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Legumes in the diet of dairy cows from the economic perspective

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Abstract. Based on the experimental data, one can conclude that feed rations may comprise peas var. 'Bruno' and faba beans var. 'Lielplatone' grown in Latvia, thereby replacing the use of imported soybean cake. After summarising the results of trials, one can conclude that the diets comprising only one kind of legumes (peas or beans) were the most economically efficient, while the highest production efficiency was achieved if incorporating 22–24% 'Lielplatone' faba beans into the diet for dairy cows. In Europe and Latvia, foods of animal origin comprise, on average, 45% of the total agricultural output value; an essential role in the production of the foods is played by the supply of protein-rich feedstuffs to the livestock industry. An analysis of the factors influencing productivity in dairy farming shows that a diet is the most important factor that promote or hinder the functioning of the inherited genetic potential. In order to meet the dietary energy, protein and mineral requirements of cows, the cows have to be fed a diet according to their physiological condition. In recent years in many countries, research investigations into protein sources have been conducted, as a high protein content of feedstuff is the most expensive component of a feed ration. For this reason, their use in livestock diets might be economically inefficient and therefore the key focus has to be placed on opportunities to increase the content of protein in domestically produced feeds.

Key words: dairy feeding, legumes, economic assessment.

INTRODUCTION

The development of dairy farming is determined by a number of agro-ecological, social and economic factors (Fraser et al., 2007; Paulesich et al., 2007), which influence this industry's profitability, competitiveness as well as sustainability in the economic aspect. These factors may be attributed not only to the industry as a whole but also to individual processes taking place in livestock farming, including livestock feeding, as well as feedstuffs used.

Animal feeding and dietary components are one of the key factors influencing profitability in livestock farming. An analysis of the factors influencing productivity in dairy farming shows that a diet is the most important factor that promote or hinder the functioning of the inherited genetic potential. One of the factors limiting the absorption of feed by a cow is the cow's ability to absorb the dry matter of the feed. Adult cattle

consume on average 1.8–2.6 kg of dry matter per 100 kg live weight, which, to a great extent, depends on feed quality (Ositis, 2005). Given the varying live weight of cattle, the dry matter requirement is a relatively constant value, yet the energy and protein contents of the dry matter vary depending on expected cattle productivity. To produce the quantity of milk reported in 2016 (978 thousand tonnes), 107–115 thousand tonnes of crude protein are necessary for dairy cows (producing 1 kg of milk requires 100–140 g of crude protein) (Report on Latvia's..., 2016).

According to an analysis of production costs, the cost of feed is the key component (Lawrence et al., 2008; Hansen & Gale, 2014), yet a detailed analysis of production costs indicates that the highest proportion of production costs relates to imported feed and its components, while the proportion of cost of domestic feed is insignificant. To meet the protein requirement, in addition to grain, by-products of food processing have been widely used in animal diets, adding feedstuffs suitable for a particular species to the feed ration. However, the production of by-products in Latvia cannot meet the need for protein in livestock farming. In contrast, imported protein-rich feedstuffs are expensive, and feeding such feedstuffs to livestock might be economically inefficient; therefore, the key focus has to be placed on increasing the protein content in domestic feed. According to studies by the Food and Agriculture Organisation (FAO) and the European Commission's responsible institutions, the use of regional (local) protein crops in the agriculture of EU Member States can provide the supply of feed at higher quality and more efficiently. For this reason, opportunities for the use of domestically grown protein crops for feed in dairy farming have to be assessed in order to minimise the cost of diets for agricultural animals.

The research aim was to assess the economic efficiency of domestic faba beans and peas used in diets of dairy cows.

MATERIALS AND METHODS

The economic efficiency of use of faba beans and peas grown in Latvia for dairy cow diets was assessed employing the experimental method, i.e. the faba beans, peas and their mixture were added to the diets, and the dietary component examined represented the key factor affecting the productivity of the dairy cows. The analytical research employed the monographic method, analysis and synthesis, data grouping etc. The research used findings of the research project 'Enhancing of Legumes Growing in Europe through Sustainable Cropping for Protein Supply for Food and Feed' (EUROLEGUME).

