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Economic assessment of use of pulses in diets for captive red deer

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Abstract. The quality of compound feeds used in livestock diets could be enhanced by means of domestically produced pulses. Nevertheless, there are available few research studies that would allow us to identify the economic efficiency of livestock diets with pulses and the digestibility of protein by livestock for deer farming. Accordingly, the present research aims to identify the economic efficiency of diets supplemented with domestically produced pulses - faba beans, peas and lupine beans - for captive deer. The research conducted a feeding experiment on captive deer (*Cervus elaphus*) kept in fenced areas to identify the economic efficiency of diets supplemented with three legume species: peas (variety 'Vitra'), faba beans (variety 'Fuego') and narrow-leaved lupin seeds (variety 'Boregine'). Deer productivity was assessed by live weight, live weight gain, feed intake and protein efficiency ratio during the experimental period, as well as feed cost per live weight gain unit. The research found that feeding deer diets containing peas, faba beans and lupine beans as protein-rich feedstuffs was economically advantageous - at the same cost of feed, deer productivity increased and per-unit production costs decreased. Live weight gains during the experimental period were 1.02% higher in group 2 (pea diet), 1.78% higher in group 3 (faba bean diet) and 2.91% higher in group 4 (lupine diet) than in the control group. During the experimental period, the highest protein efficiency ratio was found in group 4 fed a diet containing lupine beans - a unit of protein fed (1 kg) yielded the highest weight gain or 0.43 kg. Feed costs per kg of live weight gain were the lowest in group 4 (2.32 EUR kg^{-1}), 2.48 EUR kg^{-1} in group 3 and 2.70 EUR kg^{-1} in group 2, which was 20.56%, 14.81% and 7.39%, respectively, lower than those in the control group.

Key words: deer farming, feed cost, pulses, legumes, economic efficiency, animal science.

INTRODUCTION

The livestock industry needs to adapt to the changing external environment, which is affected by changing public needs regarding food, the environment and health, and is therefore still developing. In many countries research is done on protein sources and protein levels in ruminant diets with regard to animal health, product quality and environmental impacts (Gilbery et al., 2007; Joch & Kudrna 2020; White et al., 2000).

With regard to the changing and growing public needs, the livestock industry need to be economically viable; therefore, the key to its economic viability is the efficient use of available feed resources. To make the industry more profitable, the efficient use of feedstuffs becomes increasingly important (Sharasia et al., 2015). In recent years, pulses have become an increasingly popular source of feed for farm animals, and it is estimated that between 10 and 20 percent of the feed is made up of various pulses. Some authors (Wanapat et al., 2013) have pointed out that the inclusion of legume seeds in animal diets has the potential to improve animal productivity both qualitatively and quantitatively. One of the challenges to be tackled is the choice of appropriate feedstuffs that can increase productivity without increasing feed costs (Beigh et al., 2017).

Feed is divided into roughage and concentrates. Roughage is mainly pasture grass, hay, silage, root crops, straw etc., while concentrates are mainly made up of protein-rich feeds, e.g. grains and pulses, food, starch and alcohol processing residues as well as oilseed (rapeseed, maize, soybean, sunflower) meal (AAFCO, 2000). Poultry and pig feed consists of concentrates, while for ruminants concentrates make up 0.75–0.5% of the dry matter of the feed (Schöne & Rajendram, 2009).

The protein-rich feed traditionally used in deer diets (oat grains) has a dry matter crude protein content of approximately 12%, (Summary of the..., 2013), which together with roughage feedstuffs cannot provide the optimal amount of protein (14–16%) to achieve the desired level of productivity (Huapeng et al., 1997). For this reason, food processing residues (e.g. rapeseed cakes) with high protein content (up to 30% of dry matter) have become widely used in livestock production, yet the output of residues cannot meet the quantity needed for livestock farming. There is a high demand for high-protein materials for livestock feed in Europe and European agriculture has a deficit of about 70% high-protein materials, of which 87% is met by imported soybeans and soybean meal (Watson et al., 2017). The imported protein-rich products (soybean, sunflower meal), however, are expensive; therefore, using such products in livestock production could be economically unprofitable. Trends in the world market indicate that the prices of protein-rich feedstuffs are rising, thereby making a significant impact on the total price of feed and, consequently, on the cost of livestock production. Over the last 5 years, the average price of soybean meal on world stock exchanges has fluctuated from 279 to 419 EUR t^{-1}, reaching 419 EUR t^{-1} at the end of 2020 (IndexMundi, 2021). The price of soybean meal imported from the USA has increased from 333 EUR t^{-1} in January 2015 to 449 EUR t^{-1} in January 2021 (European Commission, 2021). Overall, the prices of imported full-fat soybean, rapeseed and sunflower meal have increased by 43–65% during this period. The domestic price of feed-grade wheat in July 2020 in the EU-28 was 196 EUR t^{-1}, while in Latvia 147 EUR t^{-1}. At the end of last year, the average prices of feed-grade peas and beans in the EU were 219 and 240 EUR t^{-1}, respectively, while in Latvia 202 and 227 EUR t^{-1} (EUROSTAT, 2019, CSB, 2021).

According to the available information, the main focus in Latvia should be placed on increasing the protein content in feed by means of domestically produced feedstuffs. The inclusion of pulses in the diet of ruminants is important not only in terms of chemical composition of the diet but also in terms of rate of nutrient degradation in the rumen. The rumen degradation of pulse proteins often exceeds 80%, which is similar to most cereals (Dixon & Hosking, 1992). The rumen degradation of starch is lower for faba beans and peas than for cereals (Larsen et al., 2009).

Pulses are a source of high-quality protein and energy for all kinds of livestock, ensuring a combination of great taste and digestibility (Pulse Australia, 2006). Experience is being built up in feeding cattle (Osmane et al., 2017), sheep (Kairisa & Aplocina, 2018), goats (Aplocina & Degola, 2019) and poultry (Nolte et al., 2020) legumes in the form of both green fodder and dried seeds. Faba beans can replace soybean meal in diets for dairy cows and sheep without reducing milk yield and affecting milk composition, livestock growth and carcass quality (Tufarelli et al., 2012). The authors base their research studies on the rational and efficient use of pulses in animal diets on the physiological and biological processes of metabolism in animals. Besides, the inclusion of pulses in animal diets can lead to higher animal productivity. However, there are few research studies on the economic efficiency and effectiveness of inclusion of pulses in livestock diets for a non-traditional agricultural industry -deer farming.

Deer farming is a new and intensively growing non-traditional livestock industry in Latvia, in recent years, the assortment and consumption of game meat products has increased significantly, which is mainly associated with consumer expectations of the quality and nutritional value of the products (Grunert et al., 2004). The economic and cultural transition from mass selling to niche selling (Riivits-Arkonsuo et al., 2017) plays an important role in the development of deer farming; at the same time, the food market is beginning to be dominated by product characteristics such as nutritional value and healthiness. Strazdina et al. (2011) indicate that venison is a good addition to a healthy human diet, it has a lower content of saturated fatty acids (SFA) than traditional farm animal meat has, as well as a higher protein content. The number of captive deer has increased 2.2 times between 2008 and 2019, reaching 16.01 thousand in 2019 (Animal statistics, 2019). Thereby raising a number of questions concerning effective management of the deer herds.

Composing a livestock diet of different feedstuffs, it is important to ensure all nutrients needed for the growth and normal development of livestock are supplied: protein, fats (lipids), carbohydrates (including fibre), minerals (macroelements), microelements, vitamins etc. Protein is an essential component of animal feed. It is absolutely necessary for the growth of animals and the maintenance of the animal organism, as well as for the production of livestock products (Chadd et al., 2002).The feedstuffs selected for animal diets make an effect on animal productivity and the economic performance of the farm; therefore, efficient use of feed is also essential in assessing the economic efficiency and effectiveness of the resources used. Some research studies by foreign authors (Brelurut et al., 1990; Hewitt, 2011) have found that an animal weighing 90–150 kg need to receive on average 25.0–39.0 MJ kg^{-1} of energy and 310.0–350.0 g of protein per day, depending on the climatic conditions and the physiological condition of the animal and according to the season and the physiological requirements of the red deer organism.

The efficiency of animal diets is one of the most important aspects of deer farming in relation to the production of animal products. In Latvia, few research studies are available on the economic efficiency and effectiveness of inclusion of pulses in livestock diets, yet there are some research studies indicating that pulses included in livestock and poultry diets can serve as an important source of protein, and the inclusion of pulses in the diets reduces feed costs and increases livestock productivity. A research has been done on an industry that is presently topical in Latvia which is a little-researched non-traditional agricultural industry. Since a limited amount of statistical data on the deer industry was available, to identify economic gains of using selected feed ingredients in the deer farming authors analyzed the information of primary sources - results of experiments, publications of Latvian and foreign scientists, research findings regarding theoretical aspects of deer industry as well as an unpublished information of the institutions engaged in the deer industry. Therefore, the present research aims to identify the economic efficiency of diets supplemented with domestically produced pulses - faba beans, peas and lupine beans - for captive deer.

MATERIALS AND METHODS

The research conducted a feeding experiment on captive red deer (*Cervus elaphus*) kept in fenced areas to identify the economic efficiency of diets supplemented with three legume species: peas (variety 'Vitra'), faba beans (variety 'Fuego') and narrow-leaved lupine seeds (variety 'Boregine') for captive deer. The feeding experiment was implemented for five months in the winter-spring season of 2018. It should be emphasized that the year 2018 was characterized by low rainfall (LEGMC, 2019). For this reason, the grass yield was relatively low at the beginning of the grazing period, and feeding hay and silage to the deer continued until mid-June. Feeding the deer concentrates was particularly important to maintain their productivity during both winter and summer. The quality of compound feed used in animal diets could be enhanced by including domestically produced pulses.

Table 1. Chemical feed test results

Indicators	Oats (n = 5)	Peas (n = 5)	Beans (n = 5)	Lupine (n = 5)	Hay (n = 5)	Silage (n = 5)
Dry matter, %	90.84 ± 0.53	86.87 ± 0.08	86.05 ± 0.27	90.99 ± 1.15	87.86 ± 0.08	24.75 ± 0.27
Crude protein, % of dry matter	9.36 ± 0.33	26.80 ± 0.22	33.69 ± 0.86	34.89 ± 2.53	7.66 ± 0.45	9.77 ± 0.59
Insolube protein, %	0.25 ± 0.04	0.71 ± 0.11	0.55 ± 0.21	1.24 ± 0.42	0.85 ± 0.01	0.44 ± 0.02
Soluble protein, %	2.15 ± 0.08	12.71 ± 1.15	19.89 ± 2.26	22.92 ± 1.85	2.53 ± 0.32	7.15 ± 0.27
Undegradable intake protein, %	66.85 ± 2.0	48.89 ± 4.73	38.10 ± 8.13	29.37 ± 2.37	19.08 ± 2.05	16.47 ± 4.83
Neutral detergent fibre (NDF), %	33.32 ± 2.63	12.84 ± 0.79	14.83 ± 1.48	20.58 ± 3.92	77.91 ± 0.79	61.42 ± 1.36
Acid detergent fibre (ADF), %	17.77 ± 1.02	9.32 ± 0.16	11.72 ± 0.88	20.06 ± 1.90	44.98 ± 0.69	40.91 ± 0.53
Metabolizable energy (ME), MJ kg^{-1} of dry matter	12.20 ± 0.08	13.50 ± 0.01	12.60 ± 0.07	13.00 ± 0.15	9.70 ± 0.06	10.00 ± 0.92

Data are presented as means ± *SD* – standard deviation.

For the feeding experiment, the deer were selected according to analogous physiological parameters (18 months), so that the amount of protein provided by the diet would be the main factor to be analysed. The average live weight of the deer in the control group (group 1) (n = 10) was 75.20 ± 9.83 kg, in group 2 (n = 10) 74.75 ± 5.73 kg, in group 3 (n = 10) 73.80 ± 8.71 kg and in group 4 (n = 10) 73.10 ± 8.48 kg.

In the control group (group 1), one deer received an average of 7 kg of silage, 1 kg of hay and 1 kg of rolled oats per day, vitamins, a mineral complex and freely available drinking water. For the experimental groups, the diets included 200 g kg^{-1} ground peas (group 2), 200 g kg^{-1} ground faba beans (group 3) and 150 g kg^{-1} ground lupine beans (group 4). The basic feed ration (hay, silage) was the same for all the groups, while the amount of oats was reduced according to the amount of pulses added. Since the object of the present research is the economic aspects of protein components of the concentrates fed, the protein components of feedstuffs are a focus in the research. The research results were comparatively assessed from the perspective of profitability of the industry, focusing on the economic efficiency of feedstuffs, the cost of protein-rich feedstuffs and animal productivity. To assess the quality of the feed, biochemical feed tests were performed to determine dry matter content, crude protein content, ADF, NDF (Table 1).

Table 2. Protein intake per animal per day, g

Forage	1st group (control)	2nd group (peas)	3rd group (beans)	4th group (lupine)
Silage	169.21	169.21	169.21	169.21
Hay	66.69	66.69	66.69	66.69
Oats	85.06	59.54	59.54	61.25
Peas	–	46.56	–	–
Faba beans	–	–	57.98	–
Lupine	–	–	–	47.62
Total	**320.96**	**341.99**	**353.42**	**344.76**
Change against control group	–	21.04	32.46	23.80

The basic function of protein is to provide the animal with the amino acids it contains. Protein also has nutritional energy value and contributes to meeting the energy requirements of the animal. This additional function was taken into account when designing an optimal diet; however, to meet the energy requirements, it was based primarily on the addition of carbohydrate and fat-containing feedstuffs to the diet. The average amount of crude protein in the diet for the control group was 320.96 g. The amount of crude protein in the diets for the experimental groups was similar, exceeding that for the control group by 21–32 g (Table 2). For the feeding experiment, the diet for the control group was designed so that an animal could absorb 2.6 kg of dry matter per day, providing the control group with a metabolizable energy (ME) per animal on average 33.94–35.1 MJ kg^{-1}.

The following animal productivity indicators were calculated based on (Perrett et al., 2008):

– weight gain (WG) per animal during the experimental period:

$$WG = LWe - LWi, \tag{1}$$

where WG – weight gain, LWe – live weight at the end of the experiment, LWi – initial live weight;

– average daily live weight gain (DWG) per animal:

$$DWG = \frac{LWe - LWi}{T}, \tag{2}$$

here T – experimental period in days;

– live weight gain percentage (WG (%)) per animal:

$$WG(\%) = \frac{(LWe - LWi)}{LWi} \times 100. \quad (3)$$

The animals were weighed using the electric scales EziWeigh 6 (manufacturer Tru Test Ltd) with a resolution of 0.1 kg at the beginning of the experiment and once a month during the experiment.

To determine the weight gain per unit of protein consumed or the efficiency of feed intake (Rushton, 2008),

– protein efficiency ratio (PER) was calculated:

$$PER = \frac{WG}{CPi}, \quad (4)$$

where CPi – protein intake;

– feed cost per weight gain (FC_{WG}):

$$FC_{WG} = \frac{(FS_1 \times FC_1) + \ldots + (FS_n \times FC_n)}{WG}, \quad (5)$$

where FS – fees stuff; FC – feed cost.

Research data were analyzed by a non–parametric method (Mann–Whitney U criteria test) for data comparison (Arhipova & Bāliņa, 2006) using SPSS for Windows, Version 25.0 (IBM Statistics for Windows). Two independent variables - deer of control group and deer of trial groups were compared at the essentiality level $P < 0.01$.

RESULTS AND DISCUSSION

One of the main economic aspects of livestock production is feed cost. The average price of feedstuffs over the experimental period was used to calculate feed costs. For feed cost assessment, comparing only actual unit costs is misleading. When purchasing feedstuffs, the main focus is put on one or two of their main characteristics - protein content and energy value. Protein and nutritional energy are the main ingredients to balance a ration. Most proteins from natural sources are equably usable by animals; therefore calculating price per unit of protein is a good method to determine the best feedstuff (Shewmaker, 2013). For this reason, analysing protein-rich feedstuffs for deer diets, the actual cost of protein in a feedstuff was determined, and the price of a kg of crude protein in legume seeds and oats was calculated according to the amount of protein in the feed and the price of this feed.

Table 3. Crude protein cost

Feed concentrate	Oats	Peas	Faba beans	Lupine beans
Purchase price*, EUR kg^{-1}	0.18	0.30	0.30	0.40
Cost of 1 kg of crude protein, EUR kg^{-1}	2.06	1.29	1.03	1.26
Cost of crude protein compared with the cost of oats, EUR kg^{-1}	–	-0.77	-1.02	-0.80

* The prices are calculated according to 2019 Prices Roundup provided by Central Statistical Bureau of Latvia.

The results of the experiment showed that the actual cost of a kg of protein in legume beans was higher than that in oats fed to the deer (Table 3). However, an analysis of the costs of a kg of protein in protein-rich feedstuffs revealed that oats were the most expensive feedstuff and cost 2.06 EUR kg^{-1}. The cost of protein available in pulses was in the range from 1.03 to 1.29 EUR kg^{-1}, meaning that the cost of a kg of crude protein in faba beans was the lowest, 1.02 EUR kg^{-1} lower than that in oats.

The economic efficiency of the feed ingredients used in the experiment needs to be identified in terms of production costs and productivity (Perrett et al., 2008), thus determining the most efficient diet with the highest profitability.

Table 4. Feed costs per animal per day

Forage	1st group (control)	2nd group (peas)	3rd group (beans)	4th group (lupine)
Silage, EUR	0.07	0.07	0.07	0.07
Hay, EUR	0.055	0.055	0.055	0.055
Oats, EUR	0.200	0.140	0.140	0.144
Peas, EUR	–	0.06	–	–
Faba beans, EUR	–	–	0.06	–
Lupine, EUR	–	–	–	0.06
Mineral additives, EUR	0.016	0.016	0.016	0.016
Total per animal per day, EUR	**0.341**	**0.341**	**0.341**	**0.345**
Total per group per trial, EUR	511.50	511.50	511.50	517.50
Changes against control group,%	–	0	0	1.17

A prerequisite for the production of economically efficient livestock products is to achieve the lowest possible feed cost. To make the most rational use of feed, it is important to achieve a decrease in feed consumption, i.e. the lowest feed consumption per unit of production. It should be mentioned that the inclusion of legume seeds in deer diets kept the cost of feed at the same level and even slightly increased it for group 4 by 1.17% (Table 4), which could be explained by the difference in crude protein content and cost between oats and legume seeds (Table 1).

Table 5. Economic indicators of pulse diets during experiment (150 days)

Indicators	1st group (control)	2nd group (peas)	3rd group (beans)	4th group (lupine)
LWi , kg*	75.20 ± 9.83	74.75 ± 5.73	73.80 ± 8.71	73.10 ± 8.48
LWe, kg*	92.75 ± 12.70	93.70 ± 9.99	94.40^{S} ± 11.40	95.45^{S} ± 11.60
Change against control group, %	–	1.02	1.78	2.91
WG per animal, kg* (1)	17.55 ± 3.72	18.95 ± 8.78	20.60^{S} ± 6.69	22.35^{S} ± 5.23
Change against control group, %	–	7.98	17.38	27.35
DWG, kg (2)	0.117	0.126	0.137	0.149
WG (%) (3)	23.34	25.35	27.91	30.57
Change against control group, percentage points	–	2.01	4.58	7.24
PER (4)	0.36	0.37	0.39	0.43
Change against control group, %	–	1.34	6.60	18.56
FC_{WG}, EUR kg^{-1} (5)	2.91	2.70	2.48	2.32
Change against control group, %	100	-7.39	-14.81	-20.56

*Means with superscript letter ^{S} are significantly different at $P < 0.01$ in comparison with the control group. The numbers of each columns that do not have letter have a meaningful difference ($P > 0.01$); data are presented as means ± *SD* – standard deviation.

As regards the intakes and chemical composition of feed, the diets with an addition of pulses contained higher amounts of protein at equivalent feed costs. This provides an opportunity to achieve higher productivity at equivalent resource consumption.

The economic efficiency of animal diets is determined by animal fattening and productivity. Various research studies have emphasized that feeding concentrates leads to faster live weight gain in deer, as well as positive changes in the properties of carcasses and meat (Volpelli et al., 2003). There are few research studies on feeding pulse diets to red deer and the physiological and economic efficiency of the diets. Some research studies indicate that the protein content in concentrates (16%) is provided by pulses and cereals (Gomez et al., 2006), while Lavrenčič & Veternik (2018) point out that there are no significant differences in in-vitro digestibility of feed between sheep and red deer and state that this allows the results of research on sheep to be applied to the development of feed rations for red deer (Lavrenčič & Veternik, 2018). Research studies on feeding lupine beans to ruminants have found that supplementing the ruminant diet with lupine bean meal makes a positive effect on live weight gain compared with feeding cereal grains (Van Barneveld, 1999). A similar conclusion was made by Tefera and the colleagues who pointed out that the inclusion of 300 g of lupine beans in the diet for sheep resulted in a higher average weight gain, feed conversion and carcass quality compared with the grain diet (Tefera et al., 2015).

The present research showed that supplementing the deer diets with pulses over a five-month experimental period, the deer live weight in the experimental groups exceeded that of the control group (Table 5). In the group fed peas, the total live weight gain was 1.02% higher than that in the control group fed beans (an increase of 1.78%), while in the group fed lupin beans, the increase was even 2.91%. A comparison of the final live weight with the initial one within each group revealed that the highest rate of live weight increase was found in the group fed a lupine bean additive, exceeding the initial live weight by 30.57%, which was 7.24 percentage points more than in the control group. A similar conclusion was made by Wegi et al. (2018) who found in their researches that a higher increase in live weight was observed if 30% faba beans of various varieties were included in sheep diets. However, feeding faba beans (300 g kg^{-1}) and a combination of faba beans (150 g kg^{-1}) and lupine beans (150 g kg^{-1}) to fattening lambs resulted in a higher average live weight gain and slaughter weight than that in the group fed a diet with an addition of lupine beans (250 g kg^{-1}). Lobon et al. (2020) noted that field pea can constitute up to 30% of the concentrate of light lambs, reducing the soybean inclusion 42% without deleterious effects on the apparent digestibility, lamb performance or carcass characteristic

To determine the efficiency of legume seed diets, a protein efficiency index was calculated, which showed the weight gain per unit of protein consumed. The results of the experiment confirmed that the most efficient absorption of protein was found in the group fed a diet with an addition of lupine beans, where one unit of protein fed (1 kg) resulted in the highest increase in live weight or 0.43 kg during the experimental period. The groups fed diets with an addition of peas and faba beans to concentrates had a higher protein efficiency index than the control group. Conversely, the lowest performance was found in the control group, where a kg of protein fed lead to a 0.36 kg increase in live weight during the experimental period.

Feed costs per kg live weight gain during the experimental period were calculated to identify the economic efficiency of pulse diets. An analysis of the feed costs per kg live weight gain during the experimental period revealed that the differences in cost were significant. For example, in group 2 fed a diet with an addition of peas, the feed cost per kg live weight gain was 7.39% lower than that in the control group, in group 3 fed a diet with an addition of faba beans it was 14.81% lower, and in group 4 fed a diet with an addition of lupin beans it was even 20.56% lower.

CONCLUSIONS

Feeding diets containing peas, faba beans and lupine beans as protein-rich feedstuffs to captive deer was economically advantageous - at the same cost of feed, deer productivity increased and per-unit production costs decreased. The costs of protein in various feedstuffs varied significantly. Faba beans provided the lowest protein cost, as a kg of crude protein cost 1.03 EUR, the cost of crude protein in lupine beans was 1.26 EUR kg^{-1}, in peas 1.29 EUR kg^{-1}, while the highest crude protein cost was found for oats at 2.06 EUR per kg of crude protein. The experimental groups fed diets with an addition of pulses received higher amounts of protein (21–32 g) at the same feed cost as in the control group. The live weight gain during the experimental period was 1.02% higher in group 2 (peas) than that in the control group, 1.78% higher in group 3 (faba beans) and 2.91% higher in group 4 (lupin beans). The most efficient protein absorption was found in group 4 fed a diet with an addition of lupine beans, where one unit of protein fed (1 kg) resulted in the highest live weight gain or 0.43 kg during the experimental period. The lowest feed costs per 1 kg of live weight gain were found in group 4 (2.32 EUR kg^{-1}), in group 3 - 2.48 EUR kg^{-1}, in group 2 - 2.70 EUR kg^{-1}, which were by 20.56%, 14.81%, and 7.39%, respectively, lower than that in the control group.

The economic results of feeding domestically produced feeds rich in protein convincingly show that these feeds may be recommended for deer farms for the purpose of reducing feed costs and increasing productivity. Adding pulses to deer feed rations increases the productivity of deer, which at the same time reduces the cost of feed per weight gain. It indicates that it is possible to achieve a higher efficiency in exploiting production resources and a reduction in production cost.

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REFERENCES

AAFCO. 2000. *Official Publication of Association of American Feed Control Officials*. West Lafayette, USA, pp. 444.

Animal statistics. 2019. Agricultural Data Centre Republic of Latvia. Available at https://www.ldc.gov.lv/lv/statistika/registrs/ (in Latvian).

Aplocina, E. & Degola, L. 2019. Effect of Concentrate Supplementation on Fattening Performance and Carcass Composition of Finished Meat-Goat Kids. *Agronomy Research* **17**(2), 1273–86. doi.: 10.15159/AR.19.084

Arhipova, I. & Bāliņa, S. 2006. *Statistics for Economics and Business. Solutions with SPSS and Microsoft Excel*. Datorzinību centrs, Rīga, pp. 173–180 (in Latvian).

Beigh, Y.A., Ganai, A.M. & Ahmad, H.A. 2017. Prospects of complete feed system in ruminant feeding: A review. *Veterinary World* **10**(4), 424–437. doi: 10.14202/vetworld.2017.424-437

Brelurut, A., Pingard, A. & Thériez, M. 1990. *Le cerf et son élevage: Alimentation, techniques et pathologie*. INRA, Paris, 143 pp. (in France).

Chadd, S.A., Davies, W.P. & Koivisto, J.M. 2002. Practical production of protein for food animals. Protein Sources for the Animal Feed Industry. Available at http://www.fao.org/docrep/007/y5019e/y5019e07.htm

CSB (Central Statistical Bureau of Latvia). 2021. Average purchase prices of cereals, legumes, rapeseed (euro / t). Available at https://data.csb.gov.lv/pxweb/lv/lauks/lauks__LS_cenas__isterm/LI030c.px/table/tableViewLayout1/ (in Latvian).

Dixon, R.M. & Hosking, B.J., 1992. Nutritional Value of Grain Legumes for Ruminants. *Nutrition Research Reviews* **5**(1), 19–43.

European Commission. 2021. Price monitoring by sector, Markets. Available at https://ec.europa.eu/info/food-farming-fisheries/farming/facts-and-figures/markets/prices/price-monitoring-sector_en

EUROSTAT (Statistical office of the European Union). 2019. Database – Eurostat, European Comission. Available at https://ec.europa.eu/eurostat/web/agriculture/data/database.

Gilbery, T.C., Lardy, G.P., Navarro, S.A., Bauer, M.L. & Anderson, V.L. 2007. Effect of field peas, chickpeas, and lentils on rumen fermentation, digestion, microbial protein synthesis, and feedlot performance in receiving diets for beef cattle. *Journal of Animal Science* **85**(11), 3045–53. doi: 10.2527/jas.2006-651

Gomez, J.A., Landete-Castillejos, T., Garcia, A.J. & Gallego, L. 2006. Importance of growth during lactation on body size and antler development in the Iberian red deer (*Cervus elaphus hispanicus*). *Livestock Science* **105**(1) 27–34.

Grunert, K.G., Bredahl, L. & Brunsø, K. 2004. Consumer Perception of Meat Quality and Implications for Product Development in the Meat Sector – a Review. *Meat Science* **66**(2), 259–72. doi: 10.1016/S0309-1740(03)00130-X

Hewitt, D.G. 2011. *Biology and Management of White-Tailed Deer*. CRC Press, Bocaraton, USA, 686 pp.

Huapeng, C., Liyang, L., Xuchang, X., Yazhen, H. & Yuqing, W. 1997. Protein nutrition in red deer (Cervus elaphus). *Journal of Forestry Research* **8**(3), 174–181.

IndexMundi. 2021. Soybean Meal Monthly Price - Euro per Metric Ton. Available at https://www.indexmundi.com/commodities/?commodity=soybean-meal&months=60&currency=eur

Joch, M. & Kudrna, V. 2020. Partial replacement of soybean meal by white lupine seeds in the diet of dairy cows. *Asian-Australasian Journal of Animal Sciences* **33**(6), 957–964. doi: 10.5713/ajas.19.0457

Kairisa, D. & Aplocina, E. 2018. Efficiency of the Use of Field Beans in Fattening Lambs. *Agronomy Research* **16**(4), 1698–1707. doi: 10.15159/AR.18.168

Larsen, M., Lund, P., Weisbjerg, M.R. & Hvelplund, T. 2009. Digestion site of starch from cereals and legumes in lactating dairy cows. *Animal Feed Science and Technology* **153**(3–4), 236–248. doi: 10.1016/j.anifeedsci.2009.06.017

Lavrenčič, A. & Veternik, D. 2018. Differences between sheep and red deer in in vitro apparent and true digestibility of commonly used red deer feeds. *Acta Agriculturae Slovenica* **112**(1) 5–9. doi: 10.14720/aas.2018.112.1.1

LEGMC (Latvian Environment, Geology and Meteorology Centre). 2019. Description of weather conditions in 2018. Available at https://www.meteo.lv/lapas/laika-apstakli/klimatiska-informacija/laika-apstaklu-raksturojums/2018/?nid=1131

Lobon, S., Joy, M., Casasus, I., Rufino-Moya, P.J. & Blanco, M. 2020. Field Pea Can Be Included in Fattening Concentrate without Deleterious Effects on the Digestibility and Performance of Lambs. *Animals* **10**(2), 243. doi.org/10.3390/ani10020243

Nolte, T., Jansen, S., Halle, I., Scholz, A.M., Simianer, H., Sharifi, A.R. & Weigend, S. 2020. Egg Production and Bone Stability of Local Chicken Breeds and Their Crosses Fed with Faba Beans. *Animals* **10**(9), 1480. doi: 10.3390/ani10091480

Osmane, B., Konosonoka, I.H., Trupa, A. & Proskina, L. 2017. Peas and Beans as a Protein Feed for Dairy Cows. *Agronomy Research* **15**(5), 2026–38. doi: 10.15159/AR.17.027

Perrett, T., Wildman, B.K., Jim, G.K., Vogstad, A.R., Fenton, R.K., Hannon, S.J., Schunicht, O.C., Abutarbush, S.M. & Booker, C.W. 2008. Evaluation of the efficacy and cost-effectiveness of melengestrol acetate in feedlot heifer calves in Western Canada. *Veterinary therapeutics: research in applied veterinary medicine* **9**(3), 223–240.

Pulse Australia. 2006. Pulses nutritional value and their role in the feed industry. Available at http://www.feedgrainpartnership.com.au/items/927/Pulses%20Nutritional%20Value%20and%20Their%20Role%20in%20the%20Feed%20Industry.pdf

Riivits-Arkonsuo, I., Ojasoo, M., Leppiman, A. & Mänd, K. 2017. Fair Trade and Social Responsibility – Whose Duty? Estonian Consumers' Attitudes and Beliefs. *Agronomy Research* **15**(4), 1771–81. doi.: 10.15159/AR.17.064

Rushton, J. 2008. The Economics of Animal Health and Production. CABI, Wallingford, 364 pp. doi: 10.1079/9781

Schöne, F. & Rajendram, R. 2009. Iodine in Farm Animals. In Preedy, V.R, Burrow, G.N. & Watson, R.R. (eds): *Comprehensive Handbook of Iodine. Nutritional, Biochemical, Pathological and Therapeutic Aspects*, Academic Press, pp.151–170.

Sharasia, P.L., Garg, M.R. & Bhanderi, B.M. 2017. *Pulses and their By-Products as Animal Feed*. The Food and Agriculture Organization of the United Nations (FAO), Rome, pp. 1–218. doi: 10.18356/9aa0e148-en

Shewmaker, G., Hall, J. & Baker, S. 2013. Getting the most feed nutrient for the dollar. Agricultural Experiment & UI Extension Publications, Available at https://digital.lib.uidaho.edu/utils/getfile/collection/ui_ep/id/32290/filename/uiext32290.pdf

Strazdina, V., Jemeljanovs, A., Sterna, V. & Vjazevica, V. 2011. Evaluation of Protein Composition of Game Meat in Latvian Farms and Wildlife. *Agronomy Research* **9**(2), 469–472.

Summary of the results of feed analysis 2013. Latvian Rural Advisory and Training Centre. Available at http://www.laukutikls.lv/sites/laukutikls.lv/files/upload/piena_rokasgramata/54_lopbariba_internetam.pdf. (in Latvian).

Tefera, G., Tegegne, F., Mekuriaw, Y., Melaku, S. & Tsunekawa, A. 2015. Effects of different forms of white lupin (*Lupinus albus*) grain supplementation on feed intake, digestibility, growth performance and carcass characteristics of Washera sheep fed Rhodes grass (*Chloris gayana*) hay-based diets. *Tropical Animal Health and Production* **47**(8) 1581–1590. doi: 10.1007/s11250-015-0901-9

Tufarelli, V., Khan, R.U. & Laudadio, V. 2012. Evaluating the suitability of field beans as a substitute for soybean meal in earlylactating dairy cow: Production and metabolic responses. *Animal Science Journal* **83**(2), 136–140. doi: 10.1111/j.1740-0929.2011.00934.x

Van Barneveld, R.J. 1999. Understanding the nutritional chemistry of lupin (Lupinus spp.) seed to improve livestock production efficiency. