasons. The experimental field was visited daily to record stand establishment of canola cultivars. In each plot, two quadrats (1 × 1 m) were randomly marked and the number of emerged seedlings counted daily until the constant count (Association of Official Seed Analysts 1990). The day when the first seedling emerged was recorded as the time to incipient emergence (T_0). Time to 50% emergence (T_{50}) was calculated as described by Farooq et al. (2005). Field experiments were conducted to determine the relationship between root parameters up to the four-leaf stage. Root characteristics were measured at rosette stage using mean data of ten plants in each experimental at a depth of 20 cm of soil. Root length (RL) were measured manually unit with a ruler and dry weights of root (RDW) were determined after drying at 80 °C for 24 h. Roots volume (RV) was evaluated according to the method of Musick et al. (1965) by immersion in a graduate test tube and measure of the displaced water volume. Then root diameter (RD) was determined using the equation 1 (Hajabbasi, 2001) and then root surface area density (RSAD) was calculated using the equation 2 (Schenk & Barber, 1979): RFW is root fresh weight (g).

$$RD = \left(\frac{4 \times RFW}{RL \times 3.14}\right)^{0.5} \tag{1}$$

$$RSAD = \left(RL \times RD \times 3.14\right) \tag{2}$$

Grain yield (GY) samples were harvested on 5 dates between 5 May and 20 May in 2014–2015, and 15 May and 30 May in 2015–2016. GY was assessed by harvesting plants from adjacent 50-cm lengths of 4 inner rows (6 m^2) in each plot.

Statistical analysis

The experiment was laid out in a randomized complete block design as split plot factorial with three replications. Main factor was including five sowing dates (SD) (5, 15 and 25 September, 5 and 15 October in both crop years) and three canola cultivars (Okapi, Zarfam and Talayeh) and priming treatments (including priming with water, priming with $ZnSO_4$ and control) as factorial in sub-plots. Seed priming was done by soaking in water and 35 ppm $ZnSO_4$ solution for 10 h at 20 °C. Zinc sulfate with 22% Zn manufactured by the Eksir Farayand Espadana Corporation of Iran. Concentration of zinc sulfate solution and duration of priming seeds already determined in a preliminary experiment inspired by research conducted by Harris et al. (2008). Primed seeds dried in the shade to become closer to their original weight at 28 ± 2 °C (Basra et al., 2005). Analysis of variance was done using the PROC GLM procedure of the SAS package 9.1 (SAS Institute, Cary, NC, USA) and test the significance of variance sources, while LSD test (P = 0.05) was used to compare the differences among treatment means.

RESULTS AND DISCUSSION

Results showed that the time to incipient emergence (T_0) and time to 50% emergence (T_{50}) of canola was significantly (P = 0.01) affected by year × sowing date × cultivars × priming interaction (Table 1). The results indicated in both growth seasons that hydropriming and osmopriming compared with non-primed reduced T_0 and T_{50} in all of canola cultivars.

Table 1. Significance levels of analysis of variance combined over 2014–2015 and 2015–2016

Source of variation	d.f	T_0	T_{50}	RL	RD	RSAD	RV	RDW	GY
Year (Y)	1	***	***	n.s.	***	***	***	***	***
Block (Y)	4								
Sowing date (SD)	4	***	***	***	***	***	***	***	***
Y × SD	4	***	***	***	***	***	***	*	***
Block × SD (Y)	16								
Cultivars (C)	2	***	***	***	***	***	***	***	***
Priming (P)	2	***	***	***	***	***	***	***	***
Y × C	2	***	***	n.s.	n.s.	n.s.	**	n.s.	***
Y × P	2	***	***	***	n.s.	***	**	n.s.	***
SD × C	8	***	***	***	***	n.s.	***	***	***
SD × P	8	***	***	***	***	***	***	***	*
C × P	4	***	***	***	***	*	***	***	**
Y × SD × C	8	***	***	n.s.	n.s.	n.s.	n.s.	n.s.	**
Y × SD × P	8	*	***	***	n.s.	*	n.s.	n.s.	***
Y × C × P	4	**	***	n.s.	n.s.	n.s.	*	*	**
SD × C × P	16	***	***	**	***	n.s.	***	***	**
Y × SD × C × P	16	***	***	n.s.	n.s.	n.s.	**	*	**
Block × C × P (SD ×	160								

* Significance at 0.05 probability level; ** Significance at 0.01 probability level; *** Significance at 0.001 probability level. T_0 = time to incipient emergence; T_{50} = and time to 50% emergence; RL = root length; RD = root diameter; RSAD = root surface area density; RDW = root dry weight; RV = root volume; GY = grain yield.

Primed seeds have a better ability to complete the process of germination in a short time and cope with environmental stresses including low temperature (Kant et al., 2006). Osmopriming with $ZnSO_4$ reduced the time to start emergence and T_{50} of canola. Hydropriming also complete the process of emergence in a short time, but to a lesser extent. Rehman et al. (2015b) reported that hormonal priming with 0.5 M $ZnSO_4$ and 0.1 M $ZnCl_2$ were more effective than hydropriming for earlier and synchronized germination and emergence in wheat. Results showed that T_0 and T_{50} decreased significantly in all treatments were observed in 2014–2015 compared with 2015–2016 season. In 2014–2015 and 2015–2016 mean temperature during the 30 days after sowing on the 15-Oct was 5 and 10 °C, respectively (Fig. 1). Low temperatures causes reduce seedling emergence, particularly in those crops such canola which require optimal temperatures between 20 and 25 °C for germination (Zheng et al., 2015). However osmopriming was better during both years (Table 2). T_0 and T_{50} increased significantly as SD was delayed from 5-Sep to 15-Oct in canola cultivars under hydropriming and osmopriming (Table 2). The minimum T_0 and T_{50} was on the 5-Sep under the osmopriming by 2.81 and 3.01 days in the Okapi, 3.61 and 5.04 days in Zarfam and 3.18 and 4.51 days in both growth seasons, respectively.

Increased knowledge of root architecture and root development dynamics could help improve crop productivity in agroecosystems. Better understanding of root architecture and growth dynamics of annual crops may lead to a more efficient use of applied nutrients and water (Fageria, 2011). The study of plant roots is one of the most promising research area, but has a small portion of plant growth research (Box & Ramseur, 1993; Zobel, 2005). Root length (RL) and root diameter (RD) of canola was significantly affected by sowing date × cultivars × priming interaction (Table 1). Among the five SD, the highest RL was obtained on the 5-Sep, while late in SD could cause decreased rapidly from 5-Sep in all the primed seed and control (Table 3).

The maximum RL was on the 5-Sep, so much that this date under the osmopriming and hydropriming increased by 82 and 61 percent in the Okapi, 47 and 43 percent in Zarfam and 58 and 44 percent in Talayeh in both growth seasons compared to control, respectively (Table 3). Results showed remarkable reduction in RD associated with late sowing as compared with the early sowing. Also seed priming with water (hydropriming) and zinc sulfate solution (osmopriming) increased the RD compared with control in three cultivars under all SD. However, the maximums of RD were recorded in Okapi (0.86 and 1.04), Zarfam (0.92 and 0.98) and Talayeh (1.04 and 0.91) cultivars on the 5-Sep under hydropriming and osmopriming, respectively (Table 3). Root surface area density (RSAD) were significantly affected by year × sowing date × priming interaction (Table 1). Results showed that RSAD increased significantly by 48% in 2015–2016 compared with 2014–2015 season (Table 4). Experimental evidence of the higher of RSAD were recorded in the osmopriming agent as compared to hydropriming. Among the five SD, the highest RSAD was obtained on the 5-Sep, while late in SD could cause decreased rapidly from 5-Sep in all the primed seed and control. The lowest RSAD were observed in non-primed treatments (Table 4).

Table 2. Time to incipient emergence and Time to 50% emergence of Okapi, Zarfam and Talayeh cultivars among different sowing dates under seed priming treatments

	Control			HP			OP			
	Okapi	Zarfam	Talayeh	Okapi	Zarfam	Talayeh	Okapi	Zarfam	Talayeh	Mean
Time to incipient emergence (days)										
2014–2015										
5-Sep	4.01 f	4.7 d	4.15 f	3.11 h	3.99 f	3.36 g	2.85 h	3.76 f	3.29 g	3.69 E
15-Sep	4.33 e	4.98 d	4.54 e	3.3 g	4.14 f	4.1 f	3.13 h	3.98 f	4.03 f	4.05 D
25-Sep	4.58 e	5.26 c	5.43 c	4.13 f	4.48 e	4.45 e	4.00 f	4.23 f	4.26 f	4.53 C
5-Oct	5.26 d	5.63 c	6.07 b	4.35 e	5.16 d	4.91 d	4.15 f	4.89 d	4.51 e	4.99 B
15-Oct	6.15 b	6.36 a	6.21 b	4.7 d	5.59 c	5.04 d	4.38 e	5.2 d	4.87 d	5.38 A
2015-2016										
5-Sep	3.29 g	4.00 f	3.69 g	2.89 h	3.52 g	3.27 g	2.77 h	3.46 g	3.08 h	3.33 F
15-Sep	3.87 f	4.36 e	4.05 f	3.15 h	3.93 f	3.53 g	2.98 h	3.69 f	3.17 h	3.64 E
25-Sep	4.15 f	4.87 d	4.43 e	3.58 g	4.25 f	3.87 f	3.23 h	3.98 f	3.46 g	3.98 D
5-Oct	4.77 d	5.26 c	4.97 d	4.09 f	4.59 e	4.33 e	3.92 f	4.16 f	4.05 f	4.46 C
15-Oct	5.49 c	6.00 b	5.73 b	4.43 e	5.09 d	5.29 c	4.13 f	4.93 d	4.24 f	5.04 B
Mean	4.59 C	5.14 A	4.93 B	3.77 E	4.47 C	4.21 D	3.55 F	4.22 D	3.89 E	
$LSD_{0.05}$ = 0.09										
Time to 50% emergence (days)										
2014–2015										
5-Sep	5.35 g	5.91 f	5.67 f	4.51 i	5.36 g	5.09 h	4.05 j	5.14 h	4.61 i	5.08 H
15-Sep	5.88 f	6.31 d	6.13 e	4.84 h	5.87 f	5.47 g	4.43 i	5.64 g	5.21 h	5.53 F
25-Sep	6.3 d	6.81 c	6.52 d	5.16 h	6.2 f	5.98 f	5.00 h	6.06 f	5.83 f	5.98 D
5-Oct	6.76 c	7.28 c	7.03 c	5.74 f	6.45 d	6.31 d	5.45 g	6.31 d	6.05 f	6.37 A
15-Oct	6.97 c	7.8 a	7.57 b	6.12 f	7.16 c	6.77 c	5.87 f	6.68 d	6.26 f	6.8 B
2015–2016										
5-Sep	5.04 h	5.72 f	5.37 b	4.25 j	5.09 h	4.66 i	3.97 j	4.95 h	4.41 i	4.83 I
15-Sep	5.24 h	5.93 f	5.77 a	4.57 i	5.46 g	4.95 h	4.21 j	5.28 h	4.83 h	5.14 G
25-Sep	5.42 g	6.38 d	6.13 f	4.95 h	5.82 f	5.44 g	4.47 i	5.69 f	5.29 g	5.51 F
5-Oct	6.00 f	6.87 c	6.43 d	5.13 h	6.06 f	5.88 f	4.89 h	5.96 f	5.69 g	5.88 E
15-Oct	6.34 d	7.11 c	7.02 c	5.69 f	6.46 d	6.22 f	5.25 h	6.11 f	5.97 f	6.24 C
Mean	5.93 D	6.61 A	6.36 B	5.09 G	5.99 C	5.66 E	4.76 H	4.78 H	5.41 F	
$LSD_{0.05}$ = 0.031										

T_0 = time to incipient emergence; T_{50} = and time to 50% emergence; HP = hydropriming; OP = osmopriming.

Table 3. Root length and root diameter of Okapi, Zarfam and Talayeh cultivars among different sowing dates under seed priming treatments

	Control			HP			OP			
	Okapi	Zarfam	Talayeh	Okapi	Zarfam	Talayeh	Okapi	Zarfam	Talayeh	Mean
RL (cm)										
5-Sep	7.56 h	7.45 h	7.44 h	12.22 b	10.41 cd	10.76 cd	13.77 a	10.97 cd	11.78 b	10.26 A
15-Sep	7.01 hi	6.62 ij	6.78 hi	10.39 de	8.67 g	9.31 f	11.62 bc	9.37 f	10.19 ef	8.89 B
25-Sep	6.15 jk	5.19 lm	5.66 kl	7.44 h	6.49 ij	7.42 h	8.35 g	7.17 hi	7.66 h	6.84 C
5-Oct	5.11 lm	4.13 no	4.59 mn	6.31 ij	5.39 kl	5.36 kl	6.88 hi	5.72 jk	5.98 jk	5.47 D
15-Oct	3.25 pq	2.54 q	2.98 pq	3.71 no	3.04 pq	3.31 op	4.00 no	3.29 op	3.31 pq	3.27 E
Mean	5.82 D	5.19 D	5.49 D	8.01 B	6.8 C	7.23 BC	8.89 A	7.31 B	7.78 C	
$LSD_{0.05}$ = 0.81										
RD (cm)										
5-Sep	0.37 fg	0.66 cd	0.4 fg	0.86 ab	0.92 ab	1.04 a	1.04 a	0.98 a	0.91 ab	0.79 A
15-Sep	0.54 ef	0.39 fg	0.42 fg	0.8 bc	0.86 ab	0.84 bc	0.96 a	0.71 cd	0.71 cd	0.69 A
25-Sep	0.39 fg	0.3 gh	0.37 fg	0.42 fg	0.83 bc	0.55 e	0.77 bc	0.64 d	0.69 cd	0.55 B
5-Oct	0.34 gh	0.37 fg	0.36 fg	0.38 fg	0.82 bc	0.42 fg	0.76 bc	0.56 de	0.39 fg	0.49 B
15-Oct	0.23 h	0.3 gh	0.22 h	0.27 gh	0.31 gh	0.28 gh	0.43 fg	0.29 gh	0.22 h	0.28 C
Mean	0.37 D	0.4 D	0.35 D	0.55 C	0.75 AB	0.63 BC	0.79 A	0.64 BC	0.58 C	
$LSD_{0.05}$ = 0.13										

RL = root length, RD = root diameter; HP = hydropriming; OP = osmopriming.

Table 4. Root surface area density of different sowing dates under seed priming treatments over two studied years

RSAD (m^2 m^{-3})	Control	HP	OP	Mean
2014–2015				
5-Sep	8.81 hi	23.54 d	29.12 c	20.49 B
15-Sep	7.72 hij	17.66 f	22.09 de	15.82 C
25-Sep	5.58 jkl	10.17 h	12.97 g	9.57 D
5-Oct	3.14 mn	4.04 lmn	9.59 h	5.59 E
15-Oct	2.75 n	2.94 n	3.56 mn	3.08 E
2015–2016				
5-Sep	13.17 g	36.67 b	47.73 a	32.52 A
15-Sep	9.59 h	21.68 de	27.93 c	19.73 B
25-Sep	8.53 hi	15.04 g	19.92 ef	14.49 C
5-Oct	5.94 jkl	7.39 ijk	14.34 g	9.22 D
15-Oct	3.69 lmn	4.52 klm	6.27 jkl	4.82 C
Mean	6.89 C	14.36 A	19.35 B	
$LSD_{0.05}$ = 0.68				

RSAD; root surface area density; HP = hydropriming; OP = osmopriming.

The interaction between year × sowing date × cultivars × priming on root dry weight (RDW), root volume (RV) and grain yield (GY) was significant (Table 1). The mean RDW, RV and GY of canola in response to seed priming with hydropriming, osmopriming and control is shown in Table 5. Seed priming treatments significantly affected RDW, RV and GY in late sown canola. Osmopriming with the greater impact than hydropriming in all of SD and cultivars, improved RDW, RV and GY at both seasons. Delay sowing negatively affected RDW, RV and GY. Maximum RDW, RV and GY at both seasons was recorded from osmopriming on 5-Sep in Okapi cultivar followed by hydropriming. Mean increase in GY by 25, 32, 37, 46 and 47% by Okapi cultivar under priming with $ZnSO_4$ solution was observed in plots with 5-Sep, 15-Sep, 25-Sep, 5-Oct and 15-Oct SD respectively, in comparison with their controls in both years. Low temperatures after sowing caused considerably longer emergence duration at the four delayed SD (15 and 25-Sep; 5 and 15-Oct), and canola exposed to sub-optimal temperatures for this parameters. Decreased this parameters due to low temperature in late-sown has been reported by many researchers (Finch-Savage et al., 2004; Kant et al., 2006; Guan et al., 2009; Rehman et al., 2015a).

Table 5. Root dry weight, root volume and grain yield of Okapi, Zarfam and Talayeh cultivars among different sowing dates under seed priming treatments over two growing seasons

	Control			HP			OP			
	Okapi	Zarfam	Talayeh	Okapi	Zarfam	Talayeh	Okapi	Zarfam	Talayeh	Mean
RDW (g $plant^{-1}$)										
2014–2015										
5-Sep	0.19 r	0.4 p	0.17 r	1.56 g	1.67 e	2.00 c	2.12 b	1.46 g	1.41 h	1.22 B
15-Sep	0.32 q	0.16 r	0.16 r	1.19 j	1.34 i	1.27 i	1.51 g	0.77 l	0.85 k	0.84 C
25-Sep	0.34 q	0.06 s	0.1 s	0.13 s	0.83 l	0.33 q	0.72 m	0.21 r	0.56 n	0.36 E
5-Oct	0.08 s	0.04 s	0.09 s	0.13 s	0. 58 n	0.18 r	0.56 n	0.11 s	0.12 s	0.21 F
15-Oct	0.06 s	0.02 s	0.02 s	0.02 s	0.03 s	0.03 s	0.02 s	0.02 s	0.03 s	0.028 G
2015–2016										
5-Sep	0.28 q	0.69 m	0.2 r	1.57 f	1.73 e	2.17 a	2.15 b	1.62 f	1.47 g	1.32 A
15-Sep	0.34 q	0.2 r	0.23 r	1.16 j	1.45 h	1.45 h	1.75 d	0.82 l	0.88 k	0.92 C
25-Sep	0.45 o	0.15 s	0.2 r	0.26 q	0.9 k	0.47 o	0.84 l	0.3 q	0.69 m	0.47 D
5-Oct	0.13 s	0.18 r	0.16 r	0.22 r	0.75 m	0.23 r	0.67 m	0.16 r	0.14 s	0.29 EF
15-Oct	0.16 r	0.04 s	0.07 s	0.07 s	0.07 s	0.06 s	0.05 s	0.06 s	0.04 s	0.07 G
Mean	0.23 E	0.19 E	0.14 E	0.63 D	0.93 B	0.82 C	1.04 A	0.55 D	0.62 D	
$LSD_{0.05}$ = 0.09										
RV (cm^3 $plant^{-1}$)										
2014–2015										
5-Sep	3.91 l	2.8 m	1.24 op	10.78 e	10.48 f	9.83 f	14.67 b	10.01 f	10.7 e	8.26 B
15-Sep	2.24 n	1.48 no	1.85 n	7.56 h	4.73 k	7.77 h	10.42 f	5.35 k	8.92 g	5.59 D
25-Sep	2.16 n	0.27 pq	0.72 op	2.95 m	1.46 no	1.92 n	3.27 m	1.7 n	5.89 j	2.26 F
5-Oct	0.56 pq	0.2 pq	0.33 pq	0.89 op	0.49 pq	0.75 op	0.92 op	0.64 pq	0.85 op	0.62 GH
15-Oct	0.06 q	0.03 q	0.04 q	0.11 q	0.08 q	0.09 q	0.21 pq	0.1 q	0.1 q	0.09 H

2015–2016										
5-Sep	5.04 k	3.15 m	2.67 m	11.82 d	11.23 e	11.03 e	16.15 a	12.09 d	13.4 c	9.62 A
15-Sep	3.07 m	1.95 n	2.34 n	8.71 g	5.56 jk	8.04 h	12.33 d	6.67 i	9.77 f	6.49 C
25-Sep	2.66 m	1.09 op	1.95 n	4.26 l	1.8 n	3.4 m	6.00 j	3.24 m	4.29 l	3.19 E
5-Oct	1.17 op	0.45 pq	0.97 op	2.09 n	0.81 op	1.4 op	2.51 n	0.99 op	1.75 n	1.34 G
15-Oct	0.28 pq	0.13 q	0.13 q	0.64 op	0.28 pq	0.36 pq	0.89 op	0.38 pq	0.47 pq	0.39 H
Mean	2.11 E	1.55 EF	1.22 F	4.98 BC	3.69 D	4.46 CD	6.74 A	4.11 D	5.61 B	
$LSD_{0.05}$ = 0.36										
GY (kg ha^{-1})										
2014–2015										
5-Sep	2,841 j	2,266 o	2,539 m	3,106 g	2,773 j	3,068 g	3,576 c	2,924 i	3,378 e	2,941.22 C
15-Sep	2,468 m	2,030 r	2,425 n	2,788 j	2,376 n	2,677 k	3,044 h	2,425 n	2,954 h	2,576.33 D
25-Sep	1,963 r	1,797 t	1,944 s	2,255 o	2,156 p	2,257 o	2,520 m	2,276 o	2,397 n	2,173.89 F
5-Oct	1,714 u	1,395 x	1,643 v	2,070 q	1,725 u	1,991 r	2,249 p	1,840 t	2,126 q	1,861.44 H
15-Oct	1,395 x	1,215 z	1,384 x	1,725 u	1,530 w	1,711 u	1,840 t	1,703 u	1,886 s	1,598.78 I
2015–2016										
5-Sep	3,063 g	2,453 m	2,766 j	3,497 d	3,152 g	3,345 f	3,851 a	3,466 d	3,766 b	3,262.11 A
15-Sep	2,476 m	2,041 r	2,155 p	3,110 g	2,540 m	2,870 i	3,490 d	3,049 h	3,389 e	3,124.44 B
25-Sep	2,064 q	1,683 u	1,814 t	2,672 k	2,406 n	2,525 m	3,023 h	2,785 j	2,874 i	2,427.33 E
5-Oct	1,763 t	1,437 x	1,543 w	2,361 n	2,090 q	2,164 p	2,854 i	2,515 m	2,663 k	2,154.44 F
15-Oct	1,576 v	1,330 y	1,445 x	2,140 q	1,916 s	2,036 r	2,582 l	2,253 p	2,440 n	1,968.67 G
Mean	2,132.3 F	1,764.7 H	1,965.8 G	2,572.4 C	2,266.4 E	2,464.4 D	2,902.9 A	2,823.6 AB	2,787.3 B	
$LSD_{0.05}$ = 100.1										

RDW = root dry weight; RV = root volume; GY = grain yield; HP = hydropriming; OP = osmopriming.

Micronutrients, such as Zn is important co-factors of various enzymes involved in the detoxification of AOS, such as superoxide dismutases (SODs), (Cakmak & Marschner, 1988a; Cakmak & Marschner, 1988b; Cakmak, 2000). Zinc has functions in direct membrane stabilization, in biosynthesis of auxins (Salami & Kenefick, 1970) involved in plant growth regulation and in protein synthesis in general. Therefore, limited supply of these micronutrients under conditions of low root zone temperature (Engels, 1994) may increase oxidative damage of root cells and induce disturbances in plant growth, which may be alleviated by supplementation via micronutrient seed priming. This result indicated that hydropriming and osmopriming compared with non-primed improved the root system in canola (Tables 3–5). Increased emergence rate due to seed priming may be due to increased rate of cell division in the root tips of seedlings from primed seeds as reported in tomato (Farooq et al., 2005). Seed priming triggers the emergence metabolism (e.g. the activity of hydrolytic enzymes) (Bam et al., 2006; Farooq et al., 2006a), stimulates protein synthesis and structural repair (Bray et al., 1989) and helps early and uniform stand establishment (Kaur et al., 2005; Farooq et al., 2006b). Osmopriming with $ZnSO_4$ was more effective than hydropriming in improving the RL, RD, RSAD, RDW and RV (Tables 3–5). Improving root growth at seedling stage could be also important for a positive feedback with early establishment of the root system and thus for better acquisition of nutrients including soil Zn (Prom-u-thai et al., 2012). Ozturk et al. (2006) reported that priming with Zn improved emergence and seedling growth, possibly due to the involvement of Zn in the early stages of coleoptile and radicle development. Seed priming with Zn increased the seedling RWD due to uniform and early germination, which improved the seedling growth as affirmed by strong correlations of mean emergence time, seedling shoot and RL with RWD (Rehman et al., 2015c). Zinc priming significantly enhanced RL and RDW in seedling rice (Prom-u-thai et al. 2012). Farooq et al. (2012) reported that seed hydropriming and osmopriming with ascoibic acid (AsA) improved RL in wheat. Also Jalilian et al. (2014) reported that seed priming improved RL, RDW and RV in barley.

The results obtained from the present study indicate in both growth seasons that seed priming with water and $ZnSO_4$ compared with non-primed improved GY in canola cultivars. In seven trials, mean GY of wheat was significantly increased from 2.28 to 2.42 t ha^{-1} (6%) by priming with water alone and to 2.61 t ha^{-1}(14%) by priming with 0.3% Zn (Harris et al., 2008). Harris et al. (2008) showed that enhancing Zn seed content by priming seeds with solutions of $ZnSO_4$ was highly cost effective in increasing maize yield in North West Frontier Province (NWFP). Seed priming with $ZnSO_4$ and hydropriming were effective enough to improve the GY in late sown canola. Sowing on 15-Oct primed with water and $ZnSO_4$ solution, increased GY by 29 and 27% in the Okapi, 34 and 40% in Zarfam and 31 and 45% in Talayeh compared to control (Table 5). Probably the reasons of the increased GY during late sowing under priming, as has been seen were the increasing root morphological characteristics. There was a significant increase in GY with increasing root length and dry weight in all of canola cultivars (Fig. 2). Authors found that root length as well as root weight has positive association with grain yield in crops (Barraclough, 1984; Thangaraj et al., 1990; Leon & Schwang, 1992; Fageria, 2011; Fageria & Moreira, 2011; Koscielny & Gulden, 2012).

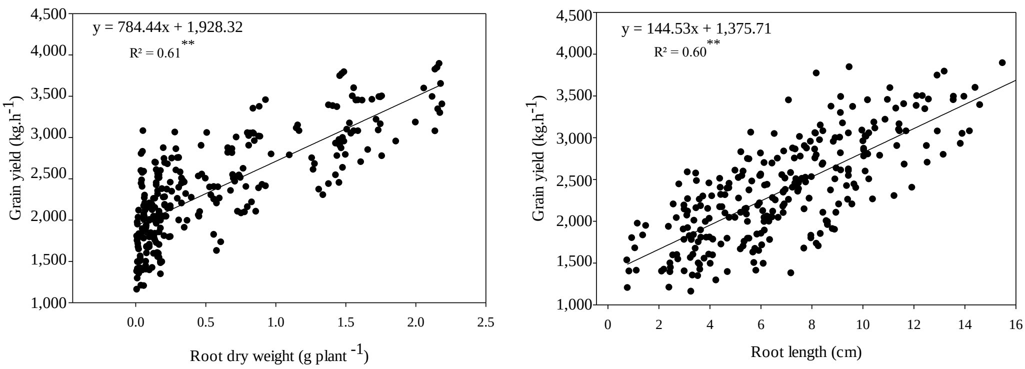

Figure 2. The relationship between root dry weight and root length with grain yield.

Conclusion

Canola seed osmopriming with zinc sulfate have an important impact in reducing the seedling emergence time and improving the root system characteristics. This treatment is important because the delay in sowing of canola can lead to a sharp reduction in seedling emergence percent and weakening of the root system and in case of delay in sowing of canola, zinc sulfate solution can be used as seed osmopriming agent to reduce above mentioned limitations. In this study also seed hydropriming treatment showed a good performance in second place after seed osmopriming by $ZnSO_4$ solution.

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Agronomy Research **15**(2), 515–520, 2017

Comparison between feed microscopy and chemical methods for determining of crude protein and crude fiber content of commercial mixed feeds

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Abstract. The use of chemical methods in the determination of protein content in feed raw materials is time consuming and costly. The aim of this study to determine the amount of crude protein and crude fiber in mixed feeds using methods feed microscopy and chemical methods. Cattle feed, cattle milk feed, lamb raising feed, and meat chick feed have been used to study mixed feeds. By determining the results to indicate that feeds microscopy method approximately how much closer to chemical methods. The percentages of raw materials of crude protein and crude fiber in mixed feeds were determined with stereo microscopy and compared with obtained results of chemical methods. As a result there is no statistically difference in crude protein between feed microscopy method and chemical method. Feed microscopy estimating method can be used instead of chemical methods for crude protein analysis. Also, there is an important difference ($P < 0.01$) between two methods for crude fiber analysis, so that it is determined that feed microscopy method cannot be used instead of chemical method. As a result, feed microscopy method can be suggested because crude protein content in raw materials of feed is more economical and shorter than chemical method.

Key words: Feed microscopy, chemical method, crude protein, crude fiber.

INTRODUCTION

Quality control of mixed feeds and raw materials is mostly done by chemical analysis methods. Although chemical analysis methods are extremely accurate, they take a long time and the process of deciding raw material purchase of feed factories is prolonged. Inspection and quality control in laboratories cause time loss and are seen as entrenched methods (Gines & Vohringer, 1998; Makowski, 1998).

Various studies are being carried out in order to prevent this loss or to reduce the most loss. One of the most important of these studies is the feed microscope (Hahn & Kruyskamp, 1997). Feed microscopy, the quality of mixed feed or feed ingredients can be decided more quickly (Klein & Marguard, 2005).

This decision is about whether it is more fraudulent, mold and pest status, physical properties such as foreign material presence. However, the ability to determine nutritional values such as crude protein and crude cellulose contained by feed microscopy can help us makes better decisions.

The feed to be subjected to the microscopic examination may consist of a single feed material or may be a mixed feed formed of two or more feed materials. Again, this subject is subject to forage crushing, crushing, grinding, baking etc. (Akyildiz, 1984; Pinotti et al., 2016), as well as in the case of preserving the natural structure.

However, in order to perform feed microscopic examination in pellet mixed feeds, the pellets must first be opened in water. During this wait, the colors of the raw materials change and they get the colors of each other. For this reason it is extremely difficult to work with feed microscopy in pellet feeds.

In order to gain experience in microscopic analysis, a programmed study and continuous practice are necessary. Getting information about the ingredients and qualities of raw materials can be done in 5–10 minutes by microscopy even though it takes hours by chemical analysis. Feed microscopy is an important and early part of an integrated quality control program developed for feed production (Khajarern & Khajarern, 2008).

In this study, the feasibility of crude protein and crude cellulose ratios in feeds was investigated more rapidly by feed microscopy instead of chemical methods and the results obtained were evaluated statistically.

MATERIALS AND METHODS

The material of the study is composed of different mixed feeds. Cattle feed, cattle milk feed, lamb raising feed, and meat chick feed have been used to study mixed feeds that can vary in the content of various animals. Powder mixed feeds was provided in 5 kg packages from the Malkara Birlik Feed Plant. Analyzes of crude protein, raw cellulose and feed microscopy of mixed feeds were carried out in the Feed Analysis Laboratory of Tekirdağ Food Control Laboratory Directorate. The 500 g packages for six samples were formed from each of the 5 kg mixed feeds and a total of 24 samples were obtained. These samples were numbered 1 to 24 and numbered, which one was recorded at one time, the analyzes were finished and the evaluation stage was not looked up. For analysis of crude protein and crude cellulose, each sample of 4 samples was grinded at about 50 g to prepare an analytical sample. For the microscopic analysis, about 50 g was taken from the sieves with 1 mm and 0.5 mm mesh and separated into 3 fractions and placed in petri dishes and made ready to be examined in stereo microscope.

Incubation method (AOAC 2003) and Leco Nitrogen-Protein device were used in crude protein analysis. This method is applicable to mixed feed and mixed feed raw materials containing 0.2–20% nitrogen (N). The principle is to measure N high thermal conductivity (850–950 °C) with pure oxygen (99.9%), for example, with the help of thermal conductivity (thermal conductivity) resulting from the burning end result and multiply by the appropriate protein factor to be expressed as% protein. When the device is ready to run the sample, empty calibrations are given for empty calibrations when the temperature and pressures are reached, and empty calibrations are performed by selecting 3 of them from the results. Thus, N from the gas cylinders is reset. Before working on the sample, 0.15 g is weighed from the EDTA, which is indicated by the N value certificate, to calibrate the nitrogen to perform the nitrogen calibration, and several values are selected from the results and N calibrations are made. After the calibrations are made, the grinded sample is weighed at about 0.25 g. The protein turnover factor is also entered into the device prior to sampling. This factor is 6.25 for mixed feeds. After the factor is entered, the device gives the results as% protein.

The quartz method was used for crude cellulose analysis (OJ (EU) Regulation 2009). In order to dissolve the organic substances outside the raw cellulose present in the method's principle feedstock; the feedstuff is boiled in successive concentrations with sulfuric acid and potassium hydroxide. Possible organic residues which remain after filtration are washed with dilute sulfuric acid, sodium hydroxide, water and acetone. The residue is dried, weighed and burned. The weight difference seen in the burning result gives the amount of crude cellulose.1.0 g of feed sample is weighed into a 250 ml beaker. 100 ml of 1.25% sulfuric acid solution is added and heated. After boiling, add 2–3 drops of anti-foaming agent (silicone, amyl alcohol etc.) and boil for 30 minutes. To keep the volume constant at the time of boiling, the beaker is covered with a cooling system (such as a 500-ml drippy round balloon provided with cold water circulation) or clock glass. After the end of the period, 10 ml of 28% potassium hydroxide solution is added and boiled for a further 30 min. On the other side, the glass filter (gosch sieve) is filled with quartz sand to a height of 8–10 mm. Before filtering, the quartz sand is thoroughly moistened with hot distilled water and sucked with water tromp or vacuum pump to form a tight quartz sand layer. The welded specimen is filtered through the hot glass filter. Crude cellulose particles may become clogged during filtration. To prevent this, the vacuum is cut and the top of the quartz sand layer is lightly mixed with a glass baguette. To the filtration, the residue on the quartz sand layer is washed twice with hot distilled water, 10 ml of 1% sulfuric acid solution, again with hot distilled water, then with 10 ml of 1% sodium hydroxide solution, again with hot distilled water and 10 ml of 1% Sulfuric acid solution and then washed twice with hot distilled water again. Finally, washed again with acetone, vacuum must be cut in order to ensure that the raw cellulose residue is well moistened during different washing operations. After washing and filtration, the glass filter residues are dried in an automatic drying cabinet at 130 °C for 1 hour. After cooling in the desiccator, weigh the sample (I). Weighing II is obtained by weighing in a desiccator at a temperature of 550–600 °C for 30 minutes. The research was carried out with 2 methods and 4 randomly selected randomized Parsell Experiment Method and variance analysis was made with the SPSS statistical program and the significances were checked by Duncan test (Soysal, 2000).

RESULTS

Samples of 5 kg of powdered cattle feed, cattle milk feed, lamb raising feed and broiler chick feeds of 500 g for six sampled were obtained from the Malkara Birlik Feed Factory in Malkara district of Tekirdağ and these 24 samples were raw Protein and crude cellulose analyzes were performed with feed microscopy and chemical methods. The results obtained are summarized in Table 1. The results of the crude protein and crude fiber analyzes, which were made by two methods according to the randomized plot design, were evaluated statistically. There is no difference between the results of crude protein analysis made with feed microscopy and the results of protein analysis made with chemical method and feed microscopy can be used instead of chemical method in crude protein analysis. According to the average of the analysis results made with the two methods, the correlations $r = 0.982$ and $r^2 = 0.964$ were found. In these figures, the prediction method with feed microscopy for crude protein analysis supports the usability of chemical methods. According to Duncan test results, raw protein ratios of mixed feeds are different from each other. Thus, the availability of feed microscopy has been proven statistically in mixed feeds with different protein ratios and therefore different rations. In terms of raw cellulose, cattle fattening feed and cattle milk feed are similar, but other feeds are not similar. The similarity between cattle feed and cattle milk diets made it difficult to estimate the proportions of raw materials correctly.

Table 1. Crude protein and fiber analysis results of mixed feeds

METOT	Mixed (Powder) Feeds	Analyses	Recurrence (%)					
			1	2	3	4	5	6
Feed microscopy	Feed (Fattening bull)	Crude protein	16.44	16.14	15.71	15.76	16.49	15.98
		Crude fiber	10.13	10.47	10.21	9.93	11.03	10.61
	Feed (dairy cow)	Crude protein	17.99	18.23	18.46	18.25	18.94	18.60
		Crude fiber	9.35	9.58	9.35	9.04	9.19	9.74
	Feed (lamb)	Crude protein	17.46	17.23	17.97	17.11	16.40	16.39
		Crude fiber	8.62	8.11	8.84	8.65	8.20	9.01
	Feed (broiler)	Crude protein	23.69	23.33	22.90	22.82	22.98	23.82
		Crude fiber	6.94	6.83	6.29	6.61	6.79	6.90
Chemical methods	Feed (Fattening bull)	Crude protein	16.23	16.30	16.58	16.43	16.60	16.56
		Crude fiber	11.48	11.48	10.92	11.82	11.24	11.18
	Feed (dairy cow)	Crude protein	18.49	18.35	18.23	18.45	18.42	18.43
		Crude fiber	11.15	11.18	11.21	11.56	11.29	11.94
	Feed (lamb)	Crude protein	16.55	16.99	16.92	16.70	16.46	17.07
		Crude fiber	10.02	9.59	9.50	9.01	9.02	9.43
	Feed (broiler)	Crude protein	24.04	23.84	23.73	24.21	24.63	24.43
		Crude fiber	5.38	5.62	5.18	5.21	5.26	5.32

The results obtained by feed microscopy for crude fiber analysis differ from those found by chemical methods. In the t-test between the averages, it was found to be important at the level of $P < 0.05$ for crude fiber and this difference was confirmed. However, the correlations for the results of raw fiber analysis with two methods are $r = 0.931$ and $r^2 = 0.867$ (Table 2). This shows that there is a strong and linear relationship between the results obtained by the two methods for crude fiber analysis.

Table 2. Correlation results of feed microscopy and chemical methods

Analysis	Correlation coefficient (r)	Determination coefficient (r^2)
Crude protein	0.982**	0.964
Crude fiber	0.931**	0.867

Huss (1976) have found that very well-recognized and highly predictable multi-cell multiplier products in microscopic view, as well as coarse-grained or grossly lightweight components (rough bran, Barley products, sunflower seeds) will be overestimated, while some of the lesser-bodied materials (such as finely ground soy products) will generally be estimated below their value.

The difference between the two methods is significant in crude protein analysis, which is important in crude fiber analysis, can create a contradiction. However, if the ration contents are carefully examined, it will be seen that the crude fiber analysis results obtained by the feed microscopy in the rations where the soybean pulp is in excess are much higher than the chemical method and even in the crude protein analysis. The reason is that the soya is in two forms as whole soybean and soya bean casserole. However, in the feed microscope, these two forms cannot be distinguished from each other and are evaluated as soybean pulp. This results in illusion in estimation. The hit rate in his estimation is undoubtedly proportional to experience. The more the feed microcopies work with various rations, the more experience he will have. For this reason, it is necessary to practice continuously and create a good collection of raw materials.

CONCLUSION

It has been determined that the difference between the results of the crude protein analyzes made by the two methods is statistically insignificant, i.e., the results are similar to each other, and therefore the prediction method can be used instead of the chemical methods by feed microscopy in crude protein analysis. The method used for crude cellulose analysis was significant at $P < 0.01$. That is, the results obtained by feed microscopy for raw cellulose analysis differed from the results obtained by chemical method, and this difference was confirmed by the fact that the difference between the averages in the t test was significant compared to $P < 0.05$.The most important reason for not developing the feed microscope is the lack of trained staff.

Because a feed microscope grows only in a few years, the Ministry of Food, Agriculture and Livestock and the universities should produce joint projects; organize courses and seminars for the identification and development of the feed microscope. For the spread of the feed microscope, which is expected to take place in the coming years, the students should be provided with a practical undergraduate course in the universities so that students learn the mixed feed and feed raw materials under the microscope so that they can graduate with preliminary knowledge about feed microscopy.

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Agronomy Research **15**(2), 521–529, 2017

Biomass yield and chemical composition of *Phalaris arundinacea* L. using different rates of fermentation residue as fertiliser

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Abstract. Using biomass of various crops for bioenergy production is a common practice all over the world. Grasses, including reed canary grass (*Phalaris arundinacea* L.), as bioenergy crops have many advantages. Therefore it is important to look for the most effective technology to produce high biomass grass yields taking into consideration the quality parameters important for this purpose, and at the same time providing sustainable plant nutrient recycling schemes. The use of fermentation residue (FR) from biogas plants as fertiliser could be environmentally and economically cost-effective, as this by-product contain considerable amount of plant nutrients. However, there is little research on the efficiency of FR use for grassland. In our experiments we evaluated the effect of FR used at different rates (from N0 to N150 kg ha^{-1}) and different treatment techniques (once/ twice/ or three times per season) on the productivity of RCG under two-cut and single-cut harvest regime. The data of three ley years (2012–2015) show that annual dry matter yields ranged from: 3.93–11.44 t ha^{-1} in two-cut and 5.89–13.94 t ha^{-1} in single-cut regime. The highest dry matter yield was obtained using FR at: 60 kg ha^{-1} N using the entire amount in a single application at the beginning of the season; 120 and 150 kg ha^{-1} N split for three applications. The chemical composition of reed canary grass biomass was mostly influenced by harvest regime: late harvest at single-cut regime ensured more appropriate sward quality for bioenergy production with a higher carbon and lower ash, nitrogen, potassium and phosphorus content.

Key words: dry matter yield; fermentation residue, fertilisation, *Phalaris arundinacea* L.

INTRODUCTION

Perennial grasses may provide a renewable source of biomass for energy production. Energy produced from biomass plays an important role in the current EU strategy to deal with climate change and to meet increasing energy demands (Ericsson & Nilsson, 2006). Grass can produce significant amount of biomass, and methane produced from grass has a good energy balance (input – output energy). Moreover, grass cultivation does not involve significant habitat destruction, land use change, application of new farming practices or annual soil tillage (Smyth, B.M. et al., 2009; Bardule et al., 2013; Rancane et al., 2014a).

Biomass from grass is a renewable energy resource with significant potential; it is a feedstock for anaerobic digestion in order to generate biogas and biomethane or for combustion in adapted heating plants (Thumm et al., 2014; Rancane et al., 2015). In the regions of northern latitudes higher energy potential is achieved from the production of cool season (C3) perennial grasses, such as reed canary grass (*Phalaris arundinacea* L.) (Carlson, 1996; Heinsoo et al., 2011). This species produces high biomass yields in cool climates and wetlands (Wrobel et al., 2008; Rancane et al., 2016). In natural grass stands most commonly it occurs in the vicinity of water. Although it tolerates an abundance or shortfall of moisture, high yields are achieved in years with higher rainfall (Strasil, 2012).

Grassland management determines not only the yield but also the quality of the harvested biomass. Different uses of grassland biomass have different quality requirements. Fuel constituents beside C, H and O are undesirable since they are potential pollutants and may increase deposit formation, corrosion, and ash (Nussbaumer, 2003; Bakker & Elbersen, 2005). Nitrogen content is a critical factor, as this is responsible for NOx emissions and N losses from the ecosystem. Unlike other plant nutrients, N is not recycled to the soil by ash (Tonn et al., 2010). Generally, the nitrogen content in biomass increases with higher N fertiliser doses and early cutting (Thumm et al., 2014). High content of ash, nitrogen, sulphur, potassium and chlorine can lead to problems in the combustion process, such as corrosion or slagging, and to environmentally critical emissions (Lewandowski & Kircherer, 1997; Nussbaumer, 2003).

One of the key factors impacting quality of grass biomass as feedstock for combustion is harvesting time (Pociene & Kadziuliene, 2016). It could strongly affect biomass chemical composition, as it has a significant influence on concentration of ash and minerals (Hadders & Olsson, 1997). Late-harvested grass biomass has a higher lignin content and lower ash, K and Cl content (Bakker & Elbersen, 2005). Therefore, late-harvested, highly lignified and low-ash biomass is more suitable for combustion (Prochnow et al., 2009; Iqbal & Lewandowski, 2014).

Fermentation of biomass produces fermentation residue or digestate. Degradation of organic compounds during the fermentation process leads to an increased ammonium content and therefore a higher proportion of plant available nitrogen in the fermentation residue (Makadi et al., 2012; Möller & Müller, 2012). It could be an excellent organic fertiliser what may have a positive effect on crop yields and long-term soil fertility. Fermentation residue contains a relatively high percentage of readily available nutrients which can be directly applied in liquid form to plants both for basal and top-dressing (Mikled et al., 2002). The application of this by-product as a fertiliser for grasslands could be an effective way to utilize residues from biogas plants (Alburquerque et al., 2012). It contributes to the reduction of artificial fertiliser needs, thereby providing both economic and ecological importance (Rancane et al., 2015).

However, liquid fertilisers including fermentation residue that is not used efficiently for plant production could be a source of pollution for groundwater, surface waters and the atmosphere (Nyord et al., 2008). NH_3 emission is considered a risk to the environment (Schulze et al., 1989; Hutchings et al., 2001). Therefore despite the fact that fermentation residue contains many important plant nutrients, studies are needed on the recommended rates of use and treatment regime in order to prevent potential risks and ensure the highest possible efficiency.

The aim of this study was to evaluate the differences in dry matter yield and chemical composition of reed canary grass under two harvest regimes using different rates in different regimes of fermentation residue.

MATERIALS AND METHODS

The field experiment was conducted from 2012 to 2015 in the central part of Latvia at the LLU Institute of Agriculture in Skriveri (56°37' N, 25°07' E). Small plots (1 m^2) of reed canary grass (RCG) were established in the sod-podzolic sandy loam soil (Eutric Retisol – WRB 2015) with pH KCl 6.4 (LVS ISO 10390/NAC), organic carbon – 25.1 g kg^{-1} (LVS ISO 10694), plant available phosphorus (P_2O_5) 81.7 mg kg^{-1} (spectrophotometrically in 0.2 M HCl extract – LVS 398), plant available potassium (K_2O) 91.7 mg kg^{-1} (in extract of 1.0M CH3COONH4 using flame atomic-absorption spectrometer) and sulphur (S) 29.2 mg kg^{-1} (using ELTRA CS 530 element analyser).

RCG 15 kg ha^{-1} was sowed with a small seed drill on August 17, 2012. Before sowing, borders of each plot were delimited with plastic plates up to the depth of 20 cm. Different amounts of FR were evenly dispersed on soil surface and after mixed with the soil using hand tiller; in the following years FR was used on the surface.

The liquid fraction of separated FR from a biogas plant was applied, and dry matter content ranged from 4.4 to 5.4%, with an average organic matter content of 3.7%. Prior to treatments, the chemical composition of FR was determined using modified Kjeldahl method (reference method for determination of total N). The content of main plant nutrients ranged between 2.7 to 5.1 g L^{-1} N; 0.4 to 0.77 g L^{-1} P_2O_5; 3.3 to 3.7 g L^{-1} K_2O.

Seven fertiliser treatments were compared, with 1–3 FR application times per growing season. The following fertiliser rates were used: FR 0 kg N ha^{-1}; FR 30 kg N ha^{-1}; FR 60 kg N ha^{-1}; FR 60 (30 + 30) kg N ha^{-1}; FR 90 (30 + 30 + 30) kg N ha^{-1}; FR 120 (40 + 40 + 40) kg N ha^{-1}; FR 150 (50 + 50 + 50) kg N ha^{-1}. The experiment was established as a randomised block design with four replicates.

The meteorological conditions and distribution of rainfall during the experimental years were monitored, average annual precipitation amounts at the study site were: 698 mm or 102% from long-term average in 2013; 807 mm (118%) in 2014; and 549 mm (80%) in 2015. Artificial watering was not used.

RCG was harvested by manually cut using two harvest regimes: two-cut and single-cut regime. Cutting height was 3–4 cm from the ground level. Half of each plot (0.5 m^2) was mowed once or twice per season. The 1st cut was done at the full heading of RCG, and the 2nd cut occurred in September. The single cut occurred in late September or early October. For determination of sward structure the samples from each harvest were divided into tillers, leaves and panicles.

The chemical composition of RCG sward was analysed 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); total phosphorous – photometrically (LVS EN 14672); potassium – using atomic absorption spectroscopy (LVS ISO 11466).

Experimental data were evaluated using analysis of variance (ANOVA) ($P > 0.05$). The test of statistically significant differences (*LSD* 0.05) and the Fisher criterion (*F*-test) were used for the analyses of data obtained.

RESULTS AND DISCUSSION

Biomass productivity is the main parameter which determines the suitability of crop cultivation for energy production. The dry matter yield (DMY) of RCG varies considerably depending on cultivation condition (Heinsoo et al., 2011; Kołodziej et al., 2016). During the three years of this project, DMY of RCG ranged considerably depending on the rate of fertiliser, ley year and harvest regime.

The DMY in a two-cut regime ranged from: 7.07 to 11.44 in the 1st ley year, 3.93 to 8.99 in the 2nd ley year, and 3.98 to 7.68 in the 3rd ley year (Fig. 1). Using two-cut regime significantly higher DMY of RCG in all treatments were obtained in the 1st year of use. Although in the 3rd year of use were obtained lower dry matter yields, they did not differ significantly between 2nd and 3rd year.

Yield reduction in the 2nd and 3rd year of use was mostly influenced by partial disappearance of RCG plants from the sward due to various reasons, particularly with the two-cut regime. It had a negative impact on total DMY.

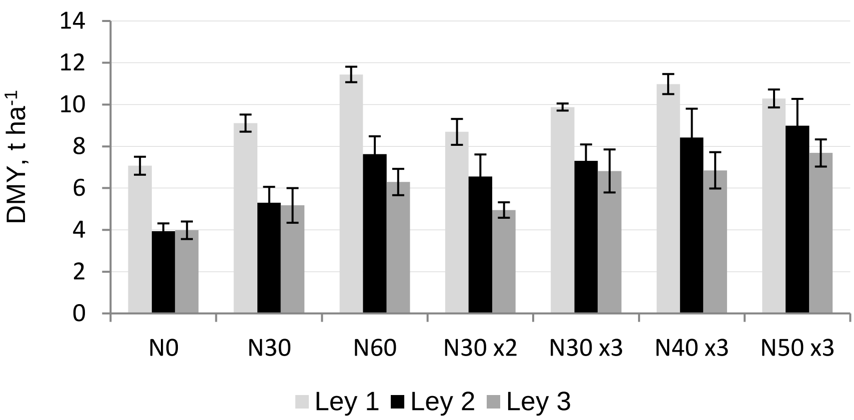

Figure 1. Total DMY of RCG in two-cut regime (error bars indicate standard error).

Using a two-cut regime, the proportion of DMY for 1st cut is usually over 60% of total yield. In our trials the following pattern was observed in the 1st and in the 3rd ley years. However, in the 2nd ley year ratio of the 1st and 2nd cut was different – the DMY of the 2nd cut was atypically slightly greater than 1st cut (Table 1). This may be the result of hard overwintering conditions with a long black frost period in previous winter and late spring as well which delayed RCG re-growth in spring, reducing 1st cut and hence the total DMY.

Table 1. The DMY of 1st and 2nd cut of RCG using two-cut regime in three ley years (2013–2015)

Variant	DMY of RCG – 1st cut			DMY of RCG – 2nd cut		
	Ley 1	Ley 2	Ley 3	Ley 1	Ley 2	Ley 3
N0	4.69 ± 0.38*	1.88 ± 0.14	2.54 ± 0.23	2.38 ± 0.16	2.05 ± 0.29	1.44 ± 0.23
N30	6.81 ± 0.23	2.89 ± 0.42	3.51 ± 0.43	2.3 ± 0.23	2.42 ± 0.47	1.67 ± 0.42
N60	8.37 ± 0.28	4.19 ± 0.24	4.44 ± 0.48	3.07 ± 0.32	3.42 ± 0.79	1.85 ± 0.17
N30 × 2	5.61 ± 0.32	3.52 ± 0.42	3.38 ± 0.22	3.08 ± 0.31	3.04 ± 0.88	1.57 ± 0.22
N30 × 3	6.76 ± 0.27	4.26 ± 0.38	4.78 ± 0.65	3.12 ± 0.26	3.06 ± 0.50	2.04 ± 0.44
N40 × 3	7.71 ± 0.29	4.89 ± 0.61	4.51 ± 0.43	3.27 ± 0.42	3.53 ± 0.81	2.34 ± 0.47
N50 × 3	7.15 ± 0.34	5.53 ± 0.57	5.2 ± 0.54	3.13 ± 0.32	3.46 ± 0.72	2.48 ± 0.28
$LSD_{0.05}$	*0.77*	*1.17*	*0.98*	*0.48*	*1.09*	*0.63*

*– standard error.

The DMY in a single-cut regime ranged from 5.82 to 10.69 in the 1st ley year, 6.48 to 13.94 in the 2nd ley year, and 5.89 to 12.06 in the 3rd ley year (Fig. 2). Although using single-cut regime there was a trend to be higher DMY in the 2nd year of use, the differences were not significant ($P > 0.05$).

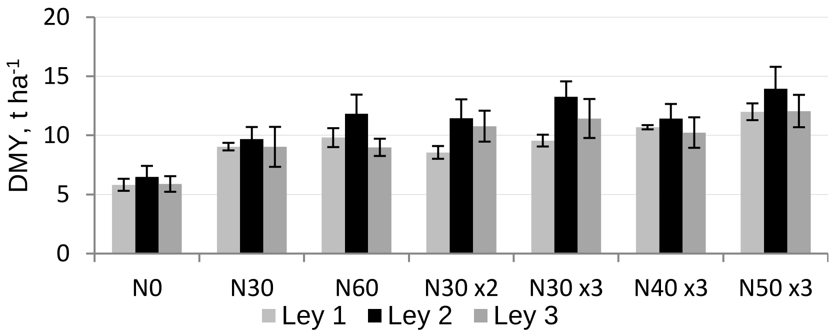

Figure 2. DMY of RCG in a single-cut regime (error bars indicate standard error).

Assessment of DMY among fertiliser treatments on average over three-year period shows that in general DMY significantly ($P < 0.05$) correlated with the rate of fertiliser: $r = 0.81$ for 1st cut; $r = 0.51$ for 2nd cut; $r = 0.75$ for total DMY using two-cut regime, and $r = 0.72$ for DMY using single-cut regime. However, the yield increase was not proportional to the level of fertiliser. Relatively good results in both harvest regimes were provided by the treatment of FR N 60 kg ha^{-1} using the entire amount in a single application at the beginning of the season.

DMY data collected over the period of three years led to the conclusion that higher effect was not achieved by split applications of fertiliser, but by the rate of fertiliser used immediately after growth initiated in the spring. Obviously the most intensive growth and, consequently, more efficient use of fertilisers take place at this time. In early spring soil moisture usually is higher, whereas the air temperatures lower, which limits volatile compounds emissions from the FR. It should be taken into account when choosing an application rates and treatment because ammonia (NH_3) volatilisation following the liquid ammoniacal fertilisers to agricultural land is a significant source of atmospheric NH_3, which not only poses a risk to the environment, but also results in a loss of plant available nitrogen (Nyord et al., 2008).

DMY was influenced inconsistently by harvest regime, it varied over the ley years. Almost no differences between mowing regimes were found in the 1st ley year. All in all the average DMY was nearly equal: 9.36 and 9.64 t ha^{-1} for two-cut and single-cut regimes, respectively. In the 2nd and 3rd ley years significantly higher DMY in all fertiliser treatments were harvested using a single-cut regime. This may be explained by the ability of RCG to remove plant nutrients from above-ground parts to the rhizomes in autumn (Wrobel et al., 2008), thus ensuring more rapid re-growth in spring and prolonging period of growth, which generally results in higher biomass production. Late harvesting is preferable for RCG, it is confirmed by our previous research (Rancane et al., 2014b; Rancane et al., 2015) and by data of other authors as well (Xiong et al., 2009; Cherney & Verma, 2013).

For determination of sward structure the biomass of each harvest was divided into culms, leaves and panicles. Results showed that in the 1st year, the highest proportion of culms was in the 1st cut (71.3–75.9%), whereas the lowest proportion of culms was in the 2nd cut (34.7–48.5%) (Fig. 3). Proportion of culms in the swards of late harvest using single-cut ranged from 58.7 to 66.4%. Proportion of leaves in swards was inversely proportional to the content of culms – the highest proportion of leaves was found in the 2nd cut (Fig. 4).

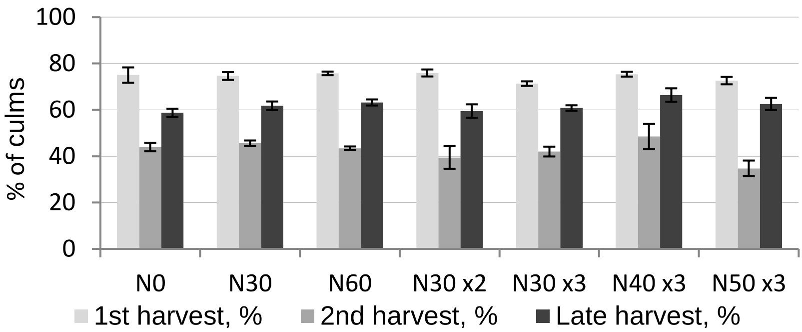

Figure 3. The proportion (%) of culms in swards of different harvests in the 1st ley year (error bars indicate standard error).

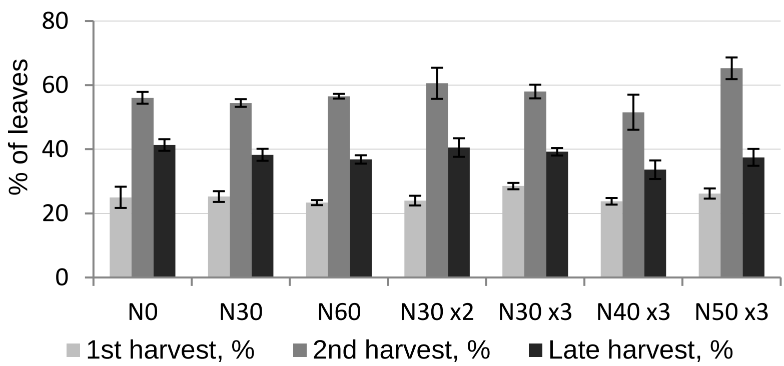

Figure 4. The proportion (%) of leaves in swards of different harvests in the 1st ley year (error bars indicate standard error).

Ash content of RCG ranged from 6.21 to 6.77 % on average (Table 2). There were not any substantial differences in ash content among fertiliser treatments. Fertiliser treatment did not significantly affect the content of carbon (C), nitrogen (N) and potassium (K) as well, parameters ranged between 469.7–480.0 g kg^{-1} for C, 13.4–15.2 g kg^{-1} for N, and 15.5–17.4 g kg^{-1} for K.

Table 2. The chemical content of RCG using different rates of FR and harvest regime

Factor	Ash content, %	C, g kg^{-1}	N, g kg^{-1}	K, g kg^{-1}	P, g kg^{-1}
Fertiliser (B)	*0.8/2.6**	*0.8/2.6*	*1.2/2.6*	*1.1/2.6*	*3.6/2.6*
N0	6.75	475.52	14.27	15.77	2.47
N30	6.21	480.04	15.11	16.79	2.27
N60	6.83	471.44	13.41	15.87	2.10
N30 × 2	6.77	475.78	13.98	17.40	2.29
N30 × 3	6.56	476.58	14.78	16.43	2.22
N40 × 3	6.53	474.99	15.18	16.95	2.26
N50 × 3	6.38	469.87	13.67	15.52	2.05
$LSD_{0.05}$	*0.73*	*11.04*	*1.89*	*1.99*	*0.21*
Harvest regime (A)	*22.4/3.5*	*8.3/3.5*	*108.6/3.5*	*448.4/3.5*	*143.8/3.5*
1st cut	6.63	477.92	16.58	26.21	2.42
2nd cut	7.31	466.84	17.15	15.32	2.69
Single-cut	5.79	479.90	9.31	7.64	1.60
$LSD_{0.05}$	*0.47*	*7.23*	*1.24*	*1.30*	*0.14*

*Fisher criterion (*F/F0.05*).

Significant differences ($P < 0.05$) between fertilised and non-fertilised treatments were found in terms of phosphorus (P) content. The highest P (2.47 g kg^{-1}) was in non-fertilised swards, while in fertilised swards P were significantly lower, ranging from 2.05 to 2.29 g kg^{-1}. This may be a positive outcome, as higher P content does not provide higher energy outcome and there is not necessity to remove P from field.

Chemical composition of swards was significantly influenced by harvest regime: there were found significant differences in terms of all parameters. Perennial grasses harvested at booting stage or full maturity accumulate different amounts of biomass with different composition (Kandel et al., 2013; Kołodziej et al., 2016). The highest ash and P content was found in swards of the 2nd cut. Significantly lower both parameters were in swards of the single-cut. Previous studies confirm that using later harvest times significantly reduces N, P, K content in biomass of RCG (Strasil, 2012; Rancane et al., 2015). This is favourable for the combustion process itself and also with respect to the environment.

Carbon (C) content was significantly higher in the swards of the single-cut and in the 1st cut as well, because the swards of both cuts had a higher proportion of culms. Swards with a high culm content consists of highly lignified biomass. High content of carbon in lignin leads to higher heating value (Wrobel et al., 2008; Prochnow et al., 2009).

Nitrogen (9.31 g kg^{-1}) and K (7.64 g kg^{-1}) content was significantly lower in the single-cut. It can be evaluated as a positive trend if biomass is intended to be used for bioenergy production, especially for combustion. Extensive grassland management systems with one late cut and low fertilisation are preferable when using grass as a solid biofuel due to higher content of lignin and lower content of ash and potassium in late harvested biomass (Thumm et al., 2014).

CONCLUSIONS

Fermentation residue used as fertiliser ensures a significant (*P < 0.05*) increase of biomass production of RCG. The DMY significantly (*P < 0.05*) correlated with the rate of fertiliser – higher rates ensured higher DMY. The best results in both harvest regimes were provided by following rates of FR: N 60 kg ha^{-1} using the entire amount in a single application at the beginning of the season; and N 120 and 150 kg ha^{-1} split for three applications.

FR treatment did not significantly (*P > 0.05*) affect the content of ash, carbon (C), nitrogen (N) and potassium (K). The chemical composition of RCG swards was mostly influenced by the harvest regime: late harvest using single-cut ensured more appropriate quality for combustion with higher C content and reduced amount of ash, N, K and P.

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Sand losses out the pens in barn with free-stall housing system

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Abstract. Proper sand management can be a critical aspect in the selection and successful use of sand as a bedding material for dairy cows. In many regions and countries, use of sand as a bedding material is considered as a useful alternative solution in dairy farms, where non-organic matter can serve as an equivalent of straw and other organic materials, e.g. sawdust. Assessment of sand management in the barn with dairy cows involves numerous problems, such as sand consumption, frequency of filling in the sand, quality of sand, as well as cows' response to comfort conditions created by lying stalls covered with sand. This paper presents results of some investigations concerning sand losses in the barn with dairy cows. In practice, sand consumption is a result of natural occurrences, when cows leave lying stalls. Moreover, part of sand, together with faeces, is taken out of the stall when the lying area is handled by persons responsible for cleanliness and hygiene in the stall. This paper indicates, based on the authors' own observations and investigations, that an improper construction of lying stalls can result in the increased losses of the sand in the barn, which translates into financial losses. In addition, a number of methods of measurement, together with the details of the structure of sand losses in the barn with a free-stall housing system, were presented. The discussion develops the issue of effective use of sand as a bedding material in the barn with dairy cows, including the need to use technical equipment in order to keep the barn floors clean and ensure the cows' comfort.

Key words: bedding, cow, dairy farm, free-stall, keeping system, management, sand.

INTRODUCTION

Barn is the place where dairy cows, as well as other groups of cattle, should have the possibility to be kept in sustainable production environment (von Keyserlingk et al., 2009). The appropriate environment is essential for dairy cattle health and welfare (Vasseur et al., 2015).

The generally considered environment in dairy production, especially in the barn area, comprises many detailed factors responsible for the assessment of dairy effectiveness. The dairy effectiveness is created, first of all, in the cow feeding area (Phillips & Rind, 2001) and associated with the results obtained in the milking area (Lawrence et al., 2014). On the other hand, the dairy production environment and effectiveness can be determined by cow comfort created not only by microclimatic conditions (Papez & Kic, 2015) but also cow lying comfort because adequate rest can be positively associated with productivity, health and welfare of dairy cattle (Solano et al., 2016).

The cow lying comfort involves the problem of the lying area and its assessment in the barn. Based on results of some investigations, Nordlund & Cook (2003) suggested that the lying surface was a particularly important component of the free-stall design. This assumption was supported by numerous experiments aimed at proposing some new and improved bedding materials (Tucker & Weary, 2004) and showing the effect of bedding quality (Fregonesi et al., 2007), the amount of bedding (Drissler et al., 2005) and bedding management (Wagner-Storch et al., 2003) on the time spent by cows in the lying position.

Certain investigations into the lying area for dairy cows emphasize the significance of the management practices associated with bedding types (Rowbotham & Ruegg, 2015). Proper bedding management shows long-term effects with regard to lying down in well-bedded stalls, compared with poorly bedded places (Tucker et al., 2003).

There are many bedding materials, more or less popular in barns, for dairy cows and heifers. As a bedding material of the lying area for dairy cows, sand is a valuable alternative to straw, sawdust and other organic materials. For the purpose of better identification of the sand used in barns, many investigations were developed in order to find the relationship between sand and cows, management practices and other dairy production indices. Management activities involving the amount of sand used on the stall surface can influence the cow's response; the lower the level of the sand in the lying area, the less time cows are likely to spend lying there (Drissler et al., 2005).

The abovementioned changes in the sand level are attributable to the decrease in the amount of sand covering lying stalls. Natural consumption of sand is caused by some activities of cows themselves and management practices in the lying area, i.e. cleaning (removing faeces) by persons responsible for bedding hygiene.

The problem of sand consumption in the barn may be a starting point for the identification of more details related to the effective management of sand as a bedding material. Sand losses are one of such details. The purpose of the paper was to investigate sand losses in the barn with a free-stall housing system.

The issue of sand losses posed some questions concerning quantity and quality aspects of such losses, as well as their causes. Generally, losses in the dairy production system, similarly to other production systems in agriculture, constitute an element of the sustainable production environment. Such losses of bedding material in the barn are associated with the assessment of dairy production effectiveness. Therefore, in order to discuss how to reduce sand losses, and thus, increase effectiveness of the bedding material management in the barn with cows kept in a free-stall housing system, it is reasonable to present the result of own investigation.

MATERIALS AND METHODS

Measurements of sand losses in the barn with dairy cows were conducted in a free-stall barn located at the University of British Columbia's Dairy Education and Research Centre in Agassiz (British Columbia, Canada) in the period between December 2015 and March 2016. The investigated, naturally ventilated (with curtained sidewalls) wooden frame barn consisted of 120 free stalls divided into smaller units, i.e. 10 pens with 12 stalls each. The lying stalls, in each individual pen, were arranged in 2 rows (with 6 stalls each), one row facing the feeding alley and the other facing the connecting alley (Fig. 1). The pens were equipped with stalls divided by individual partitions.

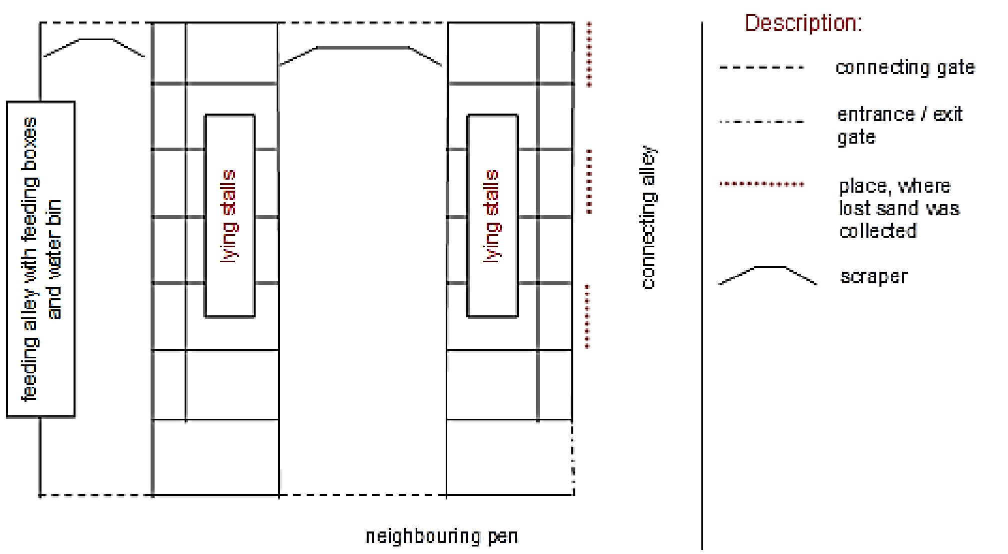

Figure 1. Diagram of (part of) the barn where measurements of sand losses were conducted.

In the investigated barn, the laying stalls were filled with sand. In order to spread the sand in the stalls, a tractor with an attached machine (spreader) had to move along the scraper alley (Fig. 1). During sand spreading, the scrapers were stopped at such a position as to enable the tractor to move along the scraper alleys without any hindrance. At the time of refilling the sand in the stalls, the animals were separated in each pen using chains to close the respective part of the pen.

Mechanical sand spreading in the stalls and animal activity were analyzed to investigate sand losses. Sand losses were measured only along one of the rows, i.e. the right-side row (Fig. 1). The front part of the lying stalls, along the right-side row, was open, without any additional wall dividing the stalls or connecting alley (opposite, the front part of the left-side row, was separated by a cement wall). During sand spreading in the stalls some sand was thrown over the stalls – onto the connecting alley. The connecting alley (between the row with the stalls and the curtained sidewall) along the pens was the place where the lost sand was collected and then measured.

Aim of the mechanical sand spreading in barn is to put all sand on the lying stalls. So sand spread out the stalls can be considered as a lost sand. Such sand is possible to put back to stalls but such activity consumes labour, time and energy. Moreover, use of tractor for such activity in the barn (Fig. 2) is the source of noise and exhaust gases, so the microclimatic conditions in the barn don't meet the animal needs. Moreover, handling of sand in the connecting alley can be additionally source of dust.

Figure 2. Lost sand in the connecting alley – part of the investigated barn.

In total, five pens bordered on the connecting alley in the barn concerned but for the purpose of sand loss measurements only a portion of the connecting alley, bordering on two of the pens, was considered. At the time of the experiment, a group of heifers were kept in these pens, including 11 or 12 animals per pen.

The sand from the connecting alley was not collected along the front part of the whole pen but only along the front part of three stalls per pen. Every other stall (odd one) from one pen and every other stall (even one) from the other pen were chosen to measure the amount of lost sand at their front part, along the connecting alley.

The sand from the connecting alley was collected with a shovel and a broom. It was first collected into a box, and then weighed. The net weight of the sand was determined as the difference between the gross weight (box with sand) and the tare (box weight). Measurement accuracy was ten grams. Moisture of the collected sand was not measured. Generally, in the farm concerned, sand was stored indoors, without exposure to rain, snow or other sources of water.

The width of the front part of the stalls taken into account for the purpose of the experiment, was also measured to an accuracy of one centimetre. The curb between the stall and the connecting alley was adequately marked in order to have the same reference points when the sand was collected.

The lost sand from the connecting alley was collected once a week (on the same day each week). At the time of the experiment, some additional data were collected, i.e. person responsible for sand spreading, date of sand spreading on the lying stalls, as well as date when the connecting alley was cleaned by the barn personnel. Four persons (employees of the farm) were involved in sand spreading and cleaning the connecting alley.

A printed version of the relevant sheet was prepared to collect data obtained from the barn measurements. In the next stage, the data were transferred into an Excel file for further analyses.

The recording of additional data facilitated interpretation of results of the investigations and the process of searching for the relationship between variables in the analysis.

Statistical analysis of all collected data was performed using the Statistica v.12 software, and the main factors were analyzed in terms of variance (ANOVA). The statistical model of the mass of the lost sand incorporated fixed effects of the stall, sand management and the operator. The level of significance (materiality) was established at $\alpha = 0.05$.

RESULTS AND DISCUSSION

The measurements were carried out in order to determine the scale of the problem of sand losses in the barn with a free-stall housing system. The scale of the problem can be determined by the amount of lost sand and the differences in sand losses attributable to different management practices in the barn. The management practices are possibly the effect of individual skills of persons responsible for sand distribution and levelling, frequency and accuracy of handling of the bedding surface in the lying area, etc.

The amount of the lost sand, collected from the connecting alley, ranged between 7.36 and 38.73 kg per distance limited by the width of one stall. Considering all collected data, the mean value ± SD was determined at 22.31 ± 11.07 kg of sand per distance limited by the width of one stall. Due to the fact that the measurements were performed once a week, the amount of the collected lost sand should be considered in relation to one week.

The following parameters were included in the analysis of variance: stall, new sand (sand management) and operator. The dependent variable in the analysis was the mass of lost sand (from the connecting alley).

Table 1 presents results of analysis of variance for the mass of the lost sand, which involved fixed effects of the stall, sand management and the operator.

Table 1. Analysis of variance for the mass of the lost sand including selected variables in the experiment

Effect	SS	df	MS	F	p
Stall	1,047.93	5	209.59	1.8571	0.116612
New sand	465.94	1	465.94	4.1287	0.046915
Operator	3,588.81	3	1,196.27	10.6001	0.000013

The results of the analysis of variance show a significant difference of mean values ($p < 0.05$) for two factors (variables), i.e. new sand (sand management) and operator. However, there was no significant difference of the mean value for the stalls considered in the experiment.

Figs 3 and 4 present the distribution of the two variables which showed significant differences of mean values in the analysis of variance.

The results of the investigations confirmed some of the previous assumptions that management practices and free-stall construction may affect the loss of the sand used as a bedding material for dairy cows (Gaworski & Rocha, 2015).

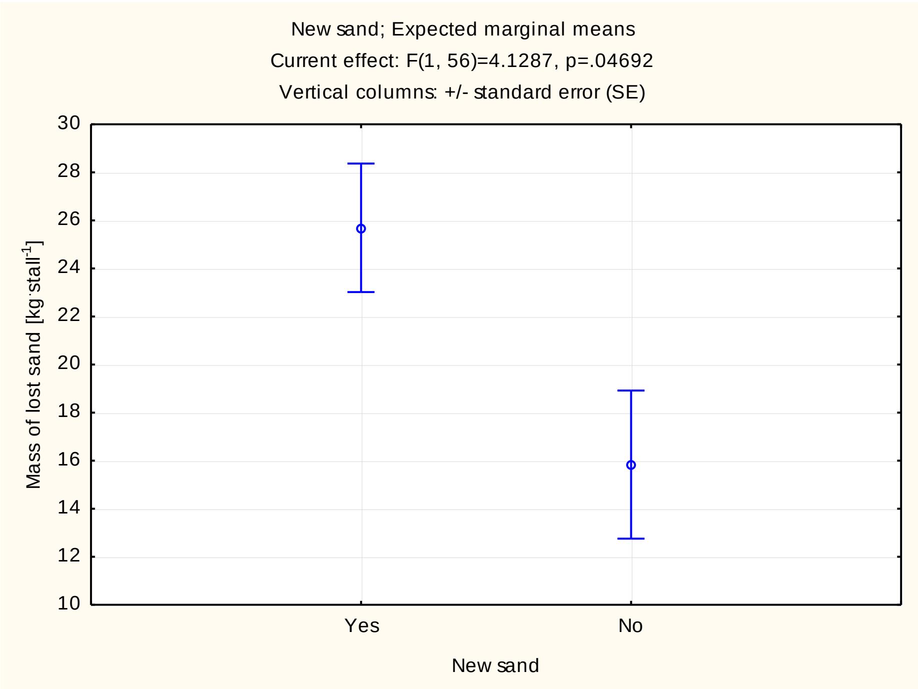

Figure 3. Distribution of marginal means ± standard error concerning mass of lost sand for the investigated variable: new sand (sand management).

The management practices include, first of all, the people responsible for keeping proper conditions in the lying area for dairy cows and other groups of cattle. It seems that the indication of individual skills of the employees who spread the sand on the lying stalls for animal herds is of essence. The results of the experiment, expressed by the mass of the lost sand in the connecting alley, show significant differences between individual persons working with the sand. The maximum difference between the amount of sand losses, considered individually for each person responsible for spreading the bedding material within the period of the experiment, was 23.29 kg (Fig. 4).

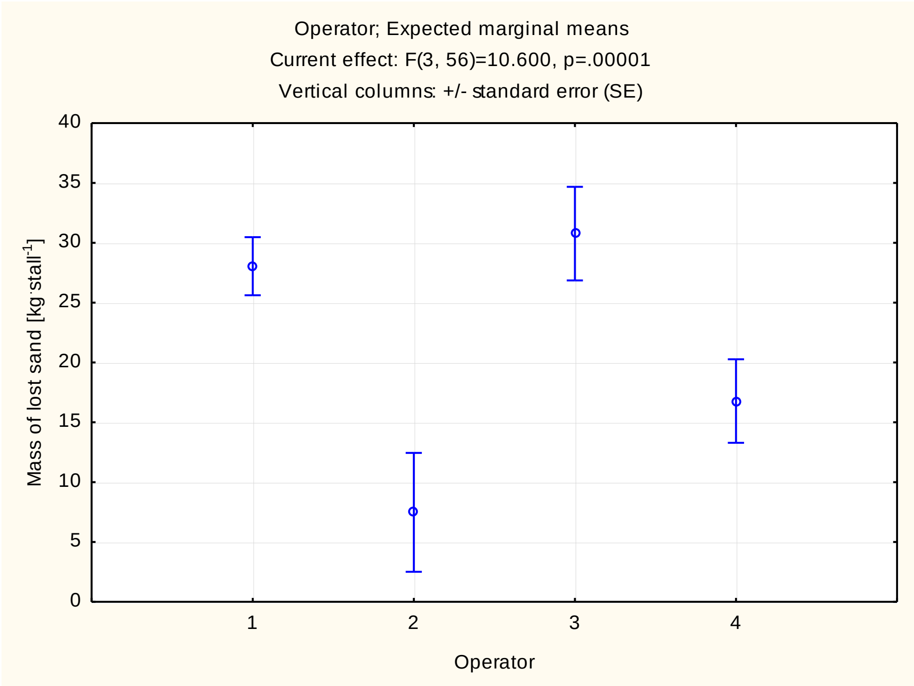

Figure 4. Distribution of marginal means ± standard error concerning mass of lost sand for the investigated variable: operator.

Individual skills and the approach of the employees responsible for sand management in the lying area for cows were discussed by Gaworski & Rocha (2016). According to their observations, persons responsible for taking the cows to the milking parlour and levelling the sand bedding seem to show a tendency to level mainly the rear part of the stalls. In order to achieve the effect of levelling, sand can be taken with a rake from the middle part of the stall to the rear zone of the lying stall, including reduced levelling of front part of the stall.

The significant difference in mean values for the new sand (Table 1, Fig. 3) shows the effect of sand management on the amount of sand losses collected in the connecting alley. The name 'new sand' was interpreted for two investigated options, i.e. sand collected directly after sand spreading (New sand – Yes, Fig. 3) and sand collected a week after the sand spreading (New sand – No, Fig. 3), when no new sand was spread. The second option confirmed the expected results of the investigations, i.e. smaller amount of lost sand collected from the connecting alley.

The problem of the investigated sand losses constitutes an alternative aspect when compared with the general problem of sand consumption in the lying area, especially for dairy cows. Detailed studies were developed to show not only how much sand was necessary to ensure the cows' comfort conditions in the lying stalls but also how much sand was used as a result of cow activities in the lying area. Stowell & Inglis (2000) recommended that at least 4 inches of 'workable' sand should be present in the stalls at all times. According to Stowell & Bickert (1995), sand usage rates can range from less than 1 to more than 10 cubic yards per stall per year, with an average of 4.6 cubic yards/stall/year. Drissler et al. (2005) indicate that sand may be removed by the cows digging or by dragging the sand out when they exit the stalls, but further research is required to understand how the sand leaves the stall. Typically, cows kick 20 to 25 kg of sand per day out of each stall when the level of sand is above the curb, and 10 to 15 kg when it is below the curb (Rodenburg, 2000). A study of 57 Midwest dairy farms showed an average sand use of 24 kg (53 lb) per stall per day (House, 2010). Buli et al. (2010) suggested a possible distinction between the American and European systems of managing sand, i.e. sand usage in the American system is approx. 20–25 kg per stall per day, while in European systems, it is 5–8 kg per stall per day.

The discussions relating to the sand in the barn focus on the bedding material consumed in the lying area, including the special role of animals in the amount of natural sand use. However, taking into account other places in the barn, where sand consumption can be identified, seems relevant. The results of the investigations showed that improper construction of the lying stalls (too low front wall) can lead to increased amount of lost sand in the barn, which translates into financial losses, as well as the need for higher amount of labour in the barn.

In comparison with some organic materials, i.e. sawdust and straw, the operational cost of sand for bedding is lower, both in terms of obtaining the product and the handling of the beds. Though sand provides more comfort and hygiene, farmers were more satisfied with manure handling and bedding costs when used mattresses (Bewley et al., 2001). The own observations during the experiment showed that in spite of winter season and low temperatures out the door (temperatures lower than -5 degrees of Celsius) the sand bedding was high quality, especially when kept dry on the stalls.

Considering the amount of lost sand and the average price of sand, it is possible to calculate financial losses. Such losses may be understood as financial expense in the absence of the relevant technology to recycle and reuse the sand collected in the barn. In order to improve the bedding material management, a system of sand manure separation, into sand, solid and liquid faeces, could be used. This technology can reduce both environmental impact and financial losses. Such technology was used in the investigated barn, so sand (lost sand) transported by manure scraper could be separated and returned again to lying stalls. Sand losses in the transportation process and cleaning of the bedding removed from the stalls weren't included in the carried out investigation. It is inspiration to investigate such elements as part of the independent research.

In order to maintain clean cattle, clean housing is required (Ruud et al., 2010). The clean housing, of course, involves pens with animals, but perhaps considering the issue of cleanness throughout the barn would be more reasonable. With fewer amounts of the lost sand in the connecting alley, dairy production could be more balanced and systematic.

CONCLUSIONS

Sand management, used as a bedding material in the barn, can be inspiration for detailed investigations into solutions to identify and reduce sand losses, and thus, make dairy production more effective.

Sand losses in the barn, especially in some of the places connecting the pens to other parts of the barn, e.g. parlour, may be caused by some constructional features of the lying stalls neighbouring on the connecting alley. The investigations showed that some constructional features, such as absence of a wall between the front part of the lying stalls and the connecting alley, can be decisive when it comes to losses of sand and such losses also depend on the persons responsible for sand management and the time when the measurements of the lost sand were taken (directly after sand spreading or later).

Sand losses in places other than a pen with dairy cattle can be taken into account in the structure of sand consumption in the barn with a free-stall housing system in order to determine, in a more precise manner, the amount of sand used in dairy production.

ACKNOWLEDGEMENTS. The authors would like to thank the University of British Columbia's Dairy Education and Research Centre in Agassiz (British Columbia, Canada) for the possibility to carry out the investigations presented in this article.
This work was conducted during a scholarship of Águida Garreth Ferraz Rocha supported by CAPES – Brazilian Federal Agency for Support and Evaluation of Graduate Education within the Ministry of Education of Brazil – Process nº BEX 3220/15-0.

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Agronomy Research **15**(X), 540–552, 2017

Quantification of biogas potential from livestock waste in Vietnam

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Abstract. Quantification of biogas potential in Vietnam is highly needed to provide sufficient information for authorities properly support their future policy decisions. To achieve the aim of this investigation, two methods were applied: (i) the method for calculation of the amount of manure and its biogas potential from chosen livestock obtained from statistical data and (ii) the method for future forecast using middle scenario applications based on previous development of specific category, presuming homogenous continuation of growth. The total biogas energy potential in Vietnam was quantified to approximate 120,000 T Jy^{-1} in 2015 and has the potential of increasing to 127,000 TJ y^{-1} by 2020. However, when considering current manure management practices (including accessibility factor and collection efficiency) biogas potential was quantified to the values of almost 67,000 T Jy^{-1} in 2015 and over 71,000 T Jy^{-1} by 2020 if the current manure management practices remain unchanged. Biogas has the potential of generating renewable energy, while meeting requirements related to waste treatment and minimizing environmental impacts. This study shows that animal waste is a promising sustainable energy source in Vietnam which can be efficiently utilized for the generation of biogas energy as well as electricity. Furthermore, anaerobic digestion of livestock waste has the potential to play a vital role in farming systems by adding value to agricultural waste and livestock excreta, and reducing their presence in the environment therefore enhancing public health. There is a high development potential for the decentralized energy generation due to the exploitation of small-scale biogas plants in Vietnam. However, it is essential to realize that competition to other energy generating technologies is present.

Key words: biogas potential, quantification, biogas, Vietnam, livestock waste, anaerobic digestion~~s~~, manure management

INTRODUCTION

The fast depleting supply of fossil fuels and growing environmental degradation by potent greenhouse gases is pushing the World´s economies towards the usage of alternate energy sources (IPCC, 2012). Constantly growing worldwide energy consumption and population expansion in developing countries increase stress and damage to the planet (Ahuja & Tatsutani, 2009). In the developing world, pollution and access to energy sources still represent a significant challenge, especially in connection with human and environmental health and with economic development (Ahuja & Tatsutani, 2009; Shane et al., 2015). Therefore, bioenergy production by fermentation reaction is gaining popularity due to its easy operation and a wide available selection of organic wastes feedstock (Priekulis et al. 2015; Ayhan, 2016; Thi et al., 2016). As rural areas in Asia are struggling to manage of vast quantities of manure (mainly from pigs, dairy and poultry) appropriate waste management systems are needed (Vu et al., 2015). By transforming of animal waste into energy, in the form of biogas, this would prevent these animals' slurry from being dumped directly into rivers and lakes, a common practice in parts of Asia that lack waste management infrastructure (Anenberg et al., 2013; Vu et al., 2015). This calls for appropriate manure management strategies with minimal impacts on the environment, simultaneously generating energy with little or no warming potential, such as biogas technology (Vu et al., 2015). Furthermore, global warming is one of the major concerns arisen in the natural environment of human beings and manure waste obtained from livestock sector is one of the main organic wastes which are hazardous if not managed suitably. Animal manure contains a high concentration of nitrogen (N) and phosphorus (P), which causes nutrient imbalance and pollution in environment (Abdeshahian et al., 2016). Livestock manure also contains residues of some harmful substances (as growth hormone, antibiotics and heavy metals) and also microorganisms in the animal manure could contaminate the environment resulting in an outbreak of human diseases (Nguyen 2011; Nguyen et al., 2012; Cu et al., 2015). Therefore, disposal of livestock manure may have significant polluting impact on the environment contaminating air, soil and water sources (Abdeshahian et al., 2016).

These days in Vietnam biogas technology is viewed as a method not only for solving environmental problems, but also for contributing to energy production and resolving economic and social issues (Chu, 2012; Cu et al., 2012; Cu et al., 2015; Roubík & Mazancová, 2016b). Having an abundance of organic waste, the country is being encouraged to further use 'Waste to Energy' technologies to properly address the treatment of waste materials (Surendra et al., 2014; Silva et al., 2016). The treatment of organic waste is necessary to keep the environment clean. Also, through the treatment of organic waste, such as livestock excreta, this allows to reintroduce materials into the material cycle (Nguyen et al., 2012).

During anaerobic digestion process, not only biogas, methane-rich gas with net calorific value of 20–25 MJ m^3 that can be used in many appliances including biogas lamps, biogas cookers or generators and engines, is produced (Cundr & Haladová, 2014; Roubík & Mazancová, 2016a). Also a product of fermentation called digestate is generated (Chu, 2012; Kouřimská et al., 2012). Digestate as a by-product can also be used as a fertilizer (Chu, 2012; Kouřimská et al., 2012; Roubík et al., 2016) or for other energy purposes (Brunerová et al., 2016).

Anaerobic digestion technologies have been utilized in Vietnam over 30 years (Silva et al., 2016) with thousands of small-scale biogas plants in usage (Roubík et al., 2016). Small-scale biogas plants were applied as an optimal livestock waste treatment as well as biogas supply for cooking and lighting demand for small-scale farmers in Vietnam (Roubík et al., 2016). Although the biogas technology was introduced nearly 30 years ago, the number of the constructed biogas plants is still limited (Nguyen, 2011; Chu, 2012; Nguyen et al., 2012; Roubík & Mazancová, 2016b).

Following a decade of expansion aided by heavy government and foreign organizations investment (over 725,000 people in Vietnam benefit ~~by~~ from the implementation of biogas technology) (BPAHS, 2016), biogas development in rural

Vietnam is currently at its crossroad. However, emerging problems call into question whether small-scale biogas technology is still able to meet the increasing energy needs of rural households (Roubík et al., 2016). Also, it is questioned by government how to make subsidies for funding this technology in a more cost-effective way (Roubík & Mazancová, 2016b). Another challenge lies in technology financial performance (York et al., 2016), which directly influences technology owners' satisfaction level (Roubík & Mazancová, 2016b). Rapid economic development and urbanization across the Vietnam is bringing also major changes to rural settings and therefore impacting small-scale biogas production (Vu et al., 2015). Migration to cities means less labour to operate biogas technology. Other difficulties include inadequate technical services for post-installation maintenance and repair It is also essential to realize that these combined factors may result in many small-scale biogas plants either functioning below their full potential or being out of use altogether (Bruun et al., 2014).

Therefore, quantification of biogas potential in Vietnam is highly needed to provide sufficient information for authorities to have their future policy decisions well supported.

MATERIALS AND METHODS

To achieve the aim of the investigation, two methods were applied: (1) the method for calculation of the amount of manure and its biogas potential from chosen livestock obtained from statistical data and (2) the method for future forecast using middle scenario applications based on previous development of a specific category, presuming homogenous continuation of growth. The second method is reflecting the continuation of past development trend assuming no significant changes and constraints within each specific category. Furthermore, the second method involves accessibility factor and collection efficiency in order to reflect current manure management practices.

Target area, data collection methods and SWOT analysis

In order to verify current situation, field visits were carried out in central Vietnam in August and September 2016. Based on those visits SWOT analysis of biogas potential as a complex method of strategic analysis (considering internal and external factors) was elaborated. SWOT analysis is a strategic planning tool, which is helping identify internal factors (strengths and weaknesses) and external factors (opportunities and threats) in order to determine the future heading. By capitalizing on strengths and eliminating or correcting weaknesses there is higher possibility to be able to take advantage of opportunities as they emerge and cope with threats before they become reality. By investigating and assessing both internal and external factors affecting the performance, a clearer vision of success and failure possibilities is achieved. The SWOT analysis, in this study, is developed based on such facts, and obtained through a series of face-to-face meetings with all concerned stakeholders from the biogas sector in the central Vietnam, including but not limited to biogas owners, local facilitators of biogas plants and experts from the local university. Then an analysis of the notes from these meetings was conducted and results were compiled to establish the strengths, weaknesses, opportunities and threats.

Biogas yield calculations

Biogas potential from various available excrements was calculated according to typical biogas yield per kg in mesophilic conditions, i.e. 20–45 °C.

The theoretical biogas potential from animal dung was determined using equation (1) (Shane et al., 2015):

$$BEP = \frac{N \cdot VS \cdot B_0 \cdot D \cdot CV}{10^6} \tag{1}$$

Where BEP (Fig. 1) is the theoretical biogas energy potential in TJ y^{-1}, N is the population of animal category, VS is the volatile solids in $kg \cdot d^{-1}$, B_0 is the methane potential $m^3\ kg^{-1}$ VS, D is the number of days in year and CV is the calorific value of biogas at 60% of methane in MJ m^{-3}. Statistical and prediction data were used for livestock production in Vietnam to determine the theoretical biogas potential from animal waste. Data about B_0 and VS were extracted from IPCC (2006) for Vietnam. Data about the population of animal category (2008–2015) were extracted from Vietnamese statistics (2015) and data about population of animal categories 2015–2020 were based on own calculations.

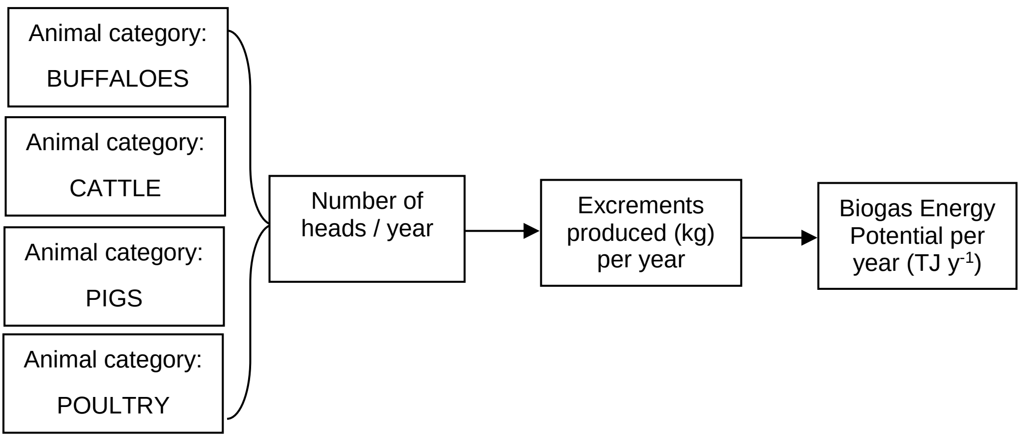

Figure 1. Simplified design of theoretical calculations.

Furthermore, there was applied the estimated accessibility factor and collection efficiency (Table 1) to the final quantifications in order to reflect current manure practices for livestock in Vietnam. These two factors were set up after field visits, which were carried out in central Vietnam August and September 2016 and after face-to-face meetings with all concerned stakeholders from the biogas sector in the central Vietnam. These factors are estimated according to the local production conditions.

Table 1. Estimated accessibility factor and collection efficiency for different livestock manure

	Accessibility factor	Collection efficiency
BUFFALOES MANURE	0.40	0.80
CATTLE MANURE	0.80	0.80
PIGS MANURE	0.80	0.95
POULTRY MANURE	0.60	0.80

(Thornton, 2010), which was based on the previous development of the specific category, presuming the homogenous continuation of population growth. Coefficient of determination between the data points and the estimated values were analysed by the R-squared value (result values are shown in Table 3, where higher R-squared value indicates higher probability of predictions to be exact – providing a measure of how well observed outcomes are replicated by the model, based on the proportion of total variation of outcomes explained by the model).

RESULTS AND DISCUSSION

Livestock production in Vietnam with taking into account manure accessibility and collection efficiency

Livestock production in Vietnam is primarily undertaken on rural household farms (where usually crops and other agricultural products are also produced). More than 92% of producers in 2003 used only household labour in livestock production sector (Nin et al., 2003) and this situation is still valid. The domestic market easily absorbs majority of livestock production in Vietnam (Nga et al., 2015). Livestock is an important source of income for the majority of Vietnamese farmers, particularly those in upland areas where poverty rates are highest, so that its development carries important implications for poverty reduction and income distribution. Livestock raising costs are dominated by feed costs, which account for an average of over 75% of total costs. Feed costs are still the dominant cost component even when household labour is valued at full cost. Poor producers use mainly grazing systems while larger households use more cut and carry grasses and complete feed systems.

The native buffalo is a traditional animal in Vietnam and is usually raised for rice culture and meat (Nha et al., 2008) and it gains important role due to the increasing demands for its meat with growing population. Even though raising buffaloes without shelter is currently habitual for farmers in Vietnam as they are fed by natural grasses (Nha et al., 2008) they were also added to the final quantifications of biogas potential. As there is potential with move towards other buffalo raising practices (such as keeping buffaloes in shelters or using manure from their sleeping shelters), however, in the current state of circumstances the estimated accessibility and collection factors were set up for buffaloes 0.4 reflecting difficult manure accessibility during the day and 0.8 respectively for relatively ease use of manure into the biogas plant when accessed.

Cattle production also plays a very important role in farming systems and Vietnamese life as the demand for beef is increasing, mainly in major urban centres (Parsons et al., 2013; Dung et al., 2013). Dairy cattle are mainly raised in smallholder farms (approximately 96%), therefore accessibility factor was set up for 0.8, reflecting relatively good accessibility of cattle manure and collection efficiency of 0.8 for relatively ease use of manure into the biogas plant when accessed. The percentages of farms falling into smallholder farms with meat cattle are around 78%. Local breeds are dominant in the smallholder farms. Cattle production in Vietnam has increased significantly during the last decade, with annual cattle population growth from 6 to 11% (MARD, 2014; Vietnamese statistics, 2015). The reasons are both tourism and increasing income of the local population and their growing purchasing power. The major constraints perceived in a study by Parsons et al. (2013) were including lack of capital, breed, feeding, labour availability, diseases and lack of knowledge. Such constraints if not managed may lead to number reductions of the animal sector.

The pig sector consistently contributes up to 80% of total meat production in Vietnam (Nga et al., 2013) and provides a livelihood for over 4.1 million small-scale farms in the country (Nga et al., 2015). Rising income is one of the driving factors of pork demand (Nga et al., 2015). At present, the smallholders provide at least 80% of total pork for domestic consumption that is mainly distributed in traditional wet markets where food production processes are not traceable and food quality remains a big concern (Nga et al., 2015). Vietnam's swine production is composed of mostly backyard/household operations or small farms. In 2006, about 85% to 90% of swine were raised in backyard/household operations, while the remainder were raised at larger, commercial farms. In Vietnam, farms are considered commercial if they have more than 20 sows. While small farms account for 85% to 90% of the total pig population, they produce only about 75% to 80% of the pork supply. Crossbred pigs are the dominant type of pig, with the proportion of crossbred and exotic pigs increasing with farm size. Local pigs are predominantly fed using only roughage; crossbred pigs are mostly fed on roughage and concentrates while for exotic pigs a diet of complete feed is used. Accessibility factor was set up for 0.8, as reflecting good accessibility in case of current way of rising pigs and collection efficiency of 0.95 as pigs' manure is currently extensively used by farmers.

Poultry production in Vietnam is also characterized by small-scale farms, where the birds are mainly fed by farm-produced grain combined with scavenging (Tung & Rasmussen, 2005). However, also middle farms are common. At present, there are 11 national poultry breeding centres with 3,000 pure breeds and 18,000 grandparent chickens. There are 106 local poultry breeding farms The characteristics of poultry intensive production system are high investment, good management and a short husbandry period. In Vietnam, there are two main poultry production systems: i) semi-subsistence (where small flock of local breeds are left to scavenge in backyards and garden area and fed with locally available feeds) ii) semi-commercial poultry systems (larger flock size with local or improved breeds and supplementary feeding with either grain or concentrate feeds or both). Poultry also plays an important role in providing food and income for small-scale households (Tung & Rasmussen, 2005). As the current poultry production in Vietnam is still mainly in the hands of small-scale farmers, where during the day, birds are often in the open area without any concrete floor accessibility factor was set up for 0.6 and collection efficiency when already applied, is generally quite sufficient for 0.8.

As shown in Table 2, where numbers of livestock of chosen categories (buffaloes, cattle, pigs and poultry) are provided, the numbers are differing in nature. Such as in the case of buffaloes, there is slow decrease in numbers (almost 2.9 million in 2008 to the approximately 2.52 million in 2014). In the case of cattle, there is also an obvious trend of slight decrease in numbers (with over 6.33 million in 2008 to the 5.23 million in 2014). In case of pigs, there are very stable numbers with over 26.7 million in 2008 to the almost 26.8 million in 2014. The poultry category has experienced significant increase in numbers from 248.3 million in 2008 to almost 328 million in 2014.

Table 2. Number of livestock in Vietnam (2008–2014)

	2008	2009	2010	2011	2012	2013	2014
BUFFALOES	2,897,700	2,886,600	2,877,000	2,712,000	2,627,800	2,559,500	2,521,400
CATTLE	6,337,700	6,103,300	5,808,300	5,436,600	5,194,200	5,156,700	5,234,300
PIGS	26,701,600	27,627,700	27,373,300	27,056,000	26,494,000	26,264,400	26,761,400
POULTRY*	248.3	280.2	300.5	322.6	308.5	317.7	327.7

*Poultry is in million heads. Source: Vietnamese general statistics office (2015).

With the application of middle scenario based on the previous development of each category, presuming the homogenous continuation of growth, there are probable predictions of development demonstrated in Table 3.

Table 3. Prediction of number of livestock in Vietnam (2015–2020) based on previous development of animal categories

	R^2	2015	2016	2017	2018	2019	2020
BUFFALOES	0.94	2,491,926	2,419,344	2,346,762	2,274,180	2,201,598	2,129,016
CATTLE	0.92	4,545,624	4,337,856	4,130,088	3,922,320	3,714,552	3,506,784
PIGS*	0.30	26.95	27.02	28. 90	28.78	28.65	29.53
POULTRY*	0.78	346.6	358.14	369.61	381.08	392.55	404.02

*Poultry and pigs are in million heads.

Table 3 provides predictions of the development of various animal categories, however the future evolution of livestock production systems is greatly related to the major constraints faced by most producers in the region. Those constraints may be those mentioned by Hanh et al. (2013) such as dependence on purchased feed, the increase of the price of animal feed, threats from animal infectious epidemics, and the environmental pollution. Other relevant factors include the economic purchasing power of consumers and policy issues. As obvious from Table 3, R-squared values are relatively high for buffaloes, cattle and poultry, indicating exact predictions for those three categories. However, quite low for pigs, showing potential higher errors between the data points and the estimated values in the case of pigs, indicating less exact predictions.

Quantification of biogas potential

It is also important to realize that livestock manure keeps releasing methane due to the anaerobic decomposition of organic material contained in the manure by bacteria exited along with the manure from the animal (Chhabra et al., 2009). Therefore, proper quantifications are relevant to be able to keep such challenges. As calculated by Tauseef et al. (2013) livestock manure contributes globally about 240 million metric tons of carbon dioxide equivalent of methane to the atmosphere and represents one of the biggest anthropogenic sources of methane. Considering that methane is the second biggest contributor to global warming, after carbon dioxide, it is imperative that ways and means are developed to capture as much of the anthropogenic methane as possible. There is a major associated advantage of methane capture: its use as a source of energy which is comparable in 'cleanness' to natural gas.

Livestock waste is composed of the organic matter that can be treated as the potential raw substance for the production of bioenergy (Abdeshahian et al., 2016). The livestock manure is one of the cost-effective and renewable substrates for biogas production and therefore the treatment of livestock manure through anaerobic digestion is an appropriate manure management method decreasing polluting effect on the environment and simultaneously producing biogas and converting manure into organic fertilizer (digestate). The biogas potential in Vietnam is large in numbers, as the livestock population is continuously growing with the higher demand for meat products. However, a major problem for biogas utilization may be the lack of large-scale farms (mainly for pigs or poultry as potential sources). The livestock sector is mainly kept in small-scale household farms. However, such small-scale farms and households are appropriate for small-scale biogas plants.

Table 4a shows quantification of biogas potential from the livestock sector based on statistical data up to 2014 Obviously, the biogas produced from the livestock waste is affected by the various factors, such as feeding regime, animal type, animal body weight, the proportion of total solids and the waste availability, therefore those numbers should be considered as a rough estimations of biogas potential considering middle scenario for country such as Vietnam.

Table 4a. Quantification of total biogas energy potential from various livestock waste in Vietnam (TJ y^{-1}) in the period 2008–2014

	2008	2009	2010	2011	2012	2013	2014
BUFFALOES	15,843	15,782	15,730	14,828	14,367	13,994	13,786
CATTLE	20,436	19,680	18,728	17,530	16,748	16,627	16,878
PIGS	32,568	33,697	33,387	33,000	32,314	32,034	32,641
POULTRY	42,329	47,768	51,228	54,996	52,592	54,161	55,865
TOTAL	111,178	116,929	119,076	120,356	116,024	116,818	119,171

Table 4b then shows the prediction of biogas potential from livestock sector from 2015 up to 2020. As obvious, livestock manure is notified as the potential feedstock for sustainable generation of biogas through the anaerobic digestion process.

Table 4b. Estimation of total biogas energy potential from various livestock waste in Vietnam (TJ y^{-1}) in the period 2015–2020*

	2015	2016	2017	2018	2019	2020
BUFFALOES	13,625	13,228	12,831	12,434	12,037	11,640
CATTLE	14,657	13,987	13,317	12,647	11,977	11,307
PIGS	32,872	32,957	35,247	35,098	34,949	36,019
POULTRY	59,099	61,054	63,010	64,966	66,921	68,877
TOTAL	120,254	121,228	124,407	125,147	125,886	127,846

*Data are based on authors´ predictions of development of each animal category.

Figure shows the total biogas potential from livestock manure in the period 2008–2020. The potential has growing trend as has the livestock population of Vietnam responding to the increasing demands for the animal products resulting huge amounts of organic waste to be handled. As demonstrated in Fig. 2, the total biogas energy potential arises from over 111,000 TJ y^{-1} in 2008 to over 120,000 TJ y^{-1} in 2015 and can with continuous trend go up to 127,000 TJ y^{-1} in 2020. In this view, it is also desirable to consider the electricity potential to be generated from the potential biogas. Furthermore, within this context, it is required for the continued development of anaerobic digestion in terms to get clean energy, which is less costly than comparable renewable technologies and thus have a great potential for a country such Vietnam.

In order to make our quantifications more precise, there were used specific accessibility factors and collection efficiency for each of the categories showing us the adjusted result of quantifications (Table 5a and 5b). As obvious in Fig. 2, where biogas energy potential in the period 2008–2020 (TJy^{-1}) from livestock manure adjusted by accessibility factors and collection efficiency is shown, the growing trend is still present and showing very high biogas potential. The potential in 2008 is over 63,000 TJy^{-1}, in 2014 already almost 67,000 TJy^{-1} and with predicted values of over 67,000 TJy^{-1} in 2015 and over 71,000 TJy^{-1} by 2020.

Table 5a. Quantification of total biogas energy potential from various livestock waste in Vietnam ($TJ\ y^{-1}$) in the period 2008–2014 adjusted by accessibility factors and collection efficiency

	2008	2009	2010	2011	2012	2013	2014
BUFFALOES	5,069	5,050	5,033	4,745	4,597	4,478	4,411
CATTLE	13,079	12,595	11,986	11,219	10,719	10,641	10,801
PIGS	24,751	25,610	25,374	25,080	24,559	24,346	24,807
POULTRY	20,318	22,928	24,589	26,398	25,244	25,997	26,815
TOTAL	63,219	66,185	66,985	67,443	65,121	65,464	66,836

Table 5b. Estimation of total biogas energy potential from various livestock waste in Vietnam ($TJ\ y^{-1}$) in the period 2015–2020* adjusted by accessibility factors and collection efficiency

	2015	2016	2017	2018	2019	2020
BUFFALOES	4,360	4,233	4,106	3,979	3,852	3,725
CATTLE	9,380	8,952	8,523	8,094	7,665	7,236
PIGS	24,983	25,047	26,788	26,674	26,561	27,375
POULTRY	28,367	29,306	30,245	31,183	32,122	33,061
TOTAL	67,092	67,539	69,663	69,932	70,202	71,398

*Data are based on authors´ predictions of development of each animal category.

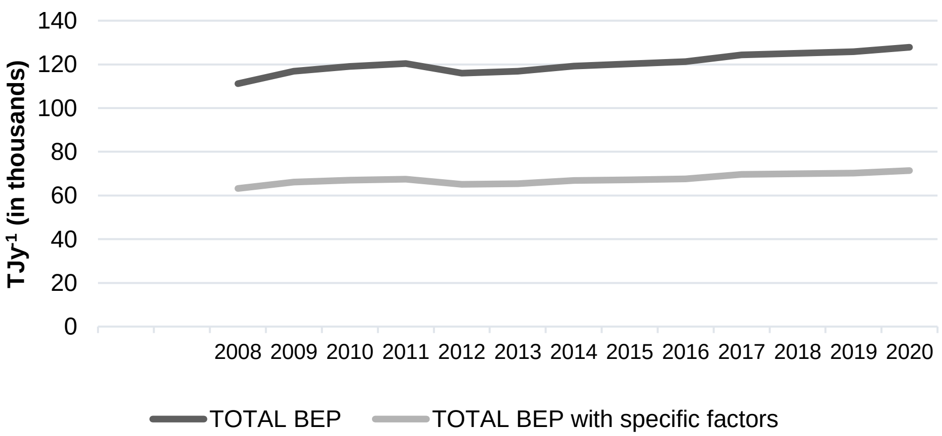

Figure 2. Comparison of total biogas energy potential in the period 2008–2020 ($TJ\ y^{-1}$) from livestock manure and biogas energy potential from livestock manure adjusted by accessibility factor and collection efficiency.

Apparently, as obvious in Table 6 where SWOT analysis of biogas potential in Vietnam is showed, strengths and opportunities are more when compared to the weakness and threats which can be easily overcome through different operation mechanisms.

Table 6. SWOT analysis of biogas potential in Vietnam

STRENGTHS	It is renewable energy and it has been supported by foreign NGOs and the Vietnamese government.
	Biogas production is a technology to reduce waste and it offers solutions for organic waste disposal.
	The combustion of methane has very low exhaust emissions (NOx, CO, Particulate Matter) compared to fossil fuels.
	Biogas can be produced in a decentralized way.
	Use of biogas prevents deforestation.
	Generated biogas may be used for cooking, lighting & electricity production.
	The digestate obtained from biogas plant has got a higher nutritive value as compared to that of ordinary farmyard manure.
	In the case of small-scale biogas plants, it is generally onetime investment.
	There is no or little maintenance in case of small-scale biogas plants needed.
WEAKNESSES	When methane escapes from biogas plant through leakages (in the case of small-scale biogas plants), it is a contributor to the greenhouse effect.
	In case of some livestock waste, due to the current stabling, a collection of feedstock for biogas plants may be difficult.
OPPORTUNITIES	Biogas may replace Liquefied Petroleum Gas (LPG) or fossil fuels.
	Biogas technology offers environmental improvement.
	There is a need for changes in government policy or regulations and legislation.
THREATS	When the organic waste is not continuously fed or overfed into the biogas plant it can lead to less or no generation of biogas.
	Subsidized low costs of LPG making biogas technology not competitive.

CONCLUSIONS

This study shows that animal waste is a promising low-cost and sustainable energy source in Vietnam which could be efficiently utilized for the generation of biogas energy as well as electricity. Furthermore, anaerobic digestion of livestock waste has potential to play a vital role in farming systems by adding value to agricultural waste and livestock excreta and may reduce their negative impacts on the environment by enhancing public health. The biogas potential has growing trend as has the livestock population of Vietnam responding to the increasing demands for the animal products resulting huge amounts of organic waste to be handled. The total biogas energy potential in Vietnam from livestock was quantified to over 120,000 TJ y^{-1} in 2015 and can with continuous trend go up to 127,000 TJ y^{-1} in 2020. However, when considered current manure management practices biogas energy potential was quantified to the values of over 67,000 TJ y^{-1} in 2015 and expected to be over 71,000 TJ y^{-1} in 2020 if the current manure management practices sustain unchanged. There is a high development potential for the decentralized energy generation due to the exploitation of small-scale biogas plants in Vietnam. However, it is essential to realize that competition to other energy generating technologies is present. Future research should focus on determining electricity potential from largescale farms and on biogas potential in fellow developing countries in Southeast Asia.

ACKNOWLEDGEMENTS. This research was supported by the Internal Grant Agency of the Czech University Life Sciences Prague [20165003]. Further support was provided by the Internal Grant Agency of the Faculty of Tropical AgriSciences, Czech University of Life Sciences Prague, project number [20175012]. Furthermore, financial assistance through Erasmus Mundus project ALFABET (Asia: Life, Food, Agriculture, Biology, Economics, Technology) number: 552071 is gratefully acknowledged by the main author.

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Agronomy Research **15**(2), 553–564, 2017

Monitoring of ammonium pollution from dairy cows farm according of urea content in milk

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Abstract. The objective of this study was to evaluation of urea content in milk to assess the potential of ammonia pollution from farms. Dairy cows in farms were located in different Latvia region with different holding system. Research was conducted under production conditions in four different agricultural holdings located in various places of Latvia and represent different animal housing and feeding technologies. Monthly together with herd control was recorded milk yield and take milk samples was analysed for fat, total protein and lactose (%), urea content (mg dL^{-1}) and somatic cell count (SCC). Milk content parameters for total 14,873 milk samples were analysed in accredited milk quality laboratory. The statistical analyses were performed with the SPSS program package. The results acquired show that in three farms (A, B and D) urea content in 59–71% of milk samples comprised 15.1–30.0 mg dL^{-1}. However, also in these holdings urea content in 29–41% of samples was below or above the optimum threshold. Unpleasant situation was observed in holding C; there urea content only in 16% of milk samples was within the optimum limits. Calculations of forecasted ammonium pollution emitted daily from agricultural holdings using tie stall housing may comprise 91.4–104.0 g from cow, while amount emitted by freestall holdings using housing may constitute 93.9–95.9 g from cow daily. By using these data, each farm may make calculations and forecast farming efficiency and environmental threats.

Key words: milk urea nitrogen, holding system.

INTRODUCTION

Profitability of dairying industry depends upon successful management of herds: it cannot be organised without suitable monitoring of cows. Monitoring allows organising herd reproduction, arrange correct feeding, improve herd productivity and thus also increase income. The main income in dairying is generated by the milk sold to processing enterprises and is influenced by the milk content, namely composition of fat and proteins; amount and proportions of these components affects milk yield and quality (Verdier-Metz et al., 2001).

Lately interest towards environmental pollution has been growing. In Europe, several regulatory enactments are controlling possible environmental pollution that may arise when performing agricultural activities. In the Netherlands, farms are monitored basing on urea content in milk; that allows specifying possible pollution sources, and notifying farms about preventive actions (Bijgaart, 2003). The optimum amount of urea in milk set in Europe is 15–30 mg dL^{-1}.

Data of the National Research Council (in USA) show that nitrogen amount in feed of dairy cows is exceeded on average by 6.6%, thus nitrogen content in urine rises by 16% and by 2.7% in manure. With an aim to calculate amount of nitrogen used, the milk urea content is used, since it is easy to find it out and it does not require collecting and testing special (urine or faeces) samples (Jonker et al., 2002; Broderick & Huhtanen, 2013). Researches show that milk urea characterises content of urea in both blood and urine. Milk urea content reflects losses of crude protein for dairy cow, especially excess in digestive tract, therefore this indicator may be used to assess environmental pollution and digestive efficiency (Broderick & Clayton, 1997; Hof et al., 1997; Burgos et al., 2010).

As compared to other ruminants, dairy cows are able to transform fodder crude protein into milk proteins more effectively and are discharging nitrogen with manure and urine. Nitrogen content in manure may be two, three times higher than one in milk. Thus, as protein volume in feed is increased, not only more milk is produced, bet also threats for environmental pollution are growing. Moreover, costs necessary to prepare fodder rich in proteins are increasing. Share of non-proteins is of a great significance as well, since in European countries and United States of America (USA) it is used to control environmental pollution (Bijgaart, 2003).

The objective of this study was to evaluation of urea content in milk to assess the potential of ammonia pollution from farms.

MATERIALS AND METHODS

Research was conducted:

- Under production conditions and in four different agricultural holdings in Latvia. All holdings are engaged in milk recording program. Holdings included in the research are located in various places of Latvia and represent different animal housing and feeding technologies.
- Data on milk quantities yielded from dairy cows, cow breed, lactation and day in lactation were acquired from monthly herd recording data available in Agricultural Data Centre database.

Within the framework of the research, information on composition of milk samples acquired from the holdings using differing cow housing and dairying facilities was compiled.

Farms taking part in the research are breeding Latvian Brown (LB) and Black and White Holstein (HM) cows, as well as mix of the both breeds (XP). Two large holdings (B and D, 503 and 164 cows, respectively) are keep indoor freestall housing system. Farms recording milk production and uses method A (recording is performed by independent certified person) in line with International Committee of Animal Recording (ICAR) guidelines and legislation of the Republic of Latvia on recording of dairy cows (ICAR, 2011).

In small farms (A and C, 28 and 20 cows, respectively) cows are tie stall housing system, they are not grouped and are grazed in summer. Farms A and C are located in central part of Latvia, near Riga; thus they are limited in availability of agricultural area for high quality grazing areas and meadows, as most of the land is envisaged for construction. Milk production is recording with the help of method B – after acquisition of certificate, person has a right to perform this task only in own herd. This is recording method suggested by ICAR guidelines.

In all farms cows are milked twice a day. Farms A and C are using milking line. Farm B is milking cows by arranging them into groups, and the process takes place in milking hall with parallel animal placement. All cow groups in farm D are milked in milking hall, animals are placed in herringbone stall.

During the research, milk samples were taken each month in control day. Milk samples were collected from all milking times made during the 24-hour period. During the 26 months, 14,873 milk samples acquired from four farms were analysed. Information on milk samples in breakdown by farm and cow breed has been compiled in the Table 1.

Table 1. Analysed milk samples by farm and cow breed

Traits	Farms											
	A (n = 400)			B (n = 10,280)			C (n = 432)			D (n = 3,761)		
Breeds	LB	HM	XP	LB	HM	XP	LB	HM	XP	LB	HM	XP
Number of samples	186	199	15	8,663	1,116	501	393	–	39	389	2,035	1,337
Breakdown of samples, %	47	49	4	84	11	5	91	–	9	10	54	36
Lactation number average	2.30			2.04			3.16			2.20		
Day in lactation, average	185			182			178			185		

Milk composition was analysed in accredited laboratory for milk quality control.

Research includes evaluation of dairy cow milk productivity traits: yield per cow in control day (yield, kg); content of fat (%), crude protein (%), casein (%), urea (mg dL^{-1}) and lactose (%). Indicator used to characterise quality in this research is somatic cell count.

With an aim to research influence left by environmental and selected physiological factors, as well as cow breed on changes in milk composition the multifactor linear model was used; it included the factors fixed:

$$y_{ijklmnsr} = \mu + S_i + Se_j + \check{S}_k + L_l + LP_m + Vn + U_s + R_r + e_{ijklmnsr} \qquad (1)$$

where: S – farms (i = 4); Se – season of the year (j = 4); Š – breed (k = 3); L – lactation (l = 1–4); LP – lactation phases (m = 1–6); Vn – health status (n = 6); U – urea content class (s = 4); R – milk yield per cow in control day (r = 6).

Credibility of factors included in linear model of multifactor dispersion analysis was found out at significance level $\alpha = 0.05$; 0.01; 0.001. Influence left by factor was assessed as significant if $p < \alpha$. Value of determination coefficient (R^2) indicates for how many per cent selected model explains dispersion of the feature researched.

Gradation class average values of the factors researched in model are characterised by last squares mean values (LMS) and standard deviations thereof. The most notable differences among factor gradation class are indicated by various letters: a, b, c etc. if $p < 0.05$.

With an aim to evaluate and compare research results with other studies and to find out possible nitrogen amount that is wasted by holdings when feeding cows in imbalanced way, content of milk urea that in laboratory was measured as mg dL^{-1} was transformed into % (FOSS Analytical, 2005) and afterwards urea volume (g) in control day was calculated in compliance with the guidelines of International Committee for Animal Recording (ICAR, 2011).

Molar mass of urea comprises 60 g moL^{-1}, while urea has two nitrogen molecules 28 g moL^{-1}. Thus, by calculating proportion from urea content, the content of nitrogen in urea may be found out. By using proportion (28/60) we may recalculate urea content in milk into content of urea nitrogen. In order to be able to compare results with the corresponding data in USA researches and standards, milk urea content was recalculated also into milk urea nitrogen (MUN) content, for further calculations using following formula (Spiekers & Obermaier, 2012):

$$MUN = urea\ content \times 0.46 \quad (2)$$

Also content of urea nitrogen (that in laboratory was measured as per cent urea nitrogen volume (g)) was recalculated in compliance with ICAR guidelines (ICAR, 2011).

$$Volume, kg = (yield, kg \times \%\ of\ content)/100 \quad (3)$$

When introducing integrated farming principles, results thereof may be controlled with the help of several indicators. In the research, holdings were assessed by using urea nitrogen volume that is taken from farm together with milk during lactation phase. Recalculation was made per standard lactation (305 days) with the following formula:

$$Urea\ nitrogen\ volume, kg\ per\ cow\ in\ lactation = (MUN\ volume, kg \times 305)/1{,}000 \quad (4)$$

Possible ammonium pollution in holdings was evaluated with the help of calculations based on model developed in University of California (Burgos et al., 2010):

$$Ammonium\ emission, g\ per\ cow\ daily = 25.0 + 5.03 \times MUN\ content\ mg\ dLdL^{-1} \quad (5)$$

Statistical processing of the data was carried out with *MS for SPSS* (SPSS Inc. Chicago, Illinois, USA) and *MS Office* programme *Excel*. Images were created with *MS Office* programme *Excel*.

RESULTS AND DISCUSSION

Farming methods may have significant influence on milk productivity and quality traits. Average milk productivity traits per cow in the control day are shown in the Table 2.

Milk yield in farms participating in research differed significant – it was the lowest in holding C (24.2 kg), while highest in farm D (25.4 kg). Content of crude protein, casein and milk urea varied significantly among the farms. Milk produced in farm B had the highest content of crude protein (3.57%). Moreover, cows in farm B received well-balanced fodder. Casein content varied significant among the holdings; it was the highest in farm B (2.72%) and the lowest in farm A (2.54%).

Table 2. Average cow milk productivity and quality traits in farms studied

Traits	Farms A (n = 400)	B (n = 10,280)	C (n = 432)	D (n = 3,761)
Yield, kg	25.2 ± 0.11^{a}	24.9 ± 0.05^{b}	24.2 ± 0.11^{c}	25.4 ± 0.05^{a}
Crude protein content, %	3.31 ± 0.018^{a}	3.57 ± 0.008^{b}	3.38 ± 0.018^{c}	3.53 ± 0.008^{d}
Casein content, %	2.54 ± 0.014^{a}	2.72 ± 0.006^{b}	2.57 ± 0.014^{a}	2.69 ± 0.006^{c}
Milk urea content, mg dL^{-1}	28.7 ± 0.21^{a}	29.8 ± 0.10^{b}	34.1 ± 0.22^{c}	30.6 ± 0.10^{d}
Fat content, %	4.25 ± 0.045^{a}	4.40 ± 0.021^{b}	4.09 ± 0.045^{c}	4.22 ± 0.021^{a}
Lactose content, %	4.65 ± 0.009^{a}	4.71 ± 0.005^{b}	4.71 ± 0.010^{b}	4.71 ± 0.005^{b}

$^{a;b,c,d}$ – productivity indicators with unequal letter differed significantly among the farm ($p < 0.05$).

Urea content in milk also varied among the holdings (from 28.7 mg dL^{-1} to 34.0 mg dL^{-1}). In farm C feeding was organised on one group, and in summer cows are grazed. Urea content in milk produced in farm C was significant higher (34.0 mg dL^{-1}), as compared to other farms. It indicates possible problems in fodder dose balancing and farming. Also Lithuanian scientists (Savickis et al., 2010) emphasize that urea content in milk depends on farm factor.

Milk yielded in farm B had significantly higher fat content (4.40%) and significant lower (4.65%) lactose content. Fat content was the lowest in holding C (4.09%), while lactose content was similar in farms B, C and D (4.71%), moreover it was significantly higher than in farm A.

Urea content in milk shows how correct or suitable is balancing of protein and energy in fodder for cows with various productivity traits. Evaluation of how great is the influence of well-balanced protein and energy amount in fodder dose to milk productivity and quality traits is based on analysis of milk productivity changes depending on urea content thereof (Table 3).

Table 3. Average milk productivity and quality traits depending on urea content

Traits	Urea content, mg dL^{-1} 3.0−15.0 (n = 1,382)	15.1−30.0 (n = 8,574)	30.1−45.0 (n = 4,447)	45.1 < (n = 470)
Average milk urea content in class, mg dL^{-1}	13.4 ± 0.14	23.8 ± 0.10	35.6 ± 0.11	50.5 ± 0.20
Yield, kg	24.8 ± 0.07^{a}	24.8 ± 0.05^{a}	$24.9 \pm 0.06^{a,b}$	25.1 ± 0.11^{b}
Crude protein content, %	3.41 ± 0.012^{a}	3.46 ± 0.008^{b}	3.47 ± 0.009^{c}	$3.46 \pm 0.017^{c,b}$
Casein content, %	2.62 ± 0.009^{a}	2.64 ± 0.006^{b}	2.65 ± 0.007^{b}	2.62 ± 0.013^{a}
Fat content, %	4.05 ± 0.029^{a}	4.23 ± 0.021^{b}	4.36 ± 0.023^{c}	4.33 ± 0.042^{c}
Lactose content, %	4.70 ± 0.006	4.71 ± 0.004	4.70 ± 0.005	4.67 ± 0.009^{a}

$^{a;b;c}$ – traits with unequal letter differed significantly between the urea level ($p < 0.05$).

Evaluation of the results acquired shows that all productivity and quality traits researched differed significantly depending on urea content in milk. Milk yield was significantly higher (25.1 kg) if urea content exceeded 45.0 mg dL^{-1}. 33% of animals in research had increased urea content in milk. It indicates a problem related to ensuring highly productive dairy cows with fodder dose having adequate proportions of energy and protein (Spohr & Wiesner, 1991; Spann, 1993).

Crude protein content was significant lower (3.41%) in milk yielded from cows the milk urea content of which did not exceed 15.0 mg dL^{-1}. The highest crude protein content was observed in milk produced by cows the milk urea of which ranged between 15.1 mg dL^{-1} and 30.0 mg dL^{-1}. Along with higher milk urea content (above 45.1 mg dL^{-1}) crude protein content tends to reduce.

The paper deals with analysing not only influence left by environmental factors on milk productivity and quality traits, but also with studying changes caused by separate physiological factors.

Several scientists (Jonker et al., 2002; Gruber & Poetsch, 2012) emphasize usefulness of crude protein and urea content estimation. Urea content together with crude protein content may be used to assess efficiency of cow feed dose and estimate nitrogen emission into environment.

Analysis of the results found have resulted in average urea content in milk in each farm and breakdown thereof by the content recommended in Europe (Fig. 1).

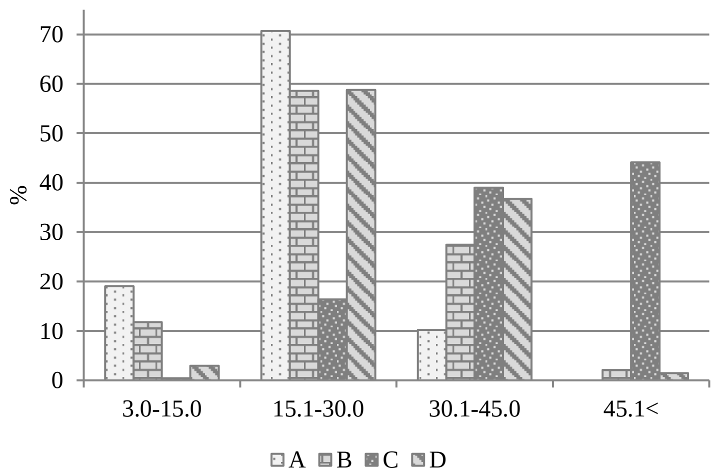

Figure 1. Milk urea content by farms.

The results acquired show that in three farms (A, B and D) urea content in 59–71% of milk samples comprised 15.1–30.0 mg dL^{-1}. However, also in these holdings urea content in 29–41% of samples was below or above the optimum threshold. Unpleasant situation was observed in holding C; there urea content only in 16% of milk samples was within the optimum limits.

The results obtained show how easy urea content in milk allows assessing efficiency with which protein is utilised in each feed dose and identifying potential threats for environmental pollution. Spanish researches on fertilising pastures with slurry, aiming at increasing nitrogen amount in fodder, showed that excessive fertilisation does not give the result desired, since urea content in milk increases, and that, in turn, points to inefficient nitrogen utilisation (Arriaga et al., 2009). Other studies on various fodder doses with 52% and 72% of dry matter and equal protein content (16.5% and 16.4%, respectively) resulted in observation that urea content in milk does not change significantly depending on fodder dose (Agle et al., 2010).

Analysis of the results compiled allows concluded that differences in the results among various holdings arise due to differing feeding methods. Results of this study show differences in average milk urea content among farms, and thus confirm also findings of other researchers about use of milk urea content for effective planning and calculation of effective fodder dose (Jonker et al., 1999). Scientists point out that changes in milk urea content may reflect even l% change in protein contained by feed dry matter. In the researches mentioned, cows were fed with feed containing 13.0%, 14.0%, 15.0% and 16.0% of protein in dry matter, and significant fluctuations were observed only in urea content, other productivity traits did not change (Zhai et al., 2006).

After evaluation of the research results and correlations, author for successful herd management suggest using milk urea content parameter together with traditional fat and crude protein parameter. Regular control of urea content allows farmer to make sure that fodder doses are effective and ensures that possible problems are discovered and solved in time.

Various researches conducted in Europe have used urea content in milk, while USA studies more often are using other parameter – milk urea nitrogen (MUN) content. In order to be able to compare research results, urea content was recalculated (2) into MUN (Fig. 2) that is used for efficiency control in USA. Advisable MUN content should comprise 8.0–12.0 mg dL^{-1} (Kohn et al., 2002; Bucholtz et al., 2007).

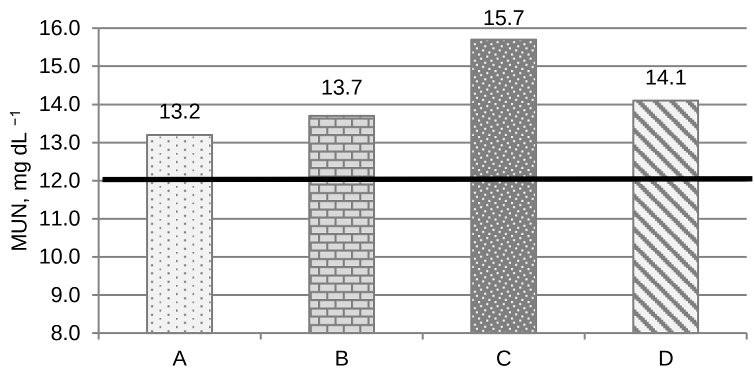

Figure 2. Milk urea nitrogen content in researched farms.

Research results show that MUN threshold was exceeded in all farms engaged in the study. Thus it may be concluded that farms have to pay attention to utilisation of protein in fodder and balancing thereof with energy in single feed dose. Findings compiled in the USA regarding fodder protein and MUN content show following: to reach MUN limit 12 mg dL^{-1}, it is necessary to reduce protein amount in food to 12.8% in dry matter (Aguilar et al., 2012).

Scientists from countries assessing nitrogen use and efficiency, with which nitrogen in single feed dose is utilised, suggest using urea content parameter to evaluate and plan farming model (Godden et al., 2001; Haig et al., 2002).

Many researchers have proved that milk content traits may be used not only to assess animal productivity, but also to characterise metabolism processes in animal body and thus also to foresee possible illnesses in time and control farming efficiency. Productivity traits characterising body metabolism processes are called biomarkers.

Somatic cell count is used to evaluate animal health status, while urea content in milk – to find out protein and energy balance in fodder and assess efficiency of feed protein use, as well as to prognosticate possible risks of metabolism illnesses (ketosis, acidosis) and possible environmental threats. It has been proved that there is significant correlation between milk urea content and nitrogen content in animal urine and manure (Eckersall & Bell, 2010; Burgos et al., 2010; Klein et al., 2011; Spek et al., 2013).

Farm may use urea volume under integrated farming. This indicator points to volume of unused nitrogen that with urine and whey after curd and cheese production gets into waste and afterwards in surrounding environment. By basing calculations (3, 4) on urea and nitrogen amount, volume of nitrogen emitted with milk on average by single cow during lactation may be calculated per each farm (Fig. 3).

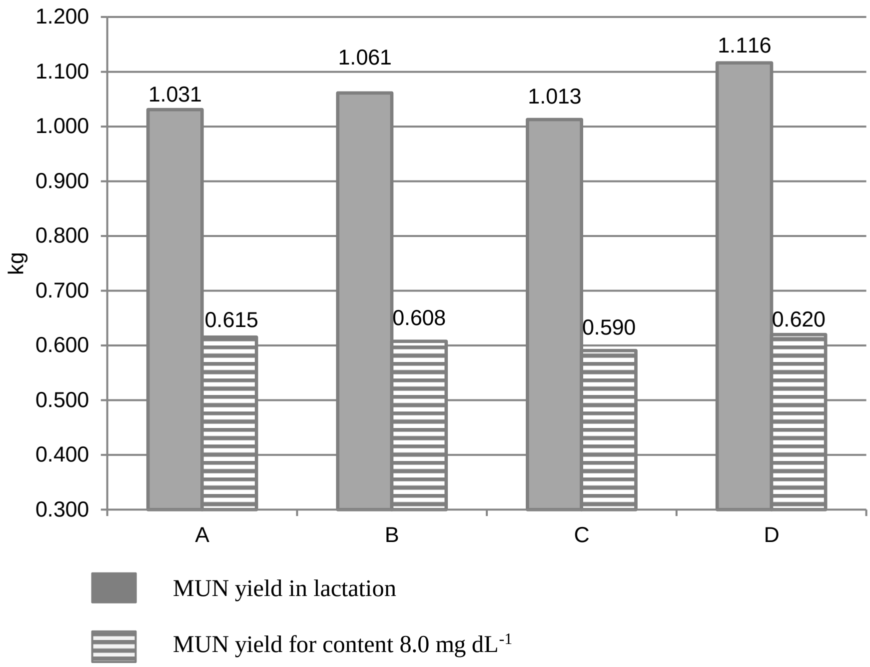

Figure 3. Average urea nitrogen emitted with milk by cow in lactation in farms researched.

When calculating average milk urea nitrogen volume that is produced with milk during lactation and possible milk urea nitrogen (MUN) amount at optimum MUN content 8.0 mg dL^{-1}, it may be concluded that these indicators differ significantly. Highest urea nitrogen with milk is emitted farm D – 1.116 kg, while at optimum MUN it would be only 0.620 kg, i.e., practically a half less than actual nitrogen volume emitted. Thus each farmer, knowing cost of one protein feed kilogram, may calculate amount of money wasted by farm.

Researches conducted prior have resulted in close positive correlation between milk urea content and milk urea nitrogen; meaning that as urea content in milk increases, also nitrogen content in urine grows, and thus environmental threats and volume of uselessly utilised protein rises as well (Shingfield et al., 2001; Gressley & Armentano, 2007).

As earth population number is growing, issue on food supply becomes increasingly more topical. It is necessary to increase agricultural produce while safeguarding environment. Many researches underline well-balanced agricultural production, seeking for a way to achieve optimum animal productivity with minimum environmental pollution.

S.A.Burgos and other scientists experimented with dairy cows in various lactation days. Cows were fed with fodder doses having various protein contents (15%, 17%, 19% and 21%). Cows received such feeding for six days. In the seventh day, milk, urine and faecal samples were taken, ammonium emission from urine and faecal samples was measured and calculated, and nitrogen content in milk samples was studied. As protein content in fodder dose increased (from 17.2% to 19%), also urine volume of dairy cows grew (from 22.2L daily to 25.6L daily). Basing on the data acquired in the research, calculations were made. Results thereof showed close correlation between ammonium emission with faeces and urine and milk urea content ($R^2 = 0.85$). Basing on the results acquired, scientists worked out equation that is used to control ammonium emission depending on milk urea content (Burgos et al., 2010).

On the basis of this equation (5), possible ammonium pollution in researched farms was calculated (Fig. 4).

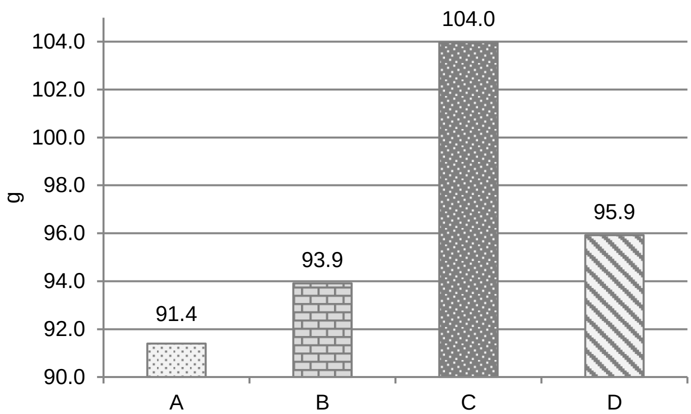

Figure 4. Calculated daily ammonium emission per cow in farms.

Calculations show that smallest ammonium pollution would be emitted by holding A, while biggest – by farm C (91.4 g and 104 g, respectively). By using these data, each farm may make calculations and forecast farming efficiency and environmental threats. Netherlands already currently are monitoring and evaluating environmental threats basing on urea content parameter acquired from cow milk monitoring data. Measures taken since 1998, covering monitoring of legislation and farmer control over and correction of fodder protein and energy amount, have produced good result. Already in three years, 12% reduction in ammonium pollution was recorded (Bijgaart, 2003).

Many researchers emphasize that use of urea content is not unambiguous, and it may not be used separately without considering factors influencing changes thereof – not only physiological, but also time, when milk samples were taken, and testing method, as well as laboratory in which testing was performed. Therefore scientists and feeding specialists suggest basing regular herd control on average results calculated that were obtained from individual animals instead of urea parameter found for total milk produced. If possible, calculations should be made for animals located in the same feeding group (Bijgaart, 2003; Ingvarsten, 2006).

Evaluation of the research results shows that, when planning farming method, it would be useful for each farm not only to consider milk composition, but also to recalculate and assess volume of key milk components in kilograms and grams. Each farmer has to evaluate advantages and disadvantages, and, by using all available milk productivity and quality traits, he/she has to make a decision on the most efficient and environmentally friendly farming method.

CONCLUSIONS

Milk urea content in holdings using freestall housing where 29.8–30.6 mg dL^{-1} comprised in farms using tie stall housing 28.7–34.1 mg dL^{-1}, respectively. It was found out that in three farms optimum milk urea content was recorded in 58–70% of milk samples, until in one farm only in 17% of samples.

Milk urea nitrogen (MUN) content in milk produced in the agricultural holdings researched ranged between 13.2 mg dL^{-1} and 15.7 mg dL^{-1}. MUN volume emitted by single cow during lactation in holdings using freestall housing was higher (from 1.061 kg to 1.116 kg), as compared to farms using tie stall housing (from 1.013 kg to 1.031 kg).

The forecasted ammonium pollution emitted daily from agricultural holdings using tie stall housing may comprise 91.4–104.0 g from cow, withal amount emitted by freestall holdings using may comprise 93.9–95.9 g from cow daily.

Milk productivity traits for farming control should be used together with controlled and known fodder dose, otherwise changes in productivity may not be explained precisely.

All agricultural holdings of milk producing should control urea content in milk yielded from each individual cow on regular basis, while farms engaged in milk monitoring should find out milk urea content for all cows within monthly control.

ACKNOWLEDGEMENTS. Research was conducted with support from ESF project No 2009/0180/1DP/1.1.2.1.2/09/IPIA/VIAA/017, agreement No 04.4-08/EF2.PD.94.

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Agronomy Research **15**(2), 565–575, 2017

Influence of manure and activators of organic matter biological transformation on selected soil physical properties of *Modal Luvisol*

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Abstract. Agricultural land in the Czech Republic threatened by a combination of water erosion, technogenic compaction and low level of soil carbon. The low levels of carbon in the soil interrelate also with the other threats mentioned. Application of organic matter into soil is one of the ways how to rectify this unfavourable condition. All of its forms can be supplemented by biological transformation's activators. The aim of this paper was to verify the effect of organic fertilizer with a conditioning activator added, i.e. manure from deep-litter housing of dairy cows with PRP Fix added, and the effect of an activator conditioning soil, i.e. PRP Sol, on the change of soil physical properties, i.e soil bulk density, infiltration ability, cone index. In this respect, field trial was established at locality Lázně Bělohrad. Soil infiltration capabilities were measured using a ring infiltrometer with a diameter of 0.15 meters. Cone index was another measured item provided by the registration penetrometer. Bulk densities of each trial variant were evaluated using Kopecky's cylinder. Concerning saturated hydraulic conductivity, all the variants treated with manure demonstrated its increase, namely with soil activators applied as well. Favourable effect on soil bulk density values could have been also observed. The change was often below the level of statistical significance. This could have been caused by a short only time of activator's activity. It can be assumed that the effect is going to be gradual and the verification should be carried out also in following trial years.

Key words: activator of organic matter, manure application, soil properties, water infiltration.

INTRODUCTION

Intensively cultivated land is permanently threatened by a loss of fertility. This is mainly due to the degradation of soil by erosion, compaction and reduction in levels of soil carbon. For the sustainability of agriculture, it is important that the level of soil carbon is maintained or increased (Smith, 2004). Decrease in levels of soil carbon is thus undisputed cause of soil degradation. The soil degradation affects soil physical properties. It for example increases soil bulk density, and thus leads to a reduction of soil water infiltration rate (Chyba et al., 2014). Decarbonised soil also loses its ability of infiltration and water retention in the soil profile (Wuest et al., 2005). The above mentioned risks have been emphasised by recent development.

Decarbonisation can be corrected by an application of organic matter to the soil (Six et al., 2000). The organic matter has usually a form of manure or compost. But its decomposition in soils with low levels of soil organic carbon may constitute a problem (Ames et al., 1984). This problem can be reduced with the help of activators of organic matter, e.g. substances added either to bedding, fresh dung, compost, slurry etc., or with the help of soil activators, i.e. substances applied directly to soil. These activators have several forms, i.e. a character of inoculant or of mineral elements. Biochar also is considered as a soil amendment that increases carbon sequestration and soil fertility (Mukherjee & Zimmerman, 2013). In general, studies of activators are often focused on the impact on soil properties and crop yields. The primary mechanism for these effects and the possible environmental consequences, such as organic contaminant or nutrient releases, are often unclear. Garcıa-Gil et al. (2000) reported a beneficial effect of biological activators contained in compost on organic carbon content in the soil, and also an increase in microbial activity in the soil. Subsequently, this increase improved the decomposition of the added organic matter in the soil. Liu et al. (2012) also confirmed this positive effect in their further study where they showed a beneficial effect on maize growth, soil organic matter content, nutrients levels, and water-storage capacity in sandy soils. Pasda et al. (2005) used activators of organic matter for the decomposition of wood chips and rice husk.

The aim of this study was to verify the effect of manure from deep-litter housing of dairy cows, of activator of organic matter PRP Fix and of soil activator PRP Sol on the change of soil physical properties, i.e soil bulk density, infiltration ability and cone index. In this respect, field trial was established at locality Lázně Bělohrad in the year 2014. In the first place, a change in the physical properties of soil was a prerequisite here. The assumption was that an increased infiltration and decreased soil density and cone index should be observed.

MATERIALS AND METHODS

Field trial was established to demonstrate the influence of organic matter and its activators on soil physical parameters. It was located near Lázně Bělohrad in North Bohemia Region (GPS N 50°27.253', E 15°34.208') and started in 2014 after the wheat harvest. The topography of the experimental field was gently sloping, facing southwest, with the altitude of 410 m. Soil type on the location Lázně Bělohrad was *Modal Luvisol*. Soil texture in the field was silt loam. The content of particles under 0.01 mm was 30% of weight (depth 0–0.3 m). Some selected soil properties at the beginning of the experiment are presented in Table 1.

The trial consisted of 6 variants. The trial plot was a 180 meters wide and 400 meters long rectangle selected to be homogenous and to avoid headland. It was divided lengthwise into six individual 30 wide and 400 meters long variants. The plots' spatial distribution had to be simple due to an operational nature of the experiment.

Table 1. Selected physical and chemical properties of soil at Lázně Bělohrad (13th August, 2014)

	Soil depth (m)	
	0.00–0.30	0.30–0.60
Clay (< 0.002 mm) (%)	15	21
Silt (0.002–0.05 mm) (%)	66	67
Very fine sand (0.05–0.10 mm) (%)	3	1
Fine sand (0.10–0.25 mm) (%)	16	11
Texture (USDA)	silt loam	silt loam
Bulk density (g cm^{-3})	1.56	1.52
Total porosity (%)	41.97	42.64
Volumetric moisture (%)	31.50	23.70
Humus content (%)	1.81	0.58
pH (H_2O)	6.26	6.23
pH (KCl)	4.99	5.09
CEC – cation exchange capacity (mmol kg^{-1})	110	120

The variants differed by fertilizers and activators used (Table 2). The fertilizers used were manure from deep-litter housing of dairy cows and NPK 15-15-15 (Lovofert). The manure was applied at the rate of 50 t ha^{-1} only in the autumn of 2014, and NPK at the rate of 200 kg ha^{-1} each production year.

Table 2. Fertilization of individual variants of field trial at Lázně Bělohrad

Variant	Fertilization
1	Manure with PRP Fix + NPK
2	Manure with PRP Fix + PRP Sol + NPK
3	Manure + NPK
4	Manure + PRP Sol + NPK
5	PRP Sol + NPK
6	NPK – control variant

As the biological transformation's activator of soil, PRP sol (PRP Technologies) was applied at the rate of 200 kg ha^{-1} using a common fertilizer spreader each autumn. It is a granulate containing 32% of CaO and 8% of MgO, which means that it is a calcium fertilizer with magnesium added, and also containing 3.5% of sodium (Na) and 3–5% of prefixes with 48 trace elements that should boosts the biological activity of the soil by stimulating soil microflora and enzyme activity. It can be used for all crops grown in the conventional and organic farming system, where the annual doses range between 150–300 kg ha^{-1}.

PRP Fix (PRP Technologies) served as the activator of the biological transformation of manure. It is a pellet formed by a matrix of calcium and magnesium carbonate with an active mixture of specific mineral salts that should help to control fermentation in solid or liquid organic substances. There were two cowsheds with loose box and deep litter housing, each containing 60 livestock units (1 LU = 500 kg) of dairy cows. In the first cowshed, the removal of fresh dung was done in 3–4 week intervals according to the condition of bedding, and spreading of straw 3 times a week. In the second cowshed with PRP Fix used, the removal of fresh dung was done 6–8 week intervals according to the condition of bedding, and spreading of straw and PRP Fix application 3 times a week. Weekly dose of PRP Fix was set at 0.7 kg per one livestock unit with respect to body weight of cows. After the removal from cowsheds and prior to the application in the experimental field, the manure stayed in separate dung hills for approximately two month. The samples of stall dung or manure were taken continuously two times a month from the cowsheds and once a month from the dung hills. At five locations in each cowshed, temperature of bedding and emissions of NH_3 at 0.25 m above the bedding surface were measured for the period of one hour every time the above mentioned samples were taken. Table 3 shows the results of chemical analysis and averages of ammonia emissions and maximum bedding temperatures.

Table 3. Averages of chemical analysis of manure samples treated with PRP Fix and of control manure samples with no activator added, and averages of ammonia emissions and maximum bedding temperatures (8/2014–11/2016)

	PRP Fix	Control	Index	P
No of samples	120	125	–	–
Dry matter [%]	23.6	23.1	–	–
N total [kg t^{-1}]	6.90	5.63	1.23	0.0294
$N\text{-}NH_4^+$ [%]	0.43	0.32	1.34	–
P_2O_5 [kg t^{-1}]	4.10	3.70	1.42	0.0563
K_2O [kg t^{-1}]	8.10	6.90	1.17	0.0479
C : N	18.1:1	22.3:1	0.82	–
NH_3 [ppm]	15.20	23.38	0.65	0.0223
T max [°C]	27.00–29.00	43.00–46.00	–	–

During the autumn of 2014, fertilizer application was carried out according to the plan (Table 2) and autumn ploughing to a depth of 0.25 m was implemented. The soil was prepared by a seedbed combinator during the spring 2015. Maize was sown on all variants in the production year 2014/15. After germination of maize in May 2015, measurements were done after growth stage of plants BBCH 10, i.e. after first true leaf had emerged. Ploughing was done after the maize harvest in October 2015. In the March 2016, spring barley was sown in the trial field. Measurements were carried out again after the growth stage BBCH 10. There were three basic methods of measurements. Soil infiltration abilities were measured using a ring infiltrometer with a diameter of 0.15 m. The method used was simplified falling-head (Bagarello et al., 2004). Bagarello et al. (2006) converts infiltration into saturated hydraulic conductivity. A known amount of water was poured into an infiltrometer, and soak time was measured (20 repetitions for each variant).

Cone index was another measured item provided by the registration penetrometer PN-10 with a cone having an angle of 30° (area of 100 mm^2), with a depth range from 0.04 to 0.72 m, and with a maximum of 7 MPa. Soil bulk density was measured at three different depths, i.e. 0.05–0.1 m, 0.1–0.15 m, and 0.15–0.2 m, by taking undisturbed soil samples using Kopecky's cylinders of 100 cm^3 that were subsequently analysed in the laboratories of the CULS Prague. Volumetric soil moisture was measured by Theta Probe (Delta Devices). Data were processed by the programmes MS Excel (Microsoft Corp., USA) and Statistica 12 (Statsoft Inc.,USA). Concerning statistical evaluation, a single factor analysis of variance at the probability level of 0.05 was used with a post hoc *Tukey HSD* test.

RESULTS AND DISCUSSION

This paper contains the results of measurements from the seasons 2015 and 2016. Fig. 1 shows weather development in the years 2014–2016 and a ten-year average. Generally, the winters were warmer than the ten-year average. Particularly in the year 2015, the weather was exceptionally dry over the whole vegetative period.

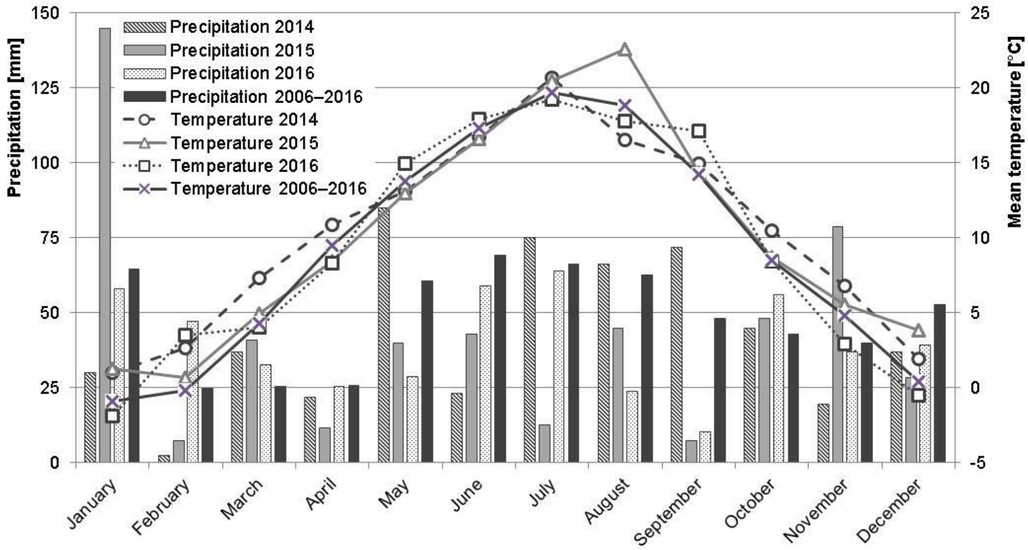

Figure 1. Graph of monthly precipitation and mean temperatures at Lázně Bělohrad in the years 2014–2016 and ten-year averages.

Fig. 2 displays results of saturated hydraulic conductivity measurements. There are noticeable differences among the variants, particularly in the year 2015. These were however lower than the initial prediction, where a statistically significant increase had been expected within the variants with PRP Fix treatment, i.e. Variants 1 and 2. The short exposure of activators and applied manure was probably the cause why it was not possible to clearly demonstrate a beneficial effect of activators on saturated hydraulic conductivity after the first year. Even favourable impact of manure application on this parameter could not be proven clearly. Results of *Tukey HSD* test ($\alpha = 0.05$) showed a statistically significant difference only between the variants 4 and 5 in the season 2015.

In the season 2016, advanced effect was discernible with regard to the measurement of saturated hydraulic conductivity. In comparison with the previous year, increased values, in particular for Variants 1, 2 and 4, were noticeable. The hydraulic conductivity of the control (Variant 6) remained unchanged though. This suggested a beneficial effect of application of organic matter and the activators. Results of *Tukey HSD* test ($\alpha = 0.05$) showed a statistically significant difference only within Variant 4. This extreme increase in the values of Variant 4 could have been caused by an undistributed and slowly (without PRP Fix) decomposing macro-particles of manure, as was observed on site. Macro-particles could significantly increase water infiltration into the soil (Kvítek &

Tippl, 2005). This, however, was not confirmed by Variant 3. All the variants treated by PRP Sol demonstrated an increase in saturated hydraulic conductivity, namely with manure applied as well. Generally, saturated hydraulic conductivity in all variants reached very high levels (Janeček, 2005). Light-textured soil of the trial plot was probably the cause. Subsoil beneath the topsoil drained water quickly into the lower layers, which is typical for light soils (Janeček, 2005). Results of *Tukey HSD* test (α = 0.05) did not prove any statistically significant difference in the season 2016.

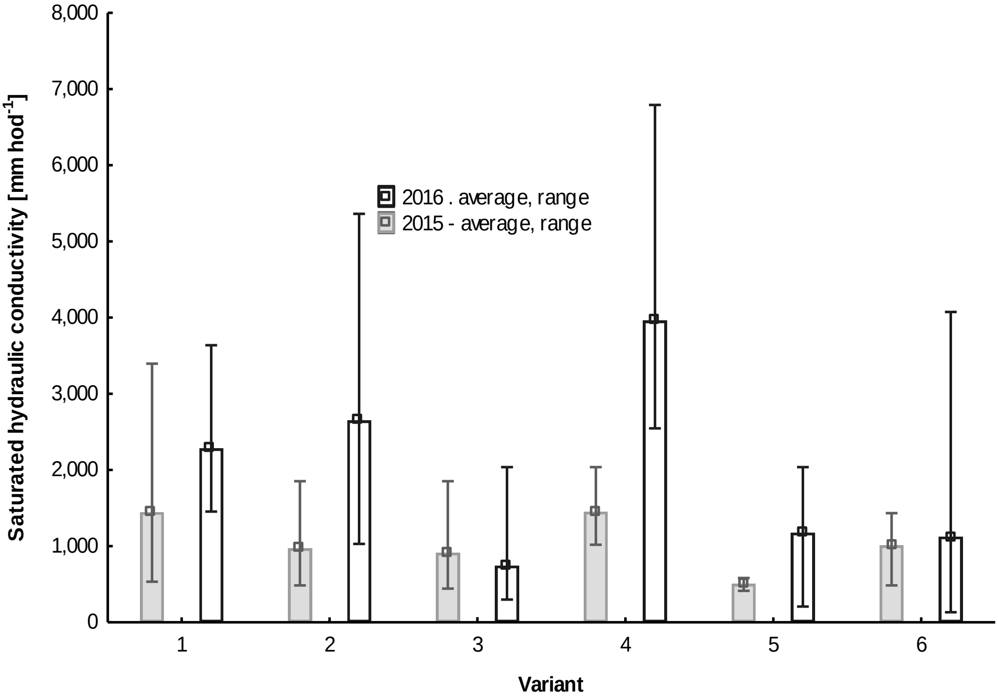

Figure 2. Saturated hydraulic conductivity of all the variants at Lázně Bělohrad in May, 2015 and April, 2016 (mean, minimum–maximum range).

Table 4 presents the values of bulk density of soil in three depths. The figures confirm the initial hypothesis. There is a noticeable positive effect particularly at the surface layer. Bulk density values decreased within the variants, which were influenced by the application of manure and/or activators. Compared to the control variant, the relative drop in values was noticeable particularly in the first year after application at Variants 1 and 2 with manure treated by PRP Fix. From the results, a decrease of soil bulk density with the relation to the application of manure treated by PRP Fix was indicated, though it was not statistically significant.

Table 4. Bulk density at Lázně Bělohrad

Variant	1	2	3	4	5	6
Depth [m]	Bulk density [g cm^{-3}] 15.10.2014					
0.05–0.1	1.35	1.46	1.33	1.33	1.44	1.55
0.1–0.15	1.51	1.47	1.46	1.35	1.41	1.50
0.15–0.2	1.55	1.52	1.55	1.37	1.39	1.61
Depth [m]	Bulk density [g cm^{-3}] 11.5.2015					
0.05–0.1	1.16	1.36	1.25	1.34	1.40	1.53
0.1–0.15	1.37	1.34	1.29	1.32	1.39	1.53
0.15–0.2	1.37	1.44	1.42	1.30	1.36	1.60
Depth [m]	Bulk density [g cm^{-3}] 14.4.2016					
0.05–0.1	1.28	1.36	1.34	1.33	1.35	1.30
0.1–0.15	1.18	1.37	1.26	1.29	1.28	1.34
0.15–0.2	1.39	1.38	1.39	1.30	1.42	1.34

Figs 3–5 describe cone index values of individual variants. The graphs show a similar pattern of cone index development depending on the depth. Measurements from spring were evaluated when possible, i.e. in the years 2015 and 2016, because of more homogeneous soil moisture distribution. In the year 2014, where autumn measurement was the only one available, cone index reached higher values at lower depths. At a depth of about 0.24–0.28 m, a sharper increase in cone index values may have been observed in each season. This increase was caused by the common depth of tillage (loosening). In the year 2014, cone index values were still affected more by the previous way of farming on the land than by the experimental manure application and the use of activators. Simultaneously, cone index values showed absence of compacted layers that could affect ability of water infiltration into the soil. Otherwise, there would have been a sudden increase of cone index values in the rate of MPa (Javůrek & Vlach, 2008). In the next two years, the values of cone index could not prove any positive effect of the application of manure and activators. This was again initiated by the soil type on the property (*Modal Luvisol*). Generally, this soil type shows relatively small values of cone index and a low binding.

Because the absolute values of cone index are influenced by soil moisture, the values were evaluated with regard to the control (Variant 6). Soil moisture measured was the volumetric one, and at the superficial layer of 0.00–0.1 m, its average values were 34.6% during the measurement in October of 2014, 12.3% in May of 2015, and 29.5% in April of 2016. The low volumetric soil moisture value in May of 2015 may imply higher values of cone index. But since volumetric soil moisture accounts also for the volume of air, porous soil would provide lower moisture values than the more compacted one at the same feed of water. This was probably the case of generally lower cone index values in May of 2015.

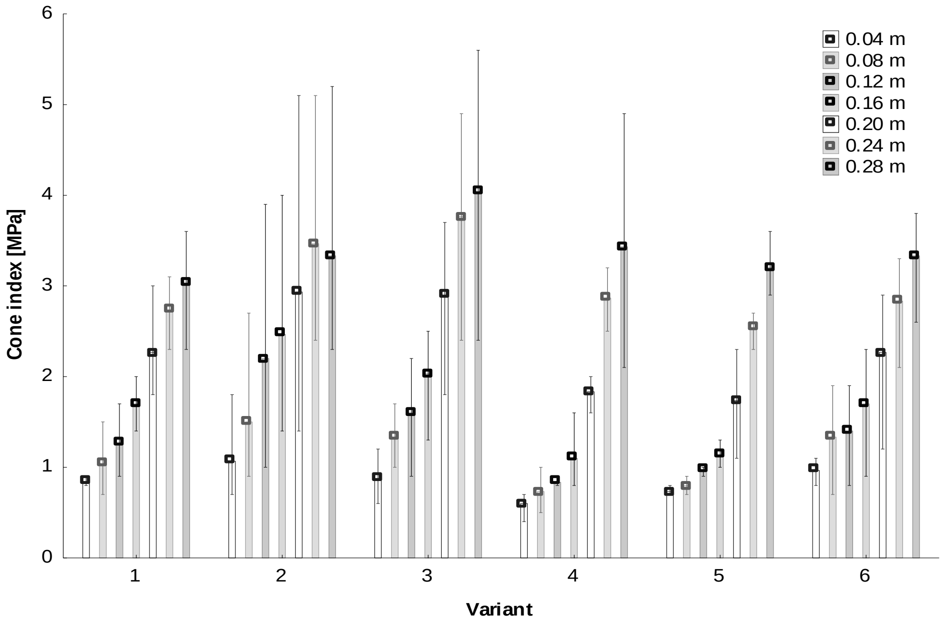

Figure 3. Cone index of all variants at Lázně Bělohrad in October, 2014 (mean, minimum–maximum range).

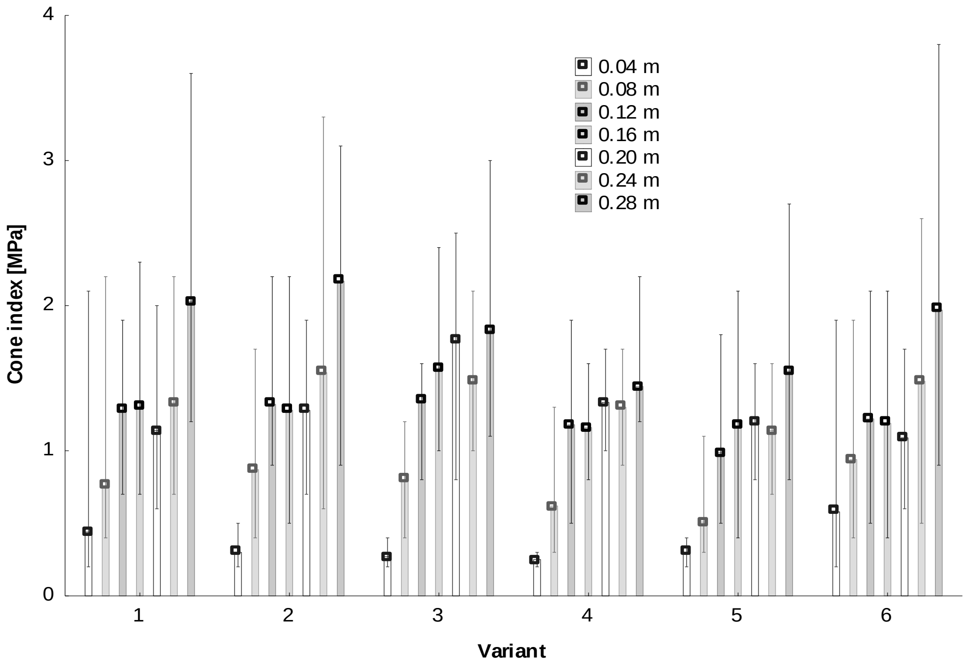

Figure 4. Cone index of all variants at Lázně Bělohrad in May, 2015 (mean, minimum–maximum range).

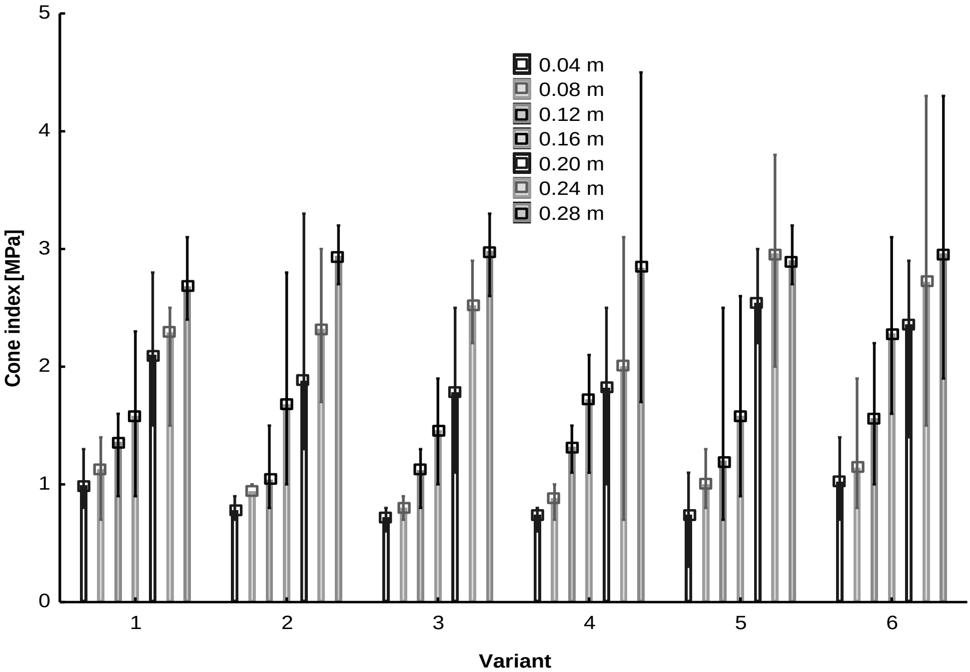

Figure 5. Cone index of all variants at Lázně Bělohrad in April, 2016 (mean, minimum–maximum range).

Light soils, like that of the trial filed, have by themselves exceptionally high rates of water infiltration, and the differences are thus difficult to register. This is consistent with the outcomes of Bagarello et al. (2006) where difficulties of measuring saturated hydraulic conductivity on light soils were found. At high levels of conductivity, the effects of soil tillage, fertilization or the influence of cultivated crops cannot be clearly demonstrated. In accordance with authors' assumptions, Celik et al. (2010) confirmed organic applications to significantly lower the soil bulk density and penetration resistance. However, the assumption was not verified by the results so far.

Beneficial effect of activated organic matter on soil properties and on production potential was confirmed by Barzegar et al. (2002). Bernal et al. (1998) pointed to the gradualness of changes in the soil and to the need for long-term exposure to carbon fixation and microbial activity.

CONCLUSIONS

The impact of the manure and the activators on the value of saturated hydraulic conductivity is difficult to precisely define. One of the factors may be the duration of the experiment. Another, probably more relevant, is the soil texture of the trial field. All the variants treated with manure demonstrated increase of saturated hydraulic conductivity, namely with PRP Sol applied as well. Generally, saturated hydraulic conductivity in all variants including the control reached very high levels, probably due to the light-textured soil of the trial plot.

Changes in soil properties are generally very slow. Favourable effect on soil bulk density was nevertheless observed. This effect was however not confirmed entirely by the cone index values measured. It was not possible to clearly demonstrate the beneficial effects of manure and activators on all three soil physical properties in question. There were two key factors. The first one was the light soil texture of the trial plot, and the second a relatively short duration of the experiment. In order to overcome these problems, the experiment has to be extended to following years and to multiple locations with different soil types. Research requires to be validated in more locations in order to eliminate the influence of the local environment (soil conditions). For future measurements, also other methods may be helpful to use. A brilliant blue dye tracer method appears perspective in this respect for evaluation of infiltration.

ACKNOWLEDGEMENTS. This work was supported by Research Project of the Technology Agency of the Czech Republic no. TA04021390.

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Agronomy Research **15**(2), 576–584, 2017

Reticulo-ruminal pH and temperature relationship between dairy cow productivity and milk composition

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Abstract. The aim of the research was to establish interrelations between reticulo-ruminal pH and temperature, cows' productivity and milk composition (milk fat, protein, lactose, somatic cell count and electrical conductivity of milk) by using specific *SmaXtec* reticulo-ruminal boluses. In the research were included four different age dairy cows in early lactation period. The reticulo-ruminal pH and temperature was measured every 600 sec. over a 79 day period. The milk yield and quality was registered three times per day with automated data recording and management system *Afmilk*. Results showed that reticulo-ruminal temperature brightly demonstrates cow drinking behaviour and did not influence any of the investigated milk parameters. There was established a weak, statistically significant correlation between reticulo-ruminal pH and energetically corrected milk ($r = 0.19$; $P < 0.01$), milk protein level ($r = 0.35$) and a weak negative correlation between milk fat/protein ratio ($r = -0.22$; $P < 0.01$). No relation between reticulo-ruminal pH, milk somatic cell count and milk electroconductivity was observed. Reticulo-ruminal pH fluctuations were at individual ranges for each cow without affecting an individual milk fat/protein ratio despite all of them received the same ration. It seems that milk fat/protein ratio is primarily dependent on the feed composition and properties. In the study was included one cow whose reticulo-ruminal pH was decreased below 5.7 for 400 min. in a day, and it had not had any individual effect on milk fat/protein ratio. That fact indicates to an individual cow tolerance to subacute rumen acidosis.

Key words: reticulo-ruminal pH, reticulo-ruminal temperature, milk composition, productivity.

INTRODUCTION

Subacute rumen acidosis (SARA), when rumen pH becomes too low for long time is a widely spread problem for high yielding dairy cows. High amount of easily digestible carbohydrates are included in dairy cow feeding ration to reach maximal productivity. That kind of feeding balances with ruminant physiological possibility to maintain homeostasis in the rumen and health in general (Krause & Oetzel, 2006). Different pathologies could occur if a cow herd suffers from SARA. The most common problems are immunosuppression, diarrhoea, reduced body condition, laminitis, rumenitis, displacement of abomasum and low milk fat content (Krause & Oetzel, 2006; Enemark, 2007; Gasteiner et al., 2012; Aditya et al., 2016). Various attempts have been applied to diagnose SARA in dairy cattle herds because that condition refers not only to cow health and productivity, but also on cow welfare (Krause et al., 2006). The most popular methods are evaluation of cow chewing activity, fat amount in milk, fat/protein ratio, and incidence of laminitis and examination of rumen fluid. The rumen pH is an important parameter to estimate nutritional and metabolic status in dairy cows (Enemark, 2007; Danscher et al., 2015). Abdela (2016) suspects that rumeno-centhesis remains the most profitable tool to detect SARA in herd. Rumen fluid sample can also be acquired with an oral-ruminal probe or through a rumen fistula (Colman et al., 2010). Repeated sampling is necessary because the rumen pH is a fluctuating parameter. These methods can cause distress for the cows (Danscher et al., 2015). In recent years many companies have elaborated intra-ruminal boluses for non-invasive, long term investigation and monitoring reticulo-ruminal pH and temperature to monitor cow intra-ruminal metabolism (Gasteiner et al., 2012; Sato, 2016).

The aim of the research was to establish possible interrelations between reticulo-ruminal pH and temperature, cow productivity and milk composition (milk fat and protein level, somatic cell count and electrical conductivity of milk) by using specific *SmaXtec* reticulo-ruminal boluses.

MATERIALS AND METHODS

In the research were included four different age dairy cows in early lactation period from 10 to 34 days in lactation over a 79 day period (cow A, B, C, D respectively). All the test cows were kept in the same feeding group and were fed with total mixed ration (TMR). TMR was distributed twice a day at 7.00 a.m. and 14.30 p.m., and it was available *ad libitum*. All cows had free access to drinking water. Average cow body weight (~650 kg) and productivity (~30 kg) were taken as a basis to calculate feed ration. Feed composition was varied: grass and maize silage, barley flour, rapeseed cake, beet pulp, molasses, propylene glycol, 'Optigen', live yeast, macro/micro elements and vitamins. TMR was made from the mentioned components. Dairy cow ration contained 45.4% of dry matter. One kilogram of dry matter contained: crude protein − 16.2%; NDF − 36%; crude oils and fats − 3.7 g; 7.04 MJ; Ca − 7.1 g; P − 4.0 g; Mg − 3.0 g; K − 12.2 g; starch − 222 g and 68 g of sugars. Calculated daily ration for cow's 100 kg body weight was intended to 3.6 kg dry matter which corresponds 23.3 kg of dry matter for one cow.

The research was carried out in the spring-summer season. The specific intraruminal boluses were given orally to monitor reticulo-ruminal pH and temperature every 600 sec., or every 10 minutes over a 79 days period. The indwelling and wireless data transmitting system (*SmaXtec Animal Care GmbH, Graz,* Austria) was used. *SmaXtec* intra-ruminal boluses combine electronic, chemical and radio functionalities. The data of reticulo-ruminal pH and temperature were collected by means of an analogue to digital converter and stored in an external memory chip.

During the study cow ration changes occurred several times. Energetically corrected milk was calculated according to the formula prescribed by Agricultural Data Centre:

$$ECM = milk(kg)x\frac{(0.383xMF\%) + (0.242xMP\%) + 0.7832}{3.140} \qquad (1)$$

where: *ECM* − energetically corrected milk, *MF* − milk fat and *MP* − milk protein.

Data statistical processing was performed with *SPSS* and *Microsoft Excel* was used for graphic figures. The Arithmetic Mean and the Standard Error were the indicators of descriptive statistics. The Pearson correlation coefficient was used for profiling the interrelations among the results obtained in the study.

The milk yield and quality was registered three times a day at 3:00 a.m., 11:00 a.m. and 17:00 p.m. with an automated data recording and management system *Afmilk*. All test cows were at first part of lactation (Table 1).

Table 1. Dairy cows parameters beginning of the research

Parameters / cows	A	B	C	D
Lactation starting day	10	14	31	34
Reticulo-ruminal pH	**6.03**	6.17	6.31	**6.45**
Reticulo-ruminal T °C	38.8	38.8	38.6	38.9
Milk fat%	3.99	3.93	3.69	3.82
Milk protein%	3.66	3.44	3.48	3.55
Milk lactose%	4.38	4.60	4.67	4.58
Milk fat/protein ratio	1.09	1.14	1.06	1.08
Energetically corrected milk, kg	31.1	36.6	33.2	28.3
Cows weight after calving, kg	560	611	649	710

An average ECM from cow was 28.3–36.6 kg in a day. The highest milk fat content was in cows A and B, but the highest milk protein amount was in cows A and D. Level of lactosis in milk was low in all test cows. Milk fat/protein ratio in milk was too low in all cows at the start of the study. Reticuloruminal temperature at the start of study was 38.6–38.9 °C. At the start of the study the lowest reticulo-ruminal pH was in cow A (6.03), but the highest it was in cow D (6.45). Body weight was different in the test cows (A 560 kg; B 611 kg; C 649 kg; D 710 kg). Cows with higher live weight are able to eat more dry matter compared with smaller cows (Rim et al., 2008).

RESULTS AND DISCUSSION

Results showed different individual range fluctuating of reticulo-ruminal pH for each cow despite the similar feeding. Mean pH reticulo-ruminal values overlapped occasionally between cow A and B, all the time between cow B and C, very often between C and D but rarely between A and D (A 6.0 ± 0.05; B 6.2 ± 0.04; C 6.3 ± 0.06; D 6.5 ± 0.05 respectively), (Fig 1).

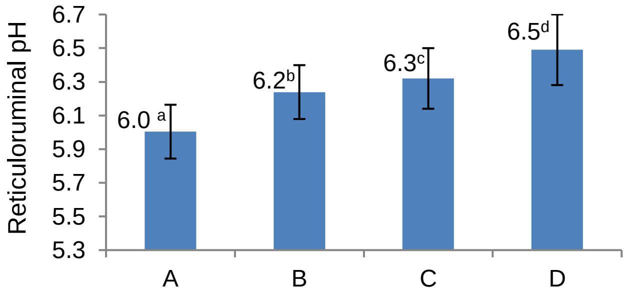

Figure 1. Test cow reticulo-ruminal pH in 79 days period under similar feeding.

Reticulo-ruminal pH was statistically different in all test cows. ($P < 0.05$). Fluctuation of reticulo-ruminal temperature brightly demonstrates cow drinking behaviour and it did not influence any of investigated milk parameters. We found out that cows had drunk 8.5 ± 3.23 times throughout the day. Presence of negative correlation between reticulo-ruminal pH and temperature was found in both healthy and from SARA suffering cows (Sato, 2016). In our study we established weak positive correlation between reticulo-ruminal pH and temperature in cow A ($r = 0.15$; $P < 0.001$), cow B ($r = 0.20$; $P < 0.001$), no correlation in cow C and a weak positive correlation in cow D ($r = 0.22$; $P < 0.001$). Higher ruminal temperature was observed in SARA cows (Wahrmund et al., 2012).

Water drinking was less frequent in night time, but more frequent in day time especially after meals and milking. It is very important not to disturb when the cow wants to drink in a routine round. We were able to evaluate different patterns of drinking and eating behaviour for each cow. Cow A had the lowest reticulo-ruminal pH during the study time (6.00 ± 0.006) and usually she had the most intensive feed intake in night time despite feed being distributed at 7:00 a.m. and 14:30 p.m. each day (Fig. 2).

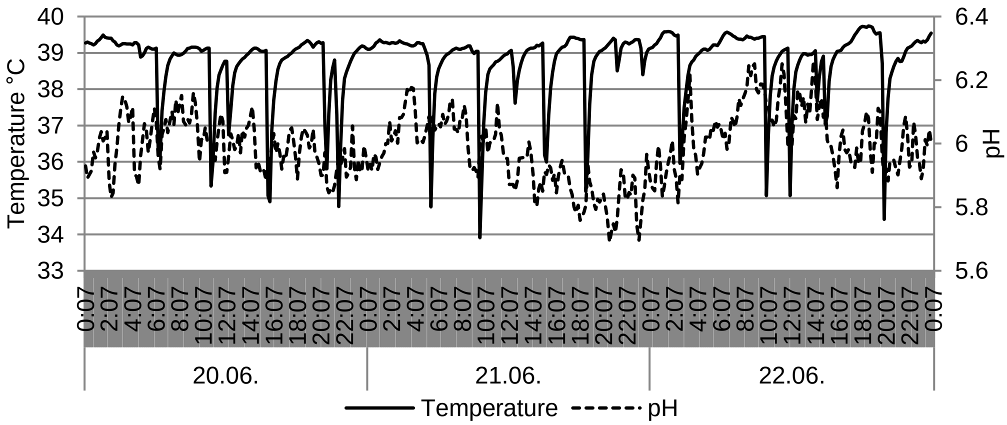

Figure 2. Cow 'A' drinking and eating pattern through three days.

This indicates the importance of feed pushing-up throughout the day to provide ad libitum access to the feed. It especially important if hierarchy problems exist in the herd (Soltysiak & Nagalski, 2010), concerning cow A it clearly seems so and this cow had the lowest body weight in comparison with other test cows. Feed must be offered to cows providing to consume small and frequent meals regularly all the time to avoid SARA (Krause & Oetzel, 2006). Increasing feeding frequency may reduce the risk of SARA and may also increase milk fat (Macmillan et al., 2016).

Cow D had the highest reticulo-ruminal pH during the study time (6.49 ± 0.006) with the most intensive feed intake at 7:00 a.m. when feed was distributed first time in a day. (Fig. 3.)

Cow D had the highest body weight. This cow drank water more frequently than cow A which had the lowest body weight (22 vs. 18 times respectively). These cows had different rumen pH patterns. It depends on eating behaviour throughout the day (Figs 2 & 3).

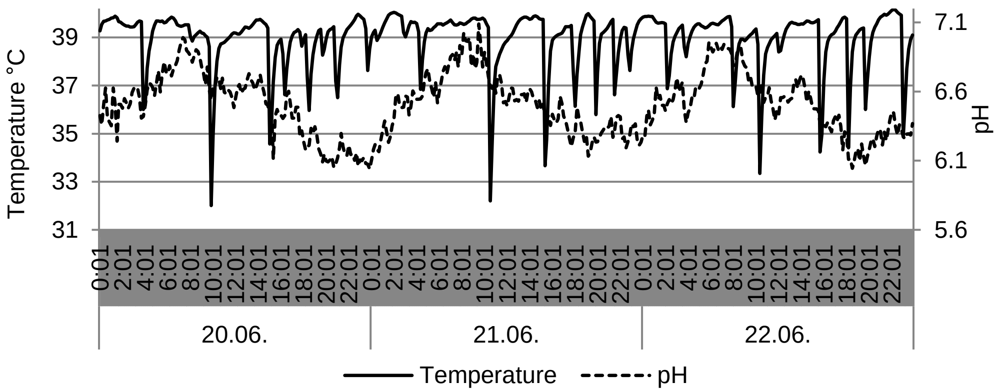

Figure 3. Cow 'D' drinking and eating pattern in a three day period.

All the evaluated parameters between cow A and D were statistically different ($P < 0.05$), except reticulo-ruminal temperature and milk fat content (Table 2). Cow D with the highest body weight had the highest productivity during the study time (average milk in a day 31.5 kg; milk fat 3.18%; milk protein 3.22%). The smallest cow A was a primiparous cow and it had the lowest productivity (average milk in a day 23.0 kg; milk fat 3.07%; milk protein 2.90%) which indicates a low dry matter intake. Both cows were in a lactation phase (45–69 d in lactation) when dry matter intake is important to maintain energy balance.

Table 2. Dairy cows A and D average parameters (20.06.–22.06. 2013)

Parameters / cows	A	D
Days of lactation	45 ± 0.6^{a}	69 ± 0.6^{b}
Reticulo-ruminal pH	6.01 ± 0.041^{a}	6.50 ± 0.015^{b}
Reticulo-ruminal T °C	38.8 ± 0.09	38.9 ± 0.03
Milk fat%	**3.07 ± 0.050**	3.18 ± 0.026
Milk protein%	**2.90 ± 0.066^{a}**	3.22 ± 0.055^{b}
Milk lactose%	4.72 ± 0.038^{a}	4.48 ± 0.007^{b}
Milk fat/protein ratio	1.06 ± 0.006^{a}	0.99 ± 0.021^{b}
Energetically corrected milk, kg	**23.0 ± 0.33^{a}**	31.5 ± 0.07^{b}

^{a,b} – productivity indicators across the tested cows are essentially different; $P < 0.05$.

Milk fat and protein level and fat/protein ratio was not significantly different just between cow B and C, but in cows A and D these parameters were higher ($P < 0.05$). Milk yield was the lowest for cow A (26.1 ± 0.32 kg day^{-1}), which had the lowest reticulo-ruminal pH, it was significantly lower than cow D (29.4 ± 0.34 kg day^{-1}), which had the highest reticulo-ruminal pH. The highest milk yield was in cows B and C, 39.2 ± 0.29 and 31.2 ± 0.31 kg per day, respectively (Table 3). In our study reticulo-ruminal pH and temperature was not an important and statistically significant parameter on the whole productivity for healthy cows.

Table 3. Dairy cows average parameters of the research period

Parameters / cows	A	B	C	D
Average days of lactation	49 ± 2.6^{a}	53 ± 2.6^{a}	70 ± 2.6^{b}	73 ± 2.6^{b}
Reticulo-ruminal pH	6.00 ± 0.006^{a}	6.24 ± 0.005^{b}	6.32 ± 0.007^{c}	6.49 ± 0.006^{d}
Reticulo-ruminal T °C	39.0 ± 1.04	39.1 ± 1.34	39.1 ± 1.29	39.0 ± 1.04
Energetically corrected milk, kg	26.1 ± 0.32^{a}	39.2 ± 0.29^{b}	31.2 ± 0.31^{c}	29.4 ± 0.34^{d}
Milk fat%	3.39 ± 0.038^{a}	3.16 ± 0.027^{b}	3.28 ± 0.025^{c}	3.44 ± 0.025^{a}
Milk protein%	3.11 ± 0.022^{a}	3.27 ± 0.023^{b}	3.34 ± 0.015^{c}	3.30 ± 0.020^{abc}
Milk lactose%	4.76 ± 0.016^{a}	4.66 ± 0.013^{b}	4.82 ± 0.017^{c}	4.79 ± 0.016^{ac}
Milk fat/protein ratio	1.09 ± 0.012^{a}	0.97 ± 0.010^{bc}	0.98 ± 0.008^{bc}	1.05 ± 0.010^{d}

a,b,c,d – productivity indicators across the tested cows are essentially different; $P < 0.05$.

The results show a weak, statistically significant correlation between reticulo-ruminal pH and energetically corrected milk (r = 0.19; $P < 0.01$), milk protein level (r = 0.35; $P < 0.01$) and weak negative correlation between milk fat/protein ratio (r = − 0.22; $P < 0.01$) for all cows together. Statistically significant correlation was not established among reticulo-ruminal pH and any of investigated parameters in cow A except reticulo-ruminal temperature with milk fat (r = 0.32; $P < 0.05$) and milk fat/protein ratio (r = 0.29; $P < 0.05$). In cow B reticulo-ruminal pH negatively correlated with milk fat (r = − 0.37; $P < 0.05$), milk fat/protein ratio (r = − 0.35; $P < 0.05$) and a positive correlation was found with productivity kg (r = 0.26; $P < 0.05$). No correlations were found regarding reticulo-ruminal temperature and investigated parameters in cow B. Similar correlations were found in cow C – reticulo-ruminal pH with milk fat (r = − 0.26; $P < 0.05$), milk fat/protein ratio (r = − 0.29; $P < 0.05$) and productivity kg (r = 0.24; $P < 0.05$). In cow D, which had the highest reticulo-ruminal pH we did not find any correlation among reticulo-ruminal pH and the investigated parameters, but a weak positive correlation was established between reticulo-ruminal temperature and productivity kg (r = 0.28; $P < 0.05$), and energetically corrected milk (r = 0.31; $P < 0.05$).

Daily milk yield did not drop if reticulo-ruminal pH was lower or even if a cow suffered from SARA (Danscher et al., 2015). No relation between reticulo-ruminal pH, milk somatic cell count, and milk electro conductivity was observed.

Cow A with the lowest reticulo-ruminal pH did not have the lowest milk fat/protein ratio. Milk fat/protein ratio is primarily dependent on the feed composition, properties (Esmaeili et al., 2016) and feeding management (Fig. 3).

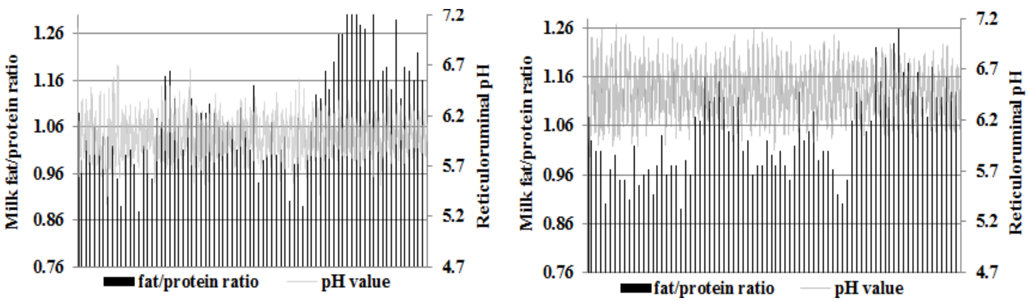

Figure 4. Milk fat/protein ratio in connection with daily reticulo-ruminal pH in cow A and D.

All the investigated cows had a decreased milk fat/protein ratio level most of the test days and it proves that the energy amount in feed is too low (Bergk & Swalve, 2011). It could be one of the evidence parameter of sub-acute rumen acidosis (Rossow, 2003). Milk fat/protein ratio fluctuations from 0.81 up to 1.38 were fixed throughout the study. Appropriate milk fat/protein ratio was fixed just for several days during the study time (Figs 3, 4.).

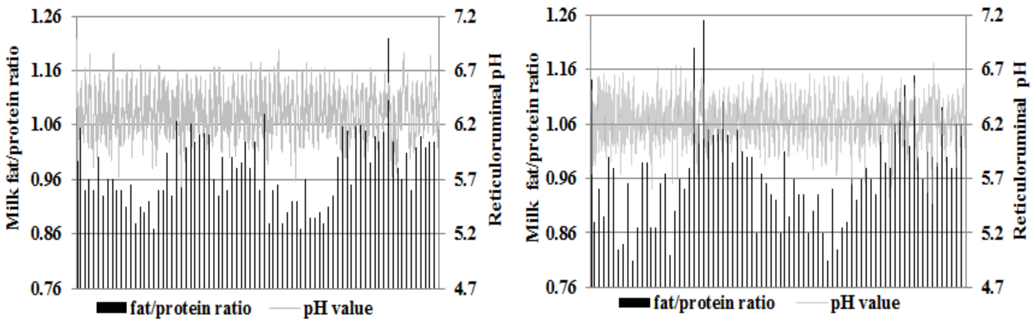

Figure 5. Milk fat/protein ratio in connection with daily reticulo-ruminal pH in cow C and B.

Production traits for 305 days of lactation were established (Table 4). These parameters did not show significant changes regarding milk yield in all cows.

Table 4. Cow productivity through 305 lactation days

Parameters / cows	A	B	C	D
Energetically corrected milk, kg	7,117.7	9,903.2	8,474.4	7,649.0
Milk fat%	4.40	3.61	3.68	3.30
Milk protein%	3.46	3.02	3.30	3.14
Milk fat/protein, kg	531.7	712.7	621.3	551.7

The highest productivity calculated to 100 kg of body weight was in the cow B (1,620.8 kg), then followed cow C (1,305.8 kg), cow A (1,271.0 kg) and cow D (1,077.3). Despite cow A had significantly lower reticulo-rumen pH (6.0) it produced the most amount of ECM calculated on 100 kg of body weight in 305 lactation days. In cow D which had the highest reticulo-rumen pH (6.5) 305 day's ECM production was the lowest. It demonstrates insufficiency regarding to energy in feed appropriate for cow with larger body weight. We did not find any correlation between this calculated productivity and reticulo-ruminal pH and temperature.

Ruminal fermentation changes during SARA are due to a combination of pH and diet effects, so this process could be named as a 'high-concentrate syndrome' (Calsamiglia et al., 2012), because milk fat level and milk fat/protein ratio could not be the main indicators to diagnose SARA in cow herd. No relation between reticulo-ruminal pH, milk somatic cell count and milk electroconductivity was observed.

CONCLUSIONS

Monitoring of the reticulo-ruminal temperature brightly reflects the cows feed and water intake habits. Reticulo-ruminal pH varieties could be in individual ranges for each cow without affecting an individual milk fat/protein ratio despite all of them receiving the same ration. The milk fat/protein ratio and reticulo-ruminal pH did not correlate with milk yield in cows with physiological reticulo-ruminal pH values. It seems that milk fat/protein ratio is primarily dependent on the feed composition and properties, as it was below 0.9 in presence to high and optimal reticulo-ruminal pH. The study included one cow (A) whose reticulo-ruminal pH was decreased below 5.7 for 400 min. in a day, and it did not have any individual effect on milk fat/protein ratio. That fact indicates to an individual cow tolerance to SARA. There weren't found out convincing interrelations between reticulo-ruminal pH and temperature, cow productivity and milk composition to diagnose early consequences of too low reticulo-ruminal pH using *SmaXtec* reticulo-ruminal boluses.

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Agronomy Research **15**(2), 585–593, 2017

Solution for automated bee colony weight monitoring

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Abstract. Future of the traditional beekeeping is to implement Precision Beekeeping approach and implement different automated and smart apiary monitoring systems for remote and optimised bee colony management. Behaviour of the bee colony can be monitored by the use of temperature, humidity, acoustic, video and weight systems. Each measurement system can give its own additional value for recognition of bee colony state. It is useful for the beekeeper to have at least one control colony with weight system equipped in the apiary. The hive scales is an important tool which gives assessment if food consumption has been high and whether there is a need for feeding. In most countries it is important to know how long the winter storage is, in addition it gives a very good indication of periods without any nectar flow. This paper presents conceptual design and prototype of honey bee colony weight monitoring system with GSM/GPRS external interface for packet-based communication with remote server. The central module with scales is placed on one of the hives and consists of temperature sensor, 4 strain gauge load cells for weighting purposes, RF and GSM/GPRS modules, photovoltaic cell array, battery, charge controller and minimal user interface for operational status signalling. The system allows sensor data logging to local storage and periodic data transfer to a remote server for further data analysis in different user applications. Data processing back-end component serves GET requests coming from remote measurement device, performs identification and raw data conversion using configuration stored in database.

Key words: precision apiculture (precision beekeeping), weight monitoring, smart apiary, internet of things.

INTRODUCTION

Recently Precision Beekeeping (Precision Apiculture) scientific sub-branch of Precision Agriculture has been defined (Zacepins et al., 2015). For implementation of PB various technical and measurement systems can be developed. Behaviour and state of bee colony can be monitored by use of temperature, humidity, acoustic, video, weight and other sensors. Each measurement system can give own additional value for recognition of bee colony state. For example, using temperature measurements death, broodless, brood rearing states can be easily detected. It is also clear that monitoring of bee colony weight is significant as well: it is very important for the beekeeper to have at least one control colony with weight system equipped. Electronic hive scales can easily supply the beekeeper / scientist with important information on several important events from honey bee colonies' life cycles (Buchmann & Thoenes, 1990; McLellan, 1977; Meikle et al., 2006). Long-term sensor data analysis and data fusion could also be used to assess development of bee colony.

Very often it is difficult to judge what is going on in honey bee colonies. The hive scale is an important tool and gives a good assessment if food consumption has been high over a longer period and whether there is a need for feeding. In most countries, it is essential to know how long the winter storage period is since it will tell if spring feeding of carbohydrates is needed. In addition, it gives a very good assessment of periods without any flow in the summertime and hence can warn of starvation danger. Finally, it gives a very good evaluation of how intense the nectar flow is, in other words, if there is a need to provide the colonies with additional supplies. Commercial beekeepers use hive scales to save unnecessary visits to the apiary when they do long-distance migration (Human & Brodschneider, 2013).

The weight of an inhabited hive (i.e., the sum of the weight of the box, combs with food stores and the bees) can be measured to monitor the different states of the colonies or to identify several colony events:

- the occurrence of nectar flow during the foraging season (start and end of nectar flow) or daily gain in nectar stores (Meikle et al., 2008; Okada et al., 2012; Human & Brodschneider, 2013);
- consumption of food during non-foraging periods (Seeley & Visscher, 1985);
- the occurrence of swarming events through a decrease in the hive weight (Meikle et al., 2008; Linton, 2012);
- estimating the number of foragers (Linton, 2012).

Important advantages of weight systems are: weighing is fast, requires little training and is not disruptive to the colony so it can be done at any time of year. There are two ways of measuring the weight of the colony: first, automatic measurements can be made using industrial scales, which allows for the continuous measurement of the bee colony weight; and second, simpler scales can be used to take measurements manually.

Weather influence should be taken into account because wooden boxes absorb moisture and thereby bias weight measurements (Meikle et al., 2008). The use of Styrofoam boxes is recommended for more accurate weighing. In the case of wooden hives, it is recommended that the changes in weight of an empty hive (with frames and honey but no bees) are taken into account to clarify the mass changes due to environmental effects such as humidity and wind.

Aim of this research is to develop conceptual design and prototype of honey bee colony weight monitoring system with GSM/GPRS external interface for packet-based communication with remote server. As well financial aspect is taken into consideration, so system should be economically feasible and return of investment coefficient should be high. This system is mainly intended for individual and small scale agricultural beekeepers which have up to 100 bee colonies. Novelty of authors approach is design of scales, optimised data transmission for energy-saving purposes and usage of solar power for system operation even in remote areas.

Review of existing solutions for bee colony weighting

Bee colony weighting is not new and number of dedicated industrial and homemade weighing systems for beekeeping (Human & Brodschneider, 2013), including Beewise (BeeWise, 2013), BeeWatch (BeeWatch, 2013) and CAPAZ (Beehive scale, 2013), indicate the applicability of this approach. Some hive scales also measure wind velocity or sun hours. A state of the art hive scale is designed to automatically transmit these data either directly via internet, to the beekeepers cell phone or to personal computer software. Systems can be used in remote monitoring of hives by communicating weight values using SMS technology accessible from any mobile phone. Due to their relatively high price, the continuous scales used in these systems are not of much interest to beekeepers. In addition, the resolution for measurements made using Beewise and CAPAZ is only 100 g, which is not sufficient for monitoring colonies during the passive state (winter period) when nectar is not harvested and the daily changes in mass do not exceed 100 g.

Other interesting solutions for bee colony weight monitoring are: Hivemind project – Firstly funded on Kick-starter campaign the Hivemind project is a nifty little box designed to remotely track how much honey is in beehives (http://hivemind.co.nz/scales#bottomboard). It uses satellite data transition to send data to Hivemind server. Arnia hive scales – Another commercial product – Arnia remote hive monitoring system which have many monitoring options (http://www.arnia.co.uk/hive-scales/). One of them is hive weight monitoring. Arnia hive scales enables option to remotely monitor how much honey is in bee hives. The hive scales integrate with Arnia hive monitoring system and it is possible to compare hive weight data with colony activity and weather conditions which is an invaluable aid for colony management. Beehive scale XLOG bee – is a SMS/GPRS remote monitoring system that enables data collection from beehives in chosen interval (http://www.microel.hr/products/gprs-sms-beehive-scale-xlog-bee). Data readings are stored in internal memory and sent via SMS/e-mail message directly to beekeeper's mobile phone or via TCP/IP protocol over GPRS data transfer to the server (optionally). In addition to regular measuring reports, special alarm messages are sent immediately in case of alarm situation (beehive theft, sudden increase or decrease in hives weight, overload of the beehive, low battery etc.) to the beekeeper's mobile phone, e-mail address and to the server.

There are also available some homemade systems for continuous bee colony weight monitoring. One solution combines together bathroom scales, instrumentation amplifier, and ATtiny85 microcontroller making a device that could weigh beehive and report the measurements. It is very inexpensive (40–50 USD) for the parts [http://makingthingswork.wordpress.com/].

Another homemade beehive scaling system is based on the simple luggage scale that cost 16 USD (http://www.instructables.com/id/Build-a-scale-to-weigh-bee-hives/). Total costs of such system are under 50 USD. The maximum range of such scales is about 56.7 kg – less than a lot of bee hives. It measures the hive by only lifting one side – and assumed that weight in the hive is more or less centrally distributed. It has a loss in accuracy but maximum range is extended to about 113.4 kg. Disadvantage of such system is that it does not have any data storage or transmission system. Real data can be only seen on scales monitor. Such system is not designed for automation systems developing. It needs to be manually used to make the measurement.

Several interesting initiatives have been set up to determine the nectar flow and share the information with other beekeepers that use Web systems, demonstrating the interest in the exchange of information among beekeepers:

- http://biavl.volatus.de/bsm0/BSM.html# – this Web system monitors colonies from different Nordic countries, including Denmark, Sweden, Norway, Latvia and Germany (Honningmeteret, 2012);
- http://www.vdrb.ch/service/waagvlker.html – this open website enables all users to see colony mass changes in Switzerland;
- http://honeybeenet.gsfc.nasa.gov – the NASA Goddard Space Flight Centre has initiated a project in which the daily weighing of hives by volunteer beekeepers are merged with satellite data (Nightingale et al., 2008).
- http://mybees.buzz/ – this Web system shows data about bee colonies from different Nordic countries, including Denmark, Sweden, Norway, Latvia

Developed automated weighting system

The high costs and inapplicability for outdoor conditions of continuously loaded general purpose electronic scales limit their application. Moreover, the manual weighing of colonies with required frequency is too laborious to perform at the industrial scale. So it is an open market for development of cheap and reliable solutions for automated bee colony monitoring.

Authors of this research developed conceptual design and prototype of honeybee colony weight monitoring system with GSM/GPRS external interface for packet-based communication with remote server. System is based on one main module, which is placed on the hive and consists of temperature sensor, 4 strain gauge load cells for weighting purposes, RF transceiver and GSM/GPRS modules, photovoltaic cell array, battery, charge controller and minimal user interface for operational status signalling. The system allows sensor data logging to local storage and periodic data transfer to a remote server for further data analysis in different user applications. RF transceiver is used to communicate with other sensor nodes to gather and present their data to remote server as well. The automated weighting system presented in this article is part of precision beekeeping system (Zacepins et al., 2017).

As usually beekeepers place their colonies outside the living regions (in open fields, in forests) advantage of authors proposed system is that it can be located in any place where mobile communication network is enabled and there is no need for classic power supply, because it uses the batteries and solar power.

The automated weighting system uses four load cell based sensors (Fig. 1). Total hive weight is calculated by adding 4 force vectors. Rated load of each cell is 50 kg, therefore total maximum weight of hive is 200 kg. The sensors are equipped with round funnel-shaped trays to help position feet of hive in proper position relative to load cell. None to minimum modifications are necessary to construction of bee hive.

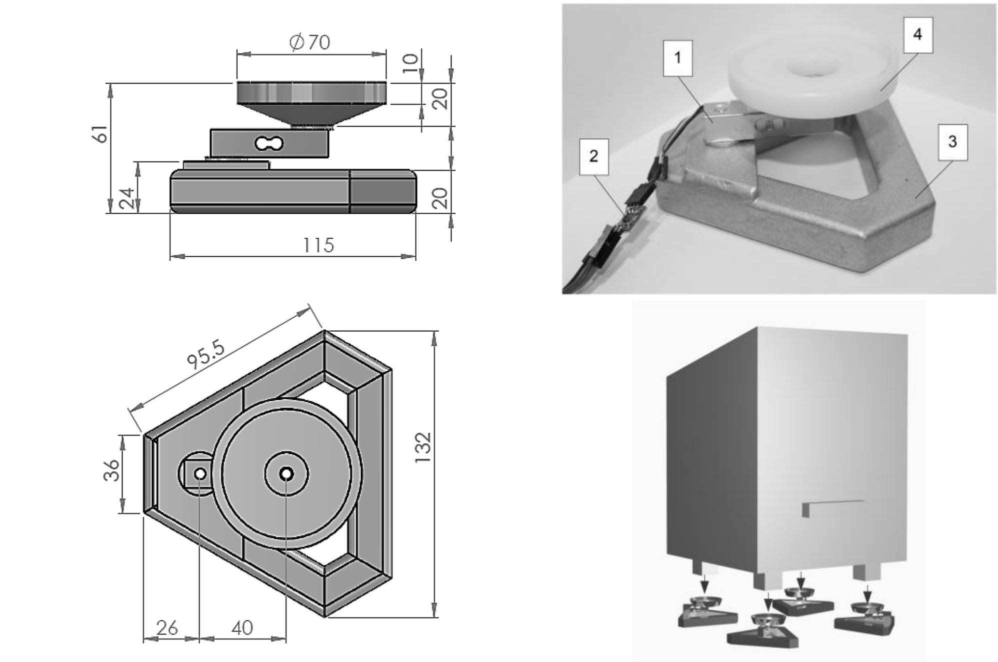

Figure 1. Concept and prototype of beehive automated weighting system sensor: 1 – load cell; 2 – AD converter; 3 – base frame; 4 – hive feet tray.

In order to minimize costs of load cell measurement circuits, analog front-end is positioned right at the each scales module. Signal from strain gauge bridge is measured and converted to digital form using MCP3421 18–bit ADC with I2C digital interface. Digital interface allows lossless data transfer to central logging device use low cost wires. MCP3421 has built-in 8x gain amplifier and voltage reference, therefore minimum external components are necessary. Measurement resolution is 32 g for one load cell, nevertheless calibration with etalon weight for each sensor is necessary. This resolution is enough for beekeepers, because during the active summer period hive weight changes starting from 1 kg up to 10 kg.

Weight measurement is performed with 1 s interval, data is then used by central module to calculate moving average value with 10 minutes step after which the calculated value along with local and remote (if any wireless sensor is used on other hives) temperature measurements are sent to cloud data server.

System components with approximate unit price are summarized (Table 1) below.

Table 1. System components with approximate unit price

Nr.	Name of the component	Quantity (pieces)	Price per piece (EUR)
1	Central data logging module (Zacepins et al. 2017)	1	53.50
2	50 kg Micro Load Cell	4	10.00
3	Base frame	4	7.00
4	MCP3421A0T on PCB and wires	4	2.50
		Total	131.50

The costs for one such system in authors case were approximately 131.50 EUR. System installation, maintenance, data storage, SIM card with appropriate data plan and usage of web system is not taken into account in those calculations.

This developed system can be easily upgraded and extended for example by temperature measurements of the whole apiary, proposed solution for this can be find in other author publication (Zacepins et al., 2017).

Weight data transfer procedure

Measurements from remote measurement node were transmitted to remote server using A6 GSM GPRS module, thus the data could be accessed by using a user-friendly Web application (Fig. 2). Successful operation of the mentioned A6 module requires mobile phone SIM card with data plan. Collected data could not only be used by beekeepers, but also could be accessible by agricultural institutions in order to evaluate overall honey production in the region.

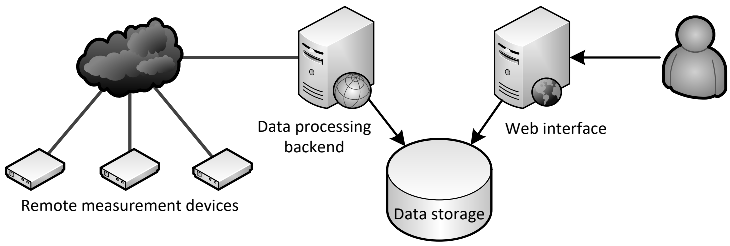

Figure 2. Concept of developed system architecture.

Hypertext Transfer Protocol (HTTP) and GET method are used to send data to server. Transmitted message consists of weight measurement data combined with central module ID, battery and PV voltage status. On server side PHP script retrieves the message, performs data processing and stores measurement information to database (Fig. 3). Data processing includes identification and raw data conversion (in order to save central module resources and power). Also using configurations stored in database allows changing measurement device parameters without accessing hardware (e.g. calibration parameters of load cell).

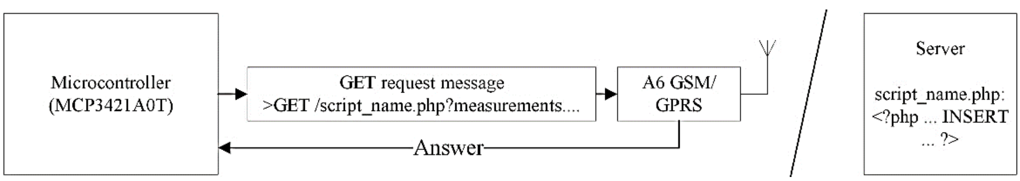

Figure 3. Schematic representation of measurement transmission.

Example of the GET method is shown below:
GET/script_name.php?type=c&devid=1&b=3500&pv=2500&t0=80&w0=2210&w1=2205&w2=2200&w3=2190
After the script is executed, results can be viewed in the developed Web application.

Practical experiments and measurements of bee colony weight

At the beginning, developed system prototype was tested in bee colony wintering building made from metal sandwich panels (Zacepins & Stalidzans, 2012). Unfortunately, it was observed, that data transmission was not stable at all and there was constant GPRS signal loss. Then system was tested in another bee wintering building, which is built from wood. Real system installation can be seen in Fig. 4. It was needed to use additional wood planks to grant stability and balance for the beehive. Measurement results for 30 minute period with 50 sec data transfer intervals are shown in Fig. 5:

Figure 4. Installation of weight measurement system for beehive monitoring.

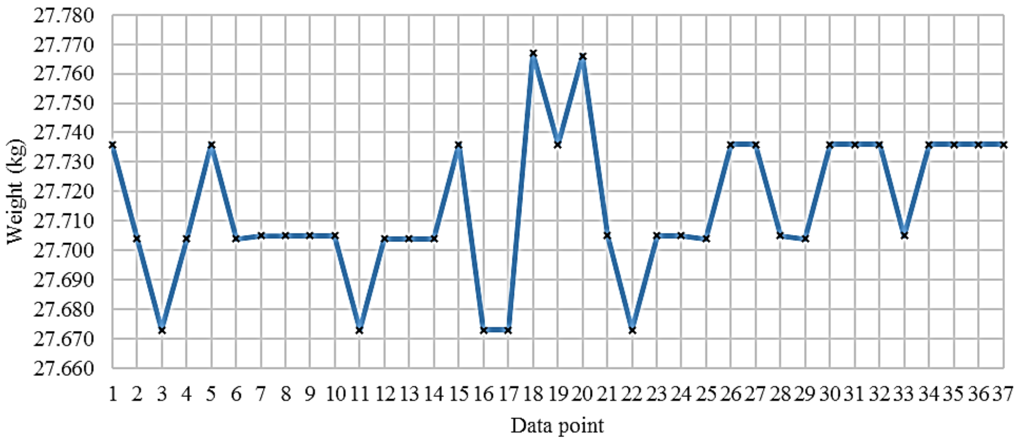

Figure 5. Measured bee colony weight data set.

As measurement period is only 30 minutes, there should be no weight change, but observing the data, some weight fluctuations occurred. Making some basic analysis it can be concluded, that average weight value is 27.715 kg with statistical variance of 587 g. This can be explained by fact, that measurement resolution for one load cell is 32 g, so measurement results can variate maximum by 128 g. This scale precision is enough for monitoring nectar flow during active summer period, but can not be used during the passive winter period, where weight change is less than 128 g.

CONCLUSIONS

Continuous and real time monitoring of bee colony parameters have become a common tool not only for research but also for practical beekeeping as electronic components become easier to deploy and maintain, owing to small, accurate, and robustly designed sensors. Monitoring hive weight allow beekeepers to observe hive health, and during pollination, those data could provide a record of quality control.

Precision Beekeeping is still in developing stage, but already there are various bee colony weight monitoring systems available.

Proposed honey bee weight monitoring system uses 4 load cells for weight measurements, very accurate (± 0.4 °C) temperature sensor and GSM/GPRS external interface for packet-based communication with remote server. Such a system can be set up also in a remote areas, since the main module is energetically self-sufficient and communicates with the database over cell network.

Weight data are sent to the cloud server in a 10-minute interval (containing measurements of weight, temperature and battery level).

For better precision of the weight system, measurement resolution for each load cell should be decreased from existing 32 g to detect weight changes during passive winter period.

Weighing honey bee hives hourly or even more often, using scales, shows data on hive growth and activity, provides precise information on timing and size of different colony events such as swarming, and permits researchers or beekeepers to control for weight changes due to foraging and rainfall.

Described system could also be extended with functionality for hive theft detection or detection of other disturbances (e.g, hives can be damaged by animals).

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Agronomy Research **15**(2), 594–601, 2017

Nitrogen and carbon release during decomposition of roots and shoots of leguminous green manure crops

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Abstract. In Nordic conditions, soils are frozen during winter, affecting the decomposition rates of crop residues. Hence, the decomposition rates of above- and underground biomass and the dynamics of the N and C released into the soil were studied in trials focused on green manure crops. The decomposition of the residue and N release from the residue varied among the five species of legume tested. There was a marked difference in decomposition rates between shoots and roots, which may also be explained by the differences in the chemical composition of the residue. The shoot residue decomposes rapidly and it serves as a source of N for the subsequent crop. The root residue decomposes more slowly and this had a positive effect in a crop rotation in the second year.

Key words: C:N ratio, residue decomposition, N and C release, green manure crops, legumes.

INTRODUCTION

Cultivation of green manure crops in crop rotations has been reintroduced into ecological farming in many European countries, as a substitute for mineral N fertilizers. Through efficient utilization of symbiotically fixed N by legumes in green manure, it is possible to achieve higher yields of subsequent crops. During decomposition, microorganisms use the organic carbon, while nutrients are mineralized and eventually returned to the soil (Brunetto et al., 2011) in forms that are available to plants.

The C and N mineralization rates depend on climatic and soil conditions such as temperature, moisture content, microbial activity, soil pH, aeration status and texture (Ha et al., 2008; Havstad et al., 2010). Mineralization rates also depend on the quality of organic matter (Tejada & Gonzalez, 2006). The main quality properties of the residue that affect mineralization include the C:N ratio, the content of cellulose and lignin (Chaves et al., 2004). A high C:N ratio (> 25) generally leads to immobilization: nitrogen is either immobilised by microorganisms during the decomposition of organic matter or mineralised into the soil as ammoniacal N.

Numerous studies of net N mineralization from decomposing legume residues have been carried out on aboveground biomass of various species in cool climates (Marstorp

& Kirchmann, 1991; Haynes, 1997; Wivstad, 1999; Trinsoutrot et al., 2000; Lupwayi et al., 2006), but there are few studies about N release to soil from roots, none of which is from a boreal or sub-boreal climate (i.e. Chaves et al., 2004; Osanai et al., 2012). The topic is important, because the proportion of plant nitrogen in roots is up to 40% of total plant N (Rochester at al., 1998; Talgre et al., 2009) and when used as fodder for animals aboveground plant parts are not returned to soil.

The objectives of this experiment were to determine the net N and C mineralization from the roots and aboveground residues of red clover (*Trifolium pratense* L.), bird's-foot trefoil (*Lotus corniculatus* L.), lucerne (*Medicago sativa* L.), large-leaved lupine (*Lupinus polyphyllus* Lind.) and white melilot (*Melilotus albus* Med), as typical pasture or green-manure legume crops for Nordic conditions. The data can be used to predict the influence of residue decomposition on soil fertility.

MATERIALS AND METHODS

The trials were carried out during 2007–2010 in the Department of Field Crop and Grassland Husbandry, Institute of Agricultural and Environmental Sciences, at the Estonian University of Life Sciences, (58° 23' N, 26° 44' E). The soil type of the experimental area was sandy loam *Stagnic Luvisol* according to the World Reference Base classification (FAO 2014). The mean characteristics of the humus horizon were as follows: C_{org} 1.1–1.2%, N_{tot} 0.10–0.12%, P 110–120 mg kg^{-1}, K 253–260 mg kg^{-1}, pH_{KCl} 5.9, soil bulk density 1.45–1.50 g cm^{-3}. The humus horizon was 27–29 cm. More detailed description of the experiment is presented in the article by Talgre et al. (2014).

The experimental area belongs to the South-Estonian upland agro-climatic region, where the mean annual temperature is 4.4 °C and total precipitation is 550–650 mm (Tarand, 2003). During the experimental period, rainfall and air temperature were recorded daily at the meteorological station located close (< 1 km) to the experimental area using the Metos Model MCR300 (Pessl Instruments GmbH, Weiz, Austria) weather station. Weather conditions during the study period (2007–2010) differed substantially (Table 1).

Table 1. Monthly precipitation and average temperature during the experimental period (2007–2010).

Month	Air temperatures, °C				Precipitation, mm			
	2007	2008	2009	2010	2007	2008	2009	2010
January	-7.1	-1.3	-3.4	-12.7	29	22	10	3
February	-6.6	0.6	-4.9	-7.9	23	34	7	5
March	-2.4	0.4	-1.5	-2.1	26	8	22	30
April	4.2	7.1	5.3	6.1	33	27	14	26
May	11.6	10.6	11.5	12.6	55	27	13	61
June	15.1	14.4	13.8	14.6	66	110	137	73
July	16.7	16.1	16.9	22.2	72	54	55	36
August	15.6	17.7	15.4	18.2	79	118	89	107
September	10.4	9.8	12.8	11.1	66	46	49	93
October	5.7	8.2	4.1	4.2	52	68	116	49
November	0.3	2.3	2.3	0.8	48	49	36	53
December	-4.2	-1.1	-3.8	-7.7	40	24	41	17

Two trials were carried out: experiment 1 in 2007–2009 and experiment 2 in 2008–2010. Plant species used in the study of experiment 1 were red clover, lucerne, bird's-foot trefoil, and white melilot. In experiment 2 there were red clover, white melilot and large-leaved lupine.

Pure crops were sown at the beginning of May (2007 and 2008). The length of their growing season was 6 months on average. The roots and shoots were collected from field-grown plants before the incorporation of green manure into the soil by ploughing at the end of October. Roots were sampled from a 0.25 m^2 frame, 0–30 cm depth (the main part of the roots being located in this soil layer), and soil was washed from the roots. Samples of aboveground biomass were taken from plot of 0.25 m^2. The roots and shoots were cut into 5 cm pieces. It is equivalent to the effect of the machinery used for green manure crushing before ploughing. Fresh plant residues (25 g) were placed in 20 × 20 cm nylon bags with 1 mm mesh. Corresponding samples were dried, milled and analysed as described below. The bags were buried in a completely randomized design at a depth of 22 cm with 0.3 m spacing at the end of October before ploughing (ploughing depth was 18–20 cm).

After 6, 12 and 24 months of decomposition, 4 bags (representing 4 replicates) for each species and plant fraction (roots and shoots) were selected for measuring the dry matter content and nutrient losses.

Plant materials remaining in the nylon bags at each sampling time were manually separated from soil and organic debris, oven-dried at 65 °C to a constant weight. The oven-dried samples were weighed separately to determine the dry matter losses. Subsequently the samples were ground to pass a 0.5 mm sieve for chemical analysis. Total N and C contents of oven-dried samples were determined by dry combustion method on varioMAX CNS elemental analyzer (Elementar, Germany).

The software STATISTICA 10 (Statsoft Inc., USA) was used for the statistical data analysis. The decomposition data were processed using descriptive statistics. Two-way ANOVA was applied to test the effect of plant species and tissue type (root or shoot). The means are presented with standard deviation (± SE). Tukey tests were used for testing significance of differences between means at $p < 0.05$. A correlation analysis was conducted to quantify the relationships between chemical composition of residue and N mineralization. The level of statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

At the beginning of decomposition process the total N content in green manure plants was 19.1–31.1 mg kg^{-1}. The N concentrations of roots (except in red clover roots in 2008) were significantly higher than those of aboveground plant parts. Carbon concentration of the residues showed also variation: 41–46% for aboveground residues and 38–44% for roots. The C:N ratio and N content of the residues have been suggested as indicators of decomposition rate. The C:N ratio varied considerably among species, while root residue had a lower C:N ratio than shoot residue in all species ($p < 0.05$) (Table 2). White melilot roots had the lowest C:N ratio. Our results about C:N ratio values differ from other studies: Chaves et al. (2004) and Osanai et al. (2012) found that shoot residue had a lower C:N ratio than root residue and shoots contained more N than roots.

Table 2. Dry matter (DM) (g kg^{-1}), C_{tot}, N_{tot} contents (mg kg^{-1}) and C:N ratio of legumes shoots and roots set for decomposition

Green manure crop	Plant part	DM	C_{tot}	N_{tot}	C:N
	2007 (Experiment 1)				
Red clover	Shoots	291 c	447 b	24.7 b	18.1 c
	Roots	342 b	429 c	27.1 ab	15.8 d
White melilot	Shoots	321 bc	465 a	19.1 d	24.3 a
	Roots	373 b	430 c	31.1 a	13.8 e
Bird's-foot trefoil	Shoots	316 bc	462 a	20.4 c	22.6 b
	Roots	402 ab	402 d	26.7 ab	15.1 de
Lucerne	Shoots	434 ab	457 b	21.2 c	21.6 b
	Roots	460 a	441 b	25.7 ab	17.1 c
	2008 (Experiment 2)				
Red clover	Shoots	251 b	415 a	21.1 ab	19.7 b
	Roots	258 b	399 b	19.3 b	18.7 bc
White melilot	Shoots	371 a	428 a	19.3 b	22.1 a
	Roots	216 b	395 b	24.1 a	16.4 c
Large-leaved lupine	Shoots	188 c	410 a	21.3 ab	19.2 b
	Roots	264 b	380 b	20.7 ab	18.5 c

Within each column and year, the mean values with different letters are significantly different (Tukey test, $p < 0.05$).

N release rate is usually considered to depend on the C:N ratio. For optimal growth of the degrading microorganisms, C:N ratios of 25–35 are usually suitable during the initial phase (Biddlestone et al., 1994). Legume residues generally have low C:N ratios, which is in accordance with our study: C:N ratio was 14–20 in roots and 18–24 in shoots. Low C:N ratio is generally associated with higher mineralization rates (Franzluebbers & Hill, 2005; Brunetto et al., 2011). The highest C:N ratio was observed in white melilot shoots. The residues with high C:N ratio are generally reported to have negative effect on the N availability (Trinsoutrot et al., 2000). Our research results confirm earlier results (Kumar & Goh 2000; 150), that C:N ratio of shoots is negatively correlated with N mineralization ($r = -0.75$, $p < 0.05$). Osanai et al. (2012) found no relationship between N mineralization and C:N ratio of residue despite the clear relationship observed between residue decomposition and C:N ratio of residue. Lupwayi et al. (2006) found that percentage of N released was positively correlated with N concentration, but our results did not confirm this. Our results also indicate a marked difference in decomposition rates between shoots and roots, which may be attributed to differences in the chemical composition of the residues. While the C:N ratio of aboveground biomass is higher than that of the roots, the nitrogen was also released from the aboveground biomass at a higher rate. Soon and Arshad (2002) found that the decomposition of roots was not controlled by the C:N ratio. Hence, the rate of crop residues decomposition cannot be explained only by the C:N ratio (Hofmann et al. 2009). This may be due to the fact that root material containing lignified tissues and other structural components, provides more recalcitrant material than shoots (Rasse et al., 2005). Moore et al. (1999) and Rasse et al. (2005) have reported that lignin:N ratio is an important factor influencing decomposition and it is lower in residues that are more easily biodegradable.

During experiment 2 (colder winter), the crop residues decomposed more slowly than in experiment 1. In experiment 1 55–59% of initial nitrogen and up to 48% of initial carbon remained in the residues after 6 months (Figs 1a and 2a). In experiment 2, the initial decomposition rate over the winter period was slower and depending on the species up to 75% of nitrogen and 57–68% (shoots) and 88% (roots) of carbon remained in the residues after 6 months (Figs 1b and 2b). The effect of climatic conditions on the decomposition rate of biomass and nutrient release was also seen by Soon & Arshad (2002). Legume roots decomposed more slowly than aboveground residue ($p < 0.001$). After 6 months the total C mineralization of the root residue was lower than that of shoot residue (Fig. 2).

Between 6 and 24 months, the nitrogen was released more slowly from the aboveground biomass of birds-foot trefoil and lucerne roots than from other species in trial ($p < 0.05$) (Fig. 1a). The slow decomposition rate of lucerne has been also observed by Harris & Hesterman (1990), whose results showed that lucerne residues did not provide significant amounts of N to a succeeding barley crop. It may be due to the lignification of root material, which led to slow decomposition and later N availability. De Neergaard et al. (2002) found that the lignin content in roots of clover is 2.5 times higher than in shoots.

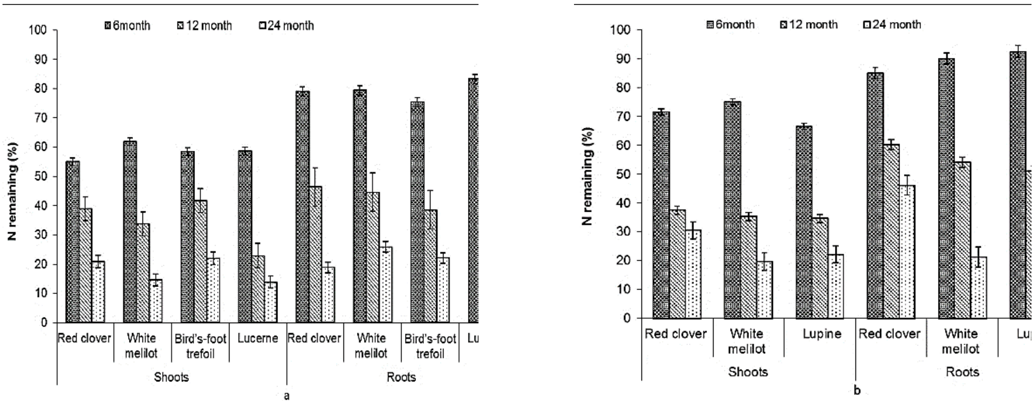

Figure 1. Nitrogen remaining in biomass (%) after 6, 12 and 24 months of decomposition in experiment 1 (a) and in experiment 2 (b). Vertical bars denote standard deviation (± SE).

In experiment 1 (Fig. 1a), 24 months after the beginning of decomposition, 20% of the initial N content remained in the shoots of red clover and birds-foot trefoil and 27% in roots of white melilot. C concentrations were still highest in residues of lucerne roots ($p < 0.05$). In experiment 2, where decomposition rate was lower, significantly more N remained in red clover residue compared to white melilot (Fig. 1b). At the end of the experiment there were still 12–21% of the initial C content remained in the shoots and 19–25% of initial C left in the roots.

During relatively warm winters (average temperature from February to March above 0 °C), crop residues decomposed faster than in cold winter conditions (average temperature from December to March below 0 °C), because little or no microbial activity takes place below 0 °C. Green manure should be ploughed into the soil in late autumn or early spring, in order to minimise the leaching of N. Lahti & Kuikman (2003) suggested that the incorporation of green manure crop should be at the onset of soil freezing to reduce the potential for N leaching.

Depending on biomass the green manure crops fixed up to 206 kg N ha^{-1} (Talgre et al., 2012) and up to 3.8 t ha^{-1} C (Talgre et al., 2009). As the legumes have an impact on almost all the chemical and physical properties of the soil, their effect is not limited to one year (Reeves, 1997). Our previous trials (Lauringson & Talgre, 2010) have shown that the higher decomposition rate of red clover has an effect on the yield of following crop. Thus we suggest that the effect of nitrogen provided to the soil with red clover would be higher after one year whilst the nitrogen left in the soil after lucerne and melilot would have a greater impact during the second year. Kanal (2005) found that the decomposition was influenced by the depth of ploughing and occurs faster in the top soil layers. Viil & Võsa (2005) found that the decomposition of green manure crops was faster in lighter and more fertile soils than in heavier and less fertile ones.

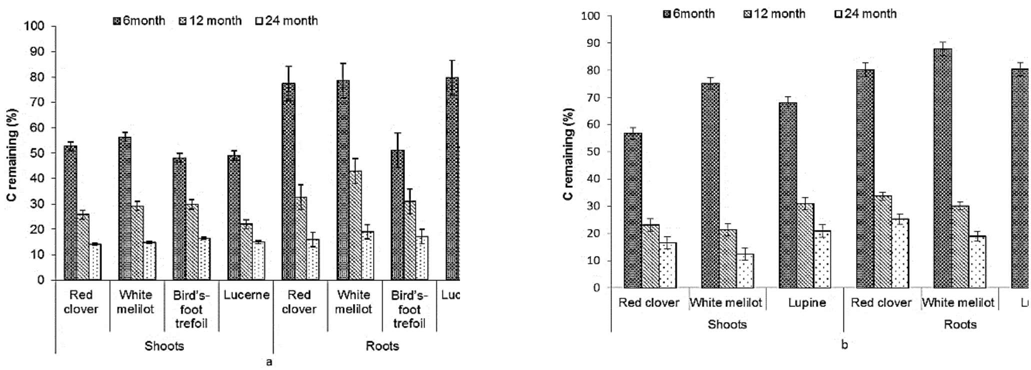

Figure 2. Carbon (%) remaining in aboveground biomass and roots after 6, 12 and 24 month decomposition in experiment 1 (a) and experiment 2 (b). Vertical bars denote standard deviation ± SE).

CONCLUSIONS

Our results showed that the rates of decomposition of residues and of N release from the residues were significantly different among plant species. After 12 months the overall N and C release from the lucerne roots was 35% of total N and 50% of total C, on average, which was lower than for the roots of red clover and birds-foot trefoil. N and C release is not only influenced by the chemical composition and decomposition time of the residues, but also by weather conditions. The root and shoot residues of green manure crops differed in their chemical composition and their N and C release patterns. We demostrated that shoot residue decomposes more rapidly than root residue.

ACKNOWLEDGEMENT. This research was supported by the Ministry of Agriculture of the Republic of Estonia within the framework of project 'Researching methods of regulating humus status and nutrient balance of soil and phytoproductivity of various green manure crops in conventional and organic farming'.

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Agronomy Research **15**(2), 602–614, 2017

Effect of altitude and vacuum pressure on flow rate of vacuum pumps on milking machines driven by gasoline engine and a generator

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Abstract. The objective of this study was to compare the performances of two vacuum pumps driven by an internal combustion (gasoline) engine (Vacuum Pump 1) and a generator powered electrical motor (Vacuum Pump 2) under different altitude and vacuum pressures. The vacuum pumps delivering a flow rate of 350 l min^{-1} at 50 kPa vacuum pressure were tested, which are commonly used in bucket type milking machines. Atmospheric pressures, maximum vacuum pump pressures, and air flow rates at milking pressures (38–50 kPa) were measured at altitudes from 0 to 2,000 m with 200 m increments. Maximum pump pressure reduced by 3.8, 11.3, and 19.9% for Vacuum Pump 1 at altitudes of 400, 1,200, and 2,000 m, respectively whereas Vacuum Pump 2 had 4.4, 12.3, and 20.4% less maximum pressure at the same altitudes. Air flow rate (457.7 l min^{-1}) of Vacuum Pump 1 at the sea level at 38 kPa working pressure reduced by 22.7% at the altitude of 2,000 m. The air flow rate reduced more (28.1%) at the operating pressure of 50 kPa for Vacuum Pump 1 at 2,000 m, compared to the sea level. Similarly, for Vacuum Pump 2, the measured flow rate at 38 kPa showed 19.1% reduction at 2,000 m while at 50 kPa the air flow rate reduced 26.4%, corresponding to 352.3 l min^{-1}. Differences in the air flow rates of vacuum pumps 1 and 2 under different vacuum pressures were insignificant ($P > 0.05$). However, the effect of altitude and vacuum pressure on measured air flow rates was significant for each pump at 5% level. The regression equations were also obtained for atmospheric pressure-altitude, maximum pump pressure-altitude, air flow rate-altitude, and air flow rate-pump vacuum-altitude. High determination coefficients that were found for these relationships suggest that pressure setting can be accurately done as the altitude at which milking needs to be changed without suffering from air flow rate during milking with bucket type machines.

Key words: Milking machine, vacuum pump, gasoline engine, generator, altitude, pump pressure, air flow rate.

INTRODUCTION

Vacuum is simply described as the air pressure less than atmospheric pressure (Chambers, 2004). Since the air in the atmosphere constantly applies pressure on earth due to the weight of the air, vacuum can only be created using vacuum pumps. Vacuum pumps are used in many different industrial areas and also used in animal production in the milking machines. The milking process is accomplished due to the vacuum (negative pressure) created in the pump.

The pressure needed in the milking unit may be from 36 kPa to 50 kPa depending on the animal type and the height of the milk transportation line. The processes such as sucking the milk from the animals, transportation of the milk to the bucket or the storage tank, and carrying the cleaning fluids through the conduits are done using the vacuum generated by the vacuum pump in the milking system (Unal, 2013).

Piston pumps, turbine type pumps, and vane type pumps are usually used as vacuum pumps in milking machines. In recent years, the use of piston pumps has been abandoned and turbine types have limited usage. Thus, the most common type of vacuum pump used for milking is the rotary/pallet type pumps (Mein et al., 1994; Southern California Edison, 2005; Unal, 2013).

Vane type pumps usually have 4 to 6 vanes, rotating around the rotor of the pump (Mein et al., 1995; Bilgen & Oz, 2006; Unal, 2013). The pump is usually powered by an electrical motor while in the absence of electricity a generator, internal combustion engine or power take-off of a tractor is also used.

The pressure that can be delivered by a vacuum pump can be determined either by using the pump characteristics curves or experimentally for a given vacuum pump. Literature was not abundant on the relationships among the flow rate, varying altitudes and pressure values in the milking machines. The performance of a vacuum pump is mainly affected by the altitude. Altitude changes the atmospheric pressure, resulting in reducing vacuum pressure that can be accomplished by a vacuum pump. While perfect vacuum cannot be obtained, in some industrial applications vacuum pumps are expected to evacuate at least 95% of the air in a tank and in some medical applications this rate needs to be greater than 99.9% (Ohio Medical Corporation, 2015). However, the efficiency of a vacuum pump may be much lower depending on the design, sealing, and operation conditions. In order to correct the performance of a vacuum pump, readily available specification sheets may be used (Anver Corporation, 2002). But, since the efficiencies of vacuum pumps differ, the maximum available flow rate and vacuum pressure of a specific vacuum pump needs to be determined experimentally. Another factor affecting the vacuum pump performance is the air temperature. The effect of air temperature on measured vacuum pressure can be corrected, but usually is neglected (Chilvers & Love, 1986). Therefore, this study focuses on a specific milking machine and attempts to determine the behaviour of the vacuum pump of the milking machine in the field conditions.

In milking, the capacity of a vacuum pump mainly depends on the number of milking units and altitude at which the milking takes place. Other factors affecting the milking pump capacity are the type of cleaning unit, automatic cluster remover, pulsator type, and air leaks in the system (Chilvers & Love, 1986; Unal, 2013; TS ISO 5707, 2014).

Small scale dairy production is generally dominant in underdeveloped or developing countries. For instance, the number of bucket type milking machines in Turkey was 292,405 in the year 2015 whereas the number of parlor milking systems was 9,744 (TSI, 2015) Eighty per cent of the dairy farms is small size (1–50 cows), 17% is mid-size (50–100 cows), and only 3.5 is big size farms (> 100 cows) (TSI, 2015). Most small enterprises use bucket type milking machines driven by electrical motors and encounter problems due to risk of electricity cut offs or are unable to use electricity in areas far from villages. Furthermore, there are many farmers living at mountainous areas with altitudes up to 2,000 m causing reduced air flow rates in the vacuum pumps.

Literature did not reveal abundant information on experimental results on the performance of bucket type milking machines at different vacuum pressures as a result of altitude change. In this study, two vacuum pumps were considered driven by a gasoline engine and a generator for areas where electricity may be out of reach for various reasons. The objectives of this study were to:

1) measure and compare the air flow rate capacities of two milking machines, i.e. gasoline engine operated (Vacuum Pump 1)and generator operated (Vacuum Pump 2) vacuum pumps, both bucket type, at altitudes ranging from 0 to 2,000 m and milking pressures from 38 to 50 kPa,

2) determine the number of milking units that can be used at different altitudes and pressure settings.

MATERIALS AND METHODS

Two vacuum pumps with the same air flow capacity were used in the study. The pumps used in the experiments are usually used on bucket type milking machines. The first vacuum pump was driven by an internal combustion (gasoline) engine (VP1) while the second one was used with a generator (VP2). Power transmission was done using a pulley in both vacuum pumps. Technical specifications of the vacuum pumps and the power sources are given in Table 1.

Table 1. Technical specifications of the vacuum pump, generator and gasoline engine

Feature	Value
Vacuum pump	
Pump type	Oil type, fibre vane pump
Vane number and vane dimensions (LxWxT)	4 / 120 x 45 x 5 mm
Stator diameter and length	∅ 110 x 120 mm
Rotor diameter and length	∅ 92 x 120 mm
Pump inlet and outlet diameters (mm)	∅ 34 / ∅ 27
Pump air capacity	350 l min^{-1}
Electrical engine	
Power (Single Phase)	1.1 kW
Voltage, Current, Frequency, Cycle	220 V, 8.0 A, 50 Hz, 1,400 rpm
Generator	
Power (Single Phase)	3.0 kVA
Voltage, Current, Frequency, Cycle	231 V, 13.0 A, 50 Hz, 3,000 rpm
Gasoline engine	
Engine type	Single cylinder, 4 stroke, air-cooled
Maximum power	3.5 HP (at 3,600 rpm)
Fuel tank capacity	1.8 l
Belt pulley unit	
Electric engine and pump pulley diameters (Generator)	∅130 / ∅120 mm
Engine and pump pulley diameters (Gasoline Engine)	∅100 / ∅130 mm
V belt number x width x length	1 x 13 mm x 875 mm

For the ease of operation, both pumps were mounted on a common frame (Fig. 1) and installed at the back of a pick-up truck. All measurements were done with the vacuum pumps on the truck during the testing.

Air flow rates were measured at different altitudes with 200 m increments starting at the sea level up to 2,000 m. The experiments were conducted in Bursa Province, started in Mudanya town at sea level (2.0 m) and ended near the top of Uludag Mountain (2,012 m).

The measurements were done at vacuum pressures from 36 to 52 kPa with 2 kPa increments. As a result, the measurements were done at 11 different altitudes and 9 different vacuum pump pressures. The pressure range used in this study was selected based on the animal species to be milked. The pressure requirement for sheep milking is about 36 kPa and greater pressures are needed for goats, cows, and water buffalo. The second reason for choosing the pressure range of 36 to 52 kPa is that pressure may go up to 50–52 kPa in high rise milking machines and systems (Mein et al., 1995; Unal, 2013).

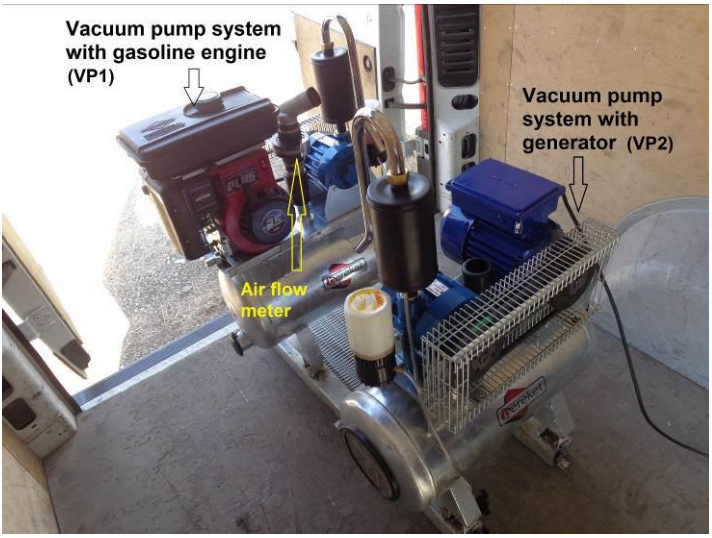


Figure 1. VP1 and VP2 driven by gasoline engine and generator, respectively.

Before the experiments, an orifice type manuel flow meter (AM 3000) was installed on the inlet line of the vacuum pump to make flow rate measurements, which had a capacity of 3,000 l min^{-1}. Vacuum changes of the pump were monitored using a digital vacuum meter (DVPM-01) with 0.1 kPa precision, mounted on the flow meter via a hose.

At each elevation, first the maximum pump pressure was measured by closing all air ports on the flow meter. Then, the air flow rate was measured at the pressure levels that are of interest. The measured parameters were the altitude, gage atmospheric pressure, relative humidity, and air temperature. Altitude and atmospheric pressure were measured using a digital device (OREGON RA123) that can measure altitudes up to 10,000 m with 1 m precision. Atmospheric pressure was measured in hPa and was converted to kPa (1 hPa = 0.1 kPa). Relative humidity and temperature were measured by using a thermo-hygrometer with 0.1 °C and 1% precision, respectively.

Vacuum pumps were set to 50 kPa (TS ISO 5707 and TS ISO 6690 standards) and the pump rotational speed was measured using a digital scope with 1.0 rpm precision.

The rotational speed of the gasoline engine was adjusted to be the same as the generator to compare the results of two vacuum pumps.

Attention was paid to make measurements at exactly 200 m increments from the sea level. However, it was not always possible to stop at the exact altitude desired for the measurements. The vehicle carrying the test units could be stopped within –13 m and + 12 m deviations from the targeted altitude.

The regression equations were found for the relations between altitude and atmospheric pressure, altitude and maximum pump pressure, and maximum vacuum pump pressure and gage atmospheric pressure to determine the appropriate operating conditions for the milking machines at different altitudes.

Maximum number of milking units was calculated using the air flow rates obtained at each operating condition (Billon, 2004; Bilgen & Oz, 2006; TS ISO 5707, 2014; TS ISO 6690, 2014). The factors used for this purpose were reserved capacity (80 + 25n), air flow requirement of milking unit (35n), regulation loss (35 l min^{-1}), 1st subtotal, correction factor based on altitude (0–300, 300–700, 700–1,200, 1,200–1,700, and 1,700–2,200 m), 2nd subtotal, air leak ((2nd subtotal/0.95)*0.05), total air capacity of vacuum pump at each altitude (2nd subtotal + air leak) (l min^{-1}) where n is the number of milking units.

The experiment data were analysed using a factorial with completed randomized design and three replicates ± standard error (SE). The results were processed by the MINITAB (Version 14, University of Texas, Austin, USA) and MS-Excel software programs. One way analysis of variance and LSD test MSTAT_C (Version 2.1., Michigan State University, USA) software program were used to analyse the results. Differences were considered significant at $P < 0.05$, unless otherwise specified.

RESULTS AND DISCUSSION

The altitude and the atmospheric pressure values were measured first at targeted altitudes. The measurements could not be done exactly at 200 m and its multiples during the experiments due to the inconveniences of the mountain road conditions. The difference between the desired and measured altitudes (Fig. 2) was about ± 1–2% and was assumed to be negligible in the calculations.

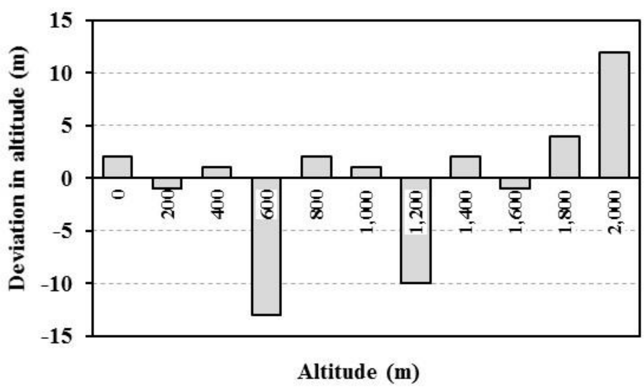


Figure 2. Deviations from the desired altitudes at the measurement locations.

Measurements started in the morning about 10.00 am with 27.7 °C air temperature, rising up to 30.6 °C at about noon at the altitude of 600 m. Then the air temperature kept decreasing with 16.3 °C at 07:00 pm at the altitude of 2,000 m. Relative humidity was 52% at the sea level while it was 31% at the highest point of the measurements. Fig. 3 shows the measured air temperature and relative humidity readings during the experiments. These values were reported to give a general idea about the test conditions in this paper.

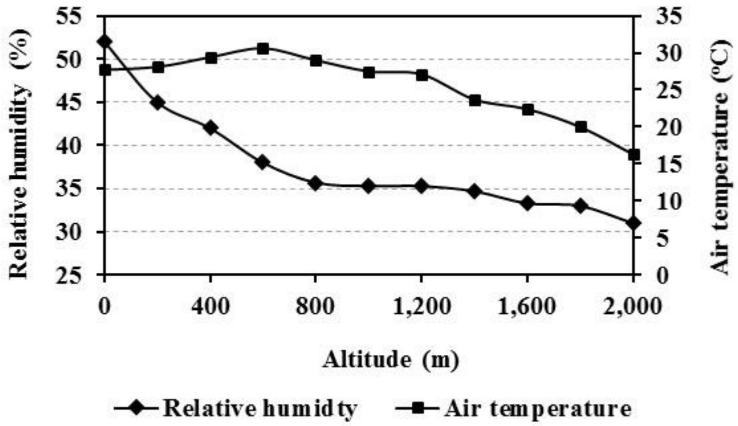


Figure 3. Measured relative humidity and air temperature as a result of altitude change.

Measured atmospheric pressure was measured to be 1006.9 hPa (100.69 kPa) at sea level and linearly decreased down to 793.6 hPa (79.36 kPa) at about 2,000 m (Fig. 4). It was calculated that atmospheric pressure decreased by 4.6, 9.2, 13.0, 17.1, and 21.2 %, respectively at 400, 800, 1,200, 1,600, and 2,000 m, compared to the sea level. Obviously it was not really necessary to measure the pressure as a function of altitude in this study since the same data could be obtained by using the universal physical rules. This evaluation was done not to confirm the governing physical rules but to verify the accuracy of the experimental devices and methods used in the study.

According to the measured data, the atmospheric pressure linearly varies with the altitude, as also well-known from the literature (Chambers, 2004). Based on experimental results, the dependence of atmospheric pressure on altitude could be calculated by using Eq. 1:

$$P_{atm} = 100.29 - 0.0106H \quad (R^2{:}0.998) \qquad (1)$$

where: P_{atm} – atmospheric pressure (gage pressure), kPa; H – altitude, m.

The linearity is very high between the altitude and the atmospheric pressure with a determination coefficient of 0.998, showing that Eq. 1 could be used to calculate the atmospheric pressure as function of altitude with high accuracy.

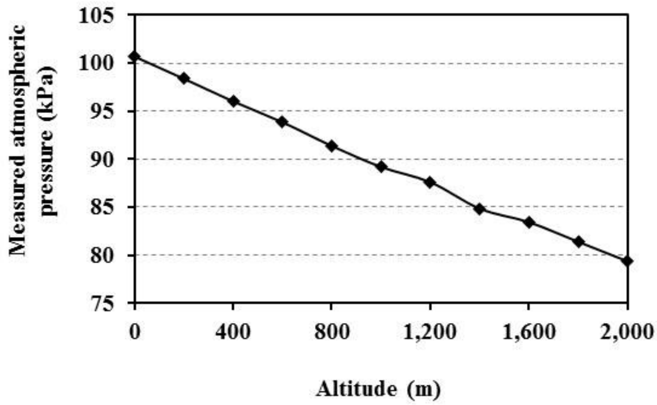


Figure 4. Measured atmospheric pressure as affected by the altitude.

Maximum pressures of vacuum pumps were given in Table 2 with 400 m increments up to 2,000 m. Although VP2 had higher measured vacuum pressures at all elevations, the difference between the two vacuum pumps was not significant ($P > 0.05$) except for altitudes of 0 and 1,600 m.

Table 2. Maximum pressure changes of vacuum pumps at different altitudes (DF = 11–24, F = 446.19, $P < 0.05$)

Altitude (m)	Maximum vacuum pump pressure (kPa)	
	VP1	VP2
0	94.3 ± 0.3^{b}	95.3 ± 0.1^{a}
400	90.7 ± 0.6^{c}	91.0 ± 0.3^{c}
800	86.7 ± 0.1^{d}	86.6 ± 0.1^{d}
1,200	83.7 ± 0.1^{e}	83.5 ± 0.1^{e}
1,600	79.3 ± 0.1^{g}	80.3 ± 0.7^{f}
2,000	75.6 ± 0.0^{h}	75.8 ± 0.4^{h}

The relationships between the altitude and the maximum vacuum pump pressure for VP1 and VP2 are given in Fig. 5, showing that maximum pump pressure decreases linearly with increasing altitude. The greatest vacuum pressure for VP1 was found at sea level with 94.3 kPa and the smallest pressure was 75.6 kPa at an altitude of 2,000 m. Maximum pump pressure decreased by 3.8, 8.0, 11.3, 15.9, and 19.9 % at altitudes of 400, 800, 1,200, 1,600, and 2,000 m, respectively. For VP2, maximum and minimum pump pressures were 95.2 and 75.8 kPa, respectively at sea level and at 2,000 m. The pressure dropped by 4.4, 9.0, 12.3, 15.6, and 20.4%, respectively at 400, 800, 1,200, 1,600, and 2,000 m, compared to sea level.

The relationship between the maximum pressures of the vacuum pump (P_{pmax}, kPa) and altitude was given in Eq. 2:

$$P_{pmax} = 94.6 - 0.0094H \quad (R^2{:}0.992) \tag{2}$$

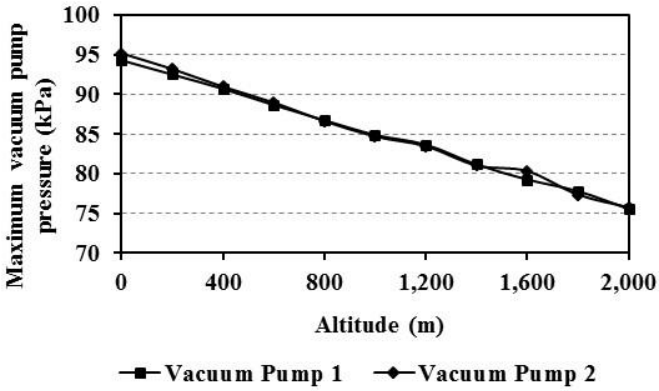


Figure 5. Maximum pressure and altitude relationships of VP1 and VP2.

Maximum vacuum pressures and true air pressure relationships were shown in Fig. 6 and can be calculated using Eq. 3:

$$P_{pmax} = 5.49 + 0.888P_{atm} \quad (R^2{:}0.992) \tag{3}$$

Therefore, maximum vacuum pump pressure can be calculated accurately using measured atmospheric pressure due to high determination coefficient.

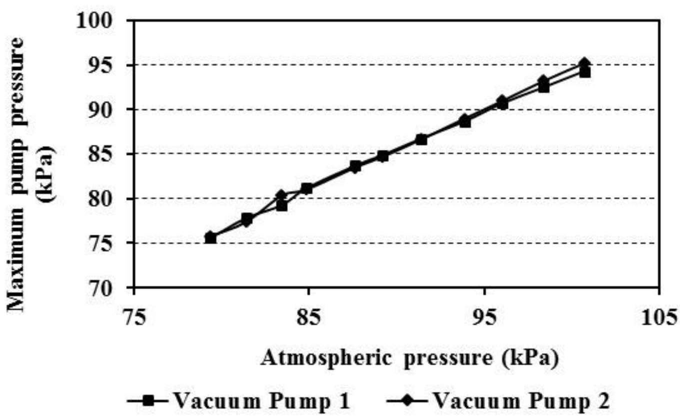


Figure 6. Maximum pressure and true air pressure relations of VP1 and VP2.

Air flow rates of vacuum pumps from 0 to 2,000 m at different vacuum levels were given in Table 3. The air flow rate of VP2 was greater than that of VP1 at a given altitude and vacuum pressure. The difference between the two pumps was found to be statistically significant at each altitude and vacuum level ($P < 0.05$). Also, the air flow rate decreased with increasing vacuum pressure at a given altitude.

Table 3. Air flow rates of vacuum pumps at different altitudes (means ±SE)

Altitude (m)	Vacuum pressure (kPa)	Air flow rate ($l\ min^{-1}$) VP1	VP2	Statistically data
0*	38	458 ± 2.6^{b}	466 ± 1.2^{a}	DF = 7–16
	42	412 ± 2.2^{d}	423 ± 0.3^{c}	F = 829.26
	46	373 ± 1.9^{f}	385 ± 0.6^{e}	P < 0.05
	50	336 ± 2.1^{h}	352 ± 0.7^{g}	
400	38	436 ± 1.7^{b}	452 ± 2.6^{a}	DF = 7–16
	42	389 ± 1.9^{d}	406 ± 1.2^{c}	F = 668.57
	46	349 ± 1.3^{f}	367 ± 2.9^{e}	P < 0.05
	50	313 ± 1.2^{h}	336 ± 1.5^{g}	
800	38	410 ± 1.2^{b}	434 ± 2.2^{a}	DF = 7–16
	42	371 ± 1.2^{d}	389 ± 3.3^{c}	F = 430.77
	46	332 ± 2.0^{f}	349 ± 3.3^{e}	P < 0.05
	50	296 ± 1.8^{h}	319 ± 2.2^{g}	
1,200	38	388 ± 1.8^{b}	415 ± 2.2^{a}	DF = 7–16
	42	346 ± 1.9^{d}	367 ± 1.2^{c}	F = 686.54
	46	310 ± 2.9^{f}	329 ± 1.9^{e}	P < 0.05
	50	276 ± 0.9^{h}	297 ± 0.9^{g}	
1,600	38	369 ± 2.3^{b}	395 ± 0.9^{a}	DF = 7–16
	42	331 ± 1.5^{d}	348 ± 1.7^{c}	F = 633.10
	46	289 ± 0.7^{f}	310 ± 1.2^{e}	P < 0.05
	50	258 ± 3.7^{h}	278 ± 1.2^{g}	
2,000	38	351 ± 2.4^{b}	377 ± 1.8^{a}	DF = 7–16
	42	312 ± 2.3^{d}	334 ± 2.9^{c}	F = 507.74
	46	275 ± 2.0^{f}	291 ± 1.9^{e}	P < 0.05
	50	242 ± 1.8^{h}	259 ± 1.2^{g}	

*A separate statistical LSD test was conducted for each altitude. Results refer to %5 confidence level.

Air flow rate values of the vacuum pumps at different pump operating pressures and altitudes are given in Fig. 7. Air flow rate decreased linearly with increased vacuum pressure setting and altitude. When VP1 was set to 38 kPa at the sea level, the measured flow rate was 458 $l\ min^{-1}$ whereas the flow rate decreased to 397 $l\ min^{-1}$ and 351 $l\ min^{-1}$, respectively at 1,000 and 2,000 m. When the pressure setting was increased to 50 kPa, the measured air flow rates were 336, 287, and 242 $l\ min^{-1}$, respectively at 0, 1,000, and 2,000 m. Similar patterns were observed for VP2 with greater flow rates compared to VP1. For instance, the flow rates at 50 kPa were 352, 311, and 259 $l\ min^{-1}$ at 0, 1,000, and 2,000 m, respectively. Measured flow rates showed significant reductions as a result of the combined effect of increased vacuum pressure and altitude.

Standard vacuum is considered to be 50 kPa in milking operations (Mein et al., 1994 and 1995; TS ISO 5707, 2014; TS ISO 6690, 2014). As shown in Fig. 7, a & 7, b, linear decrease occurred in the flow rates in both vacuum pumps as the altitude was increased. Eqs 4 & 5 were derived from these data enabling the calculation of flow rate as a function of altitude:

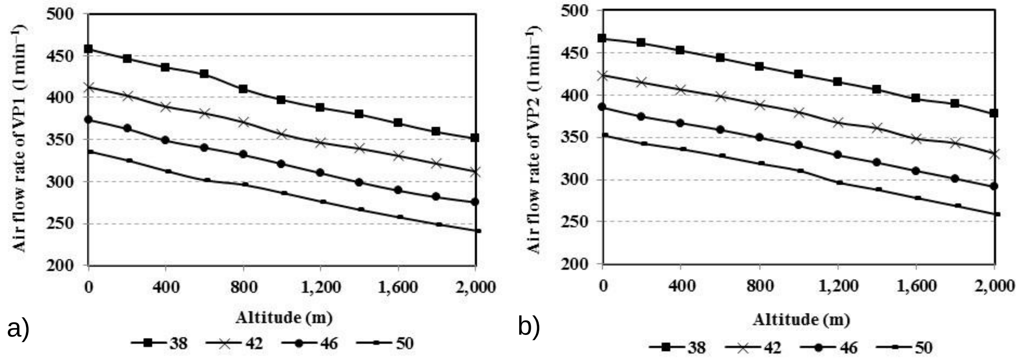


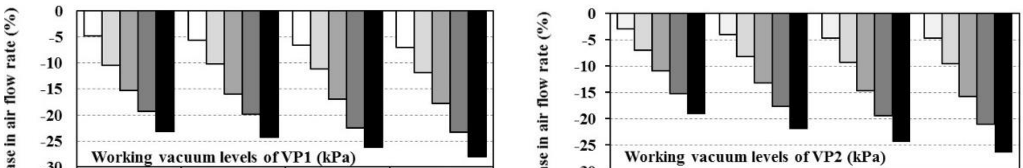
Figure 7. The effect of altitude on air flow rate of vacuum pumps at pressure range of 38–50 kPa for VP1 and VP2.

$$Q_{vp1} = 333 - 0.0469H \quad (R^2: 0.997) \tag{4}$$

$$Q_{vp2} = 354 - 0.0470H \quad (R^2: 0.997) \tag{5}$$

where: Q_{vp1}, Q_{vp2} – air flow rates of VP1 and VP2, respectively, at a vacuum pressure of 50 kPa, l min^{-1}.

It was calculated that air flow rate of VP1 reduced 6.9, 17.8, and 28.1% whereas the reductions were 4.6, 15.8, and 26.4% for VP2 at 50 kPa, respectively at 400, 1,200, and 2,000 m (Fig. 8).



Working vacuum levels of VP1 (kPa)	38	42	46	50
400	-4.7	-5.6	-6.6	-6.9
800	-10.4	-10.1	-11.2	-11.8
1,200	-15.3	-16.0	-17.0	-17.8
1,600	-19.3	-19.8	-22.5	-23.3
2,000	-23.2	-24.3	-26.3	-28.1

Working vacuum levels of VP2 (kPa)	38	42	46	50
400	-3.0	-4.0	-4.8	-4.6
800	-7.0	-8.2	-9.3	-9.6
1,200	-10.9	-13.2	-14.6	-15.8
1,600	-15.2	-17.7	-19.4	-21.0
2,000	-19.1	-21.9	-24.3	-26.4

Figure 8. Air flow rate losses of the vacuum pumps at different altitudes and working pressures.

Fig. 8 explains that when moved from sea level to 400 m, at a pressure setting of 38 kPa, flow rate of VP1 reduced 4.7% whereas the reductions were 5.6 and 6.9% at 42 and 50 kPa, respectively. It was demonstrated that at a given altitude, the increase in the pressure setting reduced the flow rate that can be supplied by the pump. At 2,000 m the air flow rate losses increased up to 23.2, 24.3, and 28.1% at 38, 42, and 50 kPa, respectively. When air flow rate losses were evaluated for VP2, similar trends were obtained to those of VP1, however the changes in the flow rate was not as high as VP1. For instance, during the operation of VP2 at 38 kPa at 400 m, the air flow rate loss was 3.0% whereas the air flow rate loss was 4.7% for VP1 in the same operating conditions. Also, at the highest altitude (2,000 m), the flow rate reduction of VP1 was 26.4% at

50 kPa whereas the loss in flow rate was 28.1% for VP1 under the same conditions. For both VP1 and VP2, whilst the change in air flow delivery was found to be significant ($P < 0.05$) in relation to pump pressure and altitude, the air flow rate capacity based on altitude*pump vacuum interaction was insignificant ($P>0.05$).

Multiple regression equation was obtained for VP1 and VP2 to determine the air flow rate capacities of vacuum pumps as a function of altitude and operating pressure:

$$Q_p = 826 - 0.0482H - 9.67P_p \quad (R^2\text{: } 0.963) \qquad (6)$$

where: Q_p – air flow capacity, l min^{-1}; P_p – operating pressure of the vacuum pump, kPa.

This equation can be used to determine the air flow rate that can be delivered by the vacuum pump at altitudes from sea level to 2,000 m with operating vacuum pressure rage of 38–50 kPa. However, Eq. 6 is only valid for vacuum pumps with air flow rate capacity of 350 l min^{-1}.

Table 4 shows that VP2 can operate one more milking unit compared to VP1 in about half of the cases (eleven out of twenty four), depending on altitude and vacuum pressure setting of the pump. In case of VP2, at vacuum pressure of 42 kPa, six milking units can be operated at sea level whereas only three units can work simultaneously at 2,000 m. When the vacuum setting needs to be higher, for instance 50 kPa, the number of milking units reduce to 4 and 1, respectively at sea level and 2,000 m. The effect of increasing vacuum pressure and altitude was the same on the number of milking units for VP1, too. However, as shown in Table 4, it is not likely to do milking at 50 kPa at 2,000 m using VP1.

Table 4. Maximum number of milking units that can be operated at different altitudes and operating vacuum pressures

Altitude (m)	Vacuum pump 1				Vacuum pump 2			
	Vacuum pressure (kPa)							
	38	42	46	50	38	42	46	50
0	7	6	4	3	7	6	5	4
400	6	5	4	3	7	5	4	4
800	6	4	3	2	6	4	4	2
1,200	5	3	3	2	6	4	3	2
1,600	4	3	2	1	5	3	2	1
2,000	4	2	1	--	4	3	2	1

In this experimental study, it was showed that the changes in altitude and vacuum pressure requirement for a given milking operation had effect on air flow rate capacity of vacuum pump used in practice. Attention should be paid in vacuum pump sizing for a milking machine in that air flow rate losses caused by increased altitude or operating pressure determines the number of milking units to be installed on a milking machine.

CONCLUSIONS

Two vacuum pumps [internal combustion engine operated (VP1) and generator operated (VP2)] used on bucket type milking machines were tested to determine the effect of altitude and pressure setting on the deliverable flow rate.

Maximum pressure of VP1 at sea level was measured to be 94.3 kPa and reduced linearly with increasing altitude resulting in 75.6 kPa a 2,000 m. The corresponding vacuum pressure values were 95.2 kPa and 75.8 kPa for VP2, respectively, which were statistically the same ($P > 0.05$) for both pumps. Maximum vacuum pressure 2,000 m reduced approximately 20% for both machines.

At operating vacuum pressure of 50 kPa, VP1 delivered air flow rates of 336, 287, and 242 l min^{-1} and VP2 delivered 352, 311, and 259 l min^{-1}, respectively at sea level, 1,000 m, and 2,000 m. At 2,000 m, the flow rates reduced 28.1 and 26.4% in VP1 and VP2, respectively. The reduction in the flow rates were greater than the rate of pressure drops (about 20%) at the same altitudes.

VP2 had greater air flow rates compared to VP1, demonstrating that one more milking unit can be operated compared to VP1 in about half of the pressure an altitude settings used in the study.

As a result of this study, it can be recommended that the flow rates of vacuum pumps should be accurately determined at different vacuum pressure and altitudes to determine how many milking units can actually be operated at given conditions. Both the altitude and the pressure setting had an effect on the flow rate reduction. The loss in the pump flow rate should be taken into the consideration when the milking machine is to be sized or selected for a specific application.

ACKNOWLEDGEMENTS. The authors would like to thank to Tarimak Company for providing the vacuum pumps, transportation, and technical support during this study.

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