The feeding experiment on dairy cows was performed through two replications per treatment in the winter period (from November to February) in Malpils municipality (Latvia), on the farm 'Plakupi', in 2014–2015 and in Sigulda municipality (Latvia), on the farm 'Upites', in 2015–2016. The cows were kept under the tied-housing system, milked twice a day at an interval of 12 hours. By using the following indicators: the milk yield in the previous lactation, the lactation phase, the live weight, the average daily milk yield in the previous monitoring month and the milk fat and protein contents, four analogous cow groups were formed; each group comprised five experimental animals (n = 5).

The basic feed ration was the same for all the experimental groups. The control group (4th group) was fed a diet with soybean cake, while the experimental groups were fed diets comprising 20–24% 'Lielplatone' faba beans (3rd group), 20–24% 'Bruno' peas (2nd group) and a combination of 10–12% 'Lielplatone' faba beans and 10–12% 'Bruno' peas (1st group), reducing the amount of soybeans in their diets (Table 1).

Table 1. Experimental design of the dairy cow feeding trials conducted in 2014/2015 and in 2015/2016 (amount of peas and beans in the protein feed)

Experimental group	Conditioned feeds	Crude protein from soybean cake, g kg^{-1} feed	Crude protein from beans and peas, g kg^{-1} feed
1st group	CF + 10–12% *Pisum sativum* 'Bruno' + 10–12% *Vicia faba minora* 'Lielplatone'	-	66.8
2nd group	CF + 20–24% *Pisum sativum* 'Bruno'	-	63.3
3rd group	CF + 20–24% *Vicia faba minora* 'Lielplatone'	-	69.8
4th group[c]	CF + 14% soybean cake	72.1	-

CF – conventional feed (different grains and rapeseed cake); [c] – control group.

Milk yield as well as fat and protein contents of milk were measured, cost per unit of production (total cost divided by total production) and feed cost per kg of milk production, as well as average indicators for the experimental groups were calculated to perform the economic assessments. Differences in the average values of milk yield were identified by comparing the productivity indicators for the experimental and control groups, as well as by comparing the productivity indicators for the initial and final stages of the experiment.

The economical aspect of dairy cows is determined not only by their productivity but also their live weight. The higher a cow's weight, the more the cow consumes feed to maintain its living functions, which does not contribute to milk production but increases milk production cost. To compare the milk yields of cows relative to the live weights of the cows, relative milk yields were calculated, which represent the amount of energy corrected milk (ECM) a cow can produce if measured per 100 kg live weight.

The quantity of milk produced was identified by measuring productivity – standard litres of energy corrected milk, which was calculated by the following formula (Garcia et al., 2006):

$$ECM = Milk\ Yield \times \frac{0.383 \times Milk\ Fat, \% + 0.242 \times Milk\ Protein, \% + 0.7832}{3.14}, \quad (1)$$

where *ECM* – energy corrected milk.

The milk productivity of cows was calculated by the following formula:

$$\text{Milk productivity} = \frac{ECM, kg}{Body\ weight, kg} \times 100 \quad (2)$$

The breeds of dairy cows may be objectively compared only if the cows are kept on the same farm, under equal feeding, housing and exploitation conditions and if they have similar milk yields. Since the feeding experiment was carried out on different farms, the economic results of the feeding experiment were examined for each trial without summarising the experimental results.

The data were analysed by a Mann-Whitney test at the significance level $\alpha = 0.05$ to identify differences in comparison with the control group (Montgomery, 2012). All statistical analyses were performed using SPSS for Windows version 20.0.

RESULTS AND DISCUSSION

It is known that the cow farming technology, including cow feeding, can considerably affect milk yield and, in its turn, change the cash flow. For this reason, it is important to analyse the economic implications derived of modifications of the average daily milk yield, the range of deviation, and the change in the milk yield caused by including peas and beans in the dairy cows' diets.

Dairy farms have built up experience in using legumes – faba beans and peas – in diets for cows in the form of both fresh biomass and dried seeds. For the purpose of the present research, the dairy cows were fed dry faba beans and peas as a component of the feed concentrate supplied. An important reason for incorporating legumes into the diet for dairy cows is that the legumes contain a considerable amount of energy in the form of starch and contribute to better protein absorption.

However, there are few research studies allowing determining the economic and protein absorption efficiency for feed rations comprising legumes. Thus, in cow diets, according to data available in the literature, faba beans might be up to 35% of the total feed concentrate ration (Tufarelli et al., 2012), although other information has suggested that dairy cow diets should not include more than 20% legumes. Latvian researchers Barbals & Brosova (2013) recommend incorporating 2 kg of faba beans into the daily feed ration for dairy cows; it causes no harm to the cow's health.

After examining the effects of different amounts of dietary legumes on the productivity of dairy cows, Vander Pol et al. (2008) demonstrated no significant changes when soybean flour was partially replaced by peas (150 g kg^{-1}). A similar finding was made by Tufarelli et al. (2012) who reported that replacing soybeans with faba beans (345 g kg^{-1}) in the diet for highly productive dairy cows (the average milk yield of 35 kg a day) did not influence the cows' productivity.

Regarding milk yield, to be efficient, dairy cows have to produce at least 1,000 kg of energy corrected milk (ECM) per 100 kg live weight per year; it is the milk with a 4.1% fat content and a 3.1% protein content (Garcia et al., 2006). An analysis of the available data on dairy farming allows concluding that in milk production, a crucial factor is the genetic potential of cows, though increasing milk yields and enhancing milk quality, to a great extent, depends on the cows' diet. As pointed out by Kureoja & Kaart (2002), the dairy cow farming technology (the kind of barn, the kind of housing, diets, animal welfare conditions etc.) as an exogenous factor makes a greater effect on cow productivity than the genetic parameters.

The milk yield changes are well seen in both trials (Table 2) if analysing relative monthly milk yields or monthly milk output per 100 kg cow live weight. No significant changes in relative milk yields were observed in any experimental group, compared with the control group, in the entire experimental period. The relative milk yields were similar in all the groups.

However, it has to be mentioned that the relative milk yield in the 3rd group (22–24% 'Lielplatone' faba beans) was the lowest at the initial stage (in November) of both the 1st trial (120.4 kg) and the 2nd one (128.0 kg). In contrast, at the final stage (in February) the relative milk yield in the 3rd group (104.2 kg) was higher than in the control group in the 1st trial, while in the 2nd trial it was the highest (128.8 kg), compared with the other experimental groups and the control group (Table 2).

Table 2. Milk production (milk productivity), kg per 100 kg live weight per month

First cow feeding trial 2014–2015				
Experimental group	Nov, 2014*	Dec, 2014	Jan, 2015	Feb, 2015
1st group	131.66 ± 27.9	141.08 ± 25.4	133.41 ± 20.4	110.85 ± 16.1
2nd group	126.51 ± 24.1	120.15 ± 25.2	121.15 ± 19.8	107.51 ± 19.3
3rd group	120.40 ± 22.9	110.96 ± 18.2	114.22 ± 20.8	104.19 ± 18.8
4th group[c]	132.22 ± 38.6	138.30 ± 40.7	121.87 ± 42.0	103.46 ± 23.7
p-value – to define differences in comparison of the control group				
1st group	0.917	0.917	0.754	0.465
2nd group	0.917	0.602	0.917	0.917
3rh group	0.347	0.251	0.917	0.917
Second cow feeding trial 2015–2016				
Experimental group	Nov, 2015*	Dec, 2015	Jan, 2016	Feb, 2016
1st group	130.2 ± 24.6	134.7 ± 19.4	134.1 ± 14.8	110.7 ± 15.4
2nd group	140.9 ± 23.1	141.6 ± 28.2	133.7 ± 29.7	119.2 ± 26.7
3rd group	128.00 ± 22.2	164.2 ± 10.5	152.0 ± 7.9	128.8 ± 6.8
4th group[c]	135.8 ± 27.4	148.7 ± 11.6	138.2 ± 10.2	117.6 ± 10.3
p-value – to define differences in comparison of the control group				
1st group	0.602	0.917	0.917	0.917
2nd group	0.917	0. 917	0.251	0.347
3rh group	0.917	0.347	0.465	0.251

Data are presented as means ± SD (standard deviation) (n = 5); * initial stage; [c] – control group.

The need for cheaper protein-rich feedstuffs has been referred to in a number of research studies owing to the problem of the high proportion of feed cost. Thus, as pointed out by Czuowska & Zekao (2016), the feed cost in dairy farming comprises 66% of total production cost. In the 1st and 2nd trials on the dairy cows, replacing soybean meal with legumes, the feed cost per cow per day for the experimental group decreased by 2.6–5.3% (Table 3). The greatest decrease in daily feed cost per cow (by 0.16 EUR), compared with the control group, was observed in the 3rd group, which was fed a diet in which soybean protein was replaced with 'Lielplatone' faba beans (22–24% of the total amount of protein feedstuffs).

Adding a combination of 'Lielplatone' faba beans (10–12%) and 'Bruno' peas (10–12%) (for the 1st group), the daily feed cost per cow decreased by 0.12 EUR, while the incorporation of only 'Bruno' peas (22–24%) into the diet (for the 2nd group), the daily feed cost per cow decreased by only 0.08 EUR (Table 3). This may be explained by the fact that the crude protein content of peas is lower, therefore the crude protein cost of this feedstuff is higher.

Table 3. Cost of dairy cow feed per day per cow 2014–2015

Indicators	1st group	2nd group	3rd group	4td group[c]
Haylage/silage EUR	0.60	0.60	0.60	0.60
Hay EUR	0.48	0.48	0.48	0.48
Grain EUR	0.75	0.75	0.75	0.75
Rapeseed oil cake, EUR	0.40	0.40	0.40	0.40
Peas, EUR	0.27	0.57	-	-
Beans, EUR	0.26	-	0.49	-
Soymeal, EUR	-	-	-	0.65
Mineral feed, EUR	0.16	0.16	0.16	0.16
Total, EUR	2.92	2.96	2.88	3.04
difference to control, EUR	-0.12	-0.08	-0.16	-
difference to control, %	-3.9	-2.6	-5.3	-

[c] – control group.

After summarising the data on feed costs and dairy cow production, feed costs per kg of milk produced were calculated. As shown in Table 4, this value differed significantly between the 1st trial and the 2nd one, which might relate to the different cow productivity levels on the experimental farms. Of course, higher productivity at the same feed cost resulted in a lower unit production cost. However, the results of both trials reveal trends in feed costs and production costs in the experimental period when soybeans were replaced with faba beans and peas as sources of dietary protein.

According to Silva et al. (2008), the performance of economic analyses by using production costs and an economic efficiency index, such as gross and net rates, contributes to decision-making. At the final stage of both trials, the productivity of cows (average milk yield per cow per day), the total milk production (kg) for each group and the total revenue from milk sales, as well as the total feed cost were calculated for the entire experimental period (December-February) (Table 4).

Table 4. Total feed costs, gross profit and average feed costs per 1 kg of milk yield in the trials (December-February)

First cow feeding trial 2014–2015				
Indicator	1st group	2nd group	3rd group	4th groupc
Milk yield per cow per day (kg)	22.07	21.57	20.48	22.51
Total milk yield per group per trial (kg)	9,957.20	9,710.90	9,064.10	10,156.00
Milk wholesale price (EUR kg^{-1})	0.21	0.21	0.21	0.21
Income from milk sales (EUR)	2,091.01	2,039.29	1,903.46	2,132.76
Total feed costs per group (EUR)	1,313.33	1,330.88	1,296.23	1,366.88
Difference to control (EUR)	-53.56	-36.01	-70.66	x
Difference to control (%)	-3.9	-2.6	-5.2	x
Income over feed costs (EUR)	777.69	708.41	607.24	765.89
Difference to control (EUR)	11.80	-57.48	-158.65	x
Difference to control (%)	1.5	-7.5	-20.7	x
Average feed costs per kg of milk yield (EUR kg^{-1})	0.132	0.137	0.143	0.135
Difference to control (EUR)	-0.003	0.002	0.008	x
Difference to control (%)	-2.3	1.5	5.9	x

Table 4 (continued)

Second cow feeding trial 2015–2016				
Indicator	1st group	2nd group	3rd group	4th groupc
Milk yield per cow per day (kg)	28.04	29.16	34.31^{S}	27.89
Total milk yield per group per trial (kg)	2,643.40	13,134.30	15,475.70	12,575.50
Milk wholesale price (EUR kg^{-1})	0.21	0.21	0.21	0.21
Income from milk sales (EUR)	2,655.11	2,758.20	3,249.90	2,640.86
Total feed costs per group (EUR)	1,313.33	1,330.88	1,296.23	1,366.88
Difference to control (EUR)	-53.56	-36.01	-70.66	x
Difference to control (%)	-3.9	-2.6	-5.2	x
Income over feed costs (EUR)	1,341.79	1,427.33	1,953.67	1,273.98
Difference to control (EUR)	67.81	153.35	679.69	x
Difference to control (%)	5.3	12.0	53.4	x
Average feed costs per kg of milk yield (EUR kg^{-1})	0.104	0.101	0.084	0.109
Difference to control (EUR)	-0.005	-0.007	-0.025	x
Difference to control (%)	-4.4	-6.8	-22.9	x

^{c} – control group; ^{S} –significant difference, $p < 0.05$

The feed components and therefore the feed costs were the same in both trials, both for the experimental groups and the control group. The feed costs for all the experimental groups (1st–3rd) were 2.6–5.2% lower, given the market price on faba beans and peas and the price on soybeans fed to the control group.

In the experimental period, compared with the control group, the cost savings (EUR 70.66) were found to be the greatest in the 3rd group (22–24% faba beans), EUR 53.56 were saved on the 1st group (10–12% peas and 10–12% beans), and EUR 36.01 on the 2nd one (22–24% peas).

From the economic perspective, it is important not only to reduce feed costs but also to provide sufficiently high productivity and to reduce production costs. However, to make an economic efficiency assessment for legumes, it is important to determine the unit production cost for the entire experimental period (December-February). In the first experimental period, the feed cost per kg milk produced was EUR 0.03–0.05 higher than in the 2nd trial.

A comparison of feed costs between the experimental groups and the control group revealed that the feed cost per kg milk produced for the 1st group (10–12% peas and 10–12% beans) was 2.3–4.4% lower. Consequently, compared with the control group, the difference between revenue from milk sales and feed costs (income over feed costs) was 1.5–5.3% greater in the 1st and 2nd trials.

The 3rd group that was fed a diet comprising faba beans showed a lower feed ration cost; however, in the 1st trial it showed a 5.9% higher feed cost per kg milk produced. In the 2nd trial, the 3rd group showed the best performance with a 22.9% or 2.5 cent lower feed cost per kg milk produced than the control group did. A similar trend was observed for the 2nd group; in the 1st trial the feed cost for this group was 1.5% higher, whereas in the 2nd trial it was 6.8% lower than for the control group.

The 1st trial (2014) showed that replacing soybean feedstuffs with peas and beans in the diet for cows of average milk productivity (20–24 kg per day) resulted in lower income over feed costs from the experimental groups than from the control group, or the profits were the same. However, in the 2nd trial, if replacing soybean feedstuffs with peas

and beans in the diet for cows of higher milk productivity (28–31 kg per day), the income over feed costs from all the experimental groups were significantly higher than from the control group. In the experimental period, the average feed cost per kg milk produced followed a similar trend – replacing soybean feedstuffs with 220–240 g kg^{-1} faba beans (3rd group) resulted in a 22.9% (2.5 cents) lower cost than for the control group.

Lima et al. (2015) assessed the economic efficiency of feedstuffs used in an experiment in conjunction with production costs and productivity, thereby identifying the most economically efficient diet providing the highest profitability. After performing a comprehensive assessment of the results of both trials, one can conclude that the highest production efficiency was achieved if incorporating 22–24% 'Lielplatone' faba beans into the dairy cow diet. The experimental diet comprising faba beans allowed reducing feed cost, whereas dairy cow productivity was constant. This means that replacing soybean feedstuffs with faba beans resulted in higher economic returns from the feedstuffs used in livestock farming, i.e. the same cow productivity at lower resource consumption. The most economically efficient diets were those comprising only one kind of legumes (peas or beans).

CONCLUSIONS

Based on the experimental data, one can conclude that feed rations may comprise peas and beans grown in Latvia, thereby reducing the consumption of imported soybeans. An analysis of the effects of the use of faba beans and peas **in the dairy cow diet** on feed cost and productivity in the experimental period revealed that:

- the daily feed ration cost decreased by EUR 0.16 for the 3rd group (22–24% 'Lielplatone' faba beans), EUR 0.12 for the 1st group (10–12% 'Bruno' peas and 10–12% 'Lielplatone' beans), and EUR 0.08 for the 2nd group (22–24% 'Bruno' peas);
- compared with the control group, the total saving on feed was EUR 70.66 in the 3rd group, EUR 53.56 in the 1st group (10–12% peas and 10–12% beans) and EUR 36.01 in the 2nd group (22–24% peas);
- in the 2nd trial, the average milk yield in the 3rd group (22–24% faba beans) was significantly higher than in the control group, whilst the 1st and 2nd groups showed no significant changes in the average daily milk yield, as well as in the milk fat content and the milk protein content;
- both trials showed that the feed cost per kg milk produced for dairy cows in the group fed with 10–12% peas and 10–12% beans was 2.3–4.4% lower than for the control group.

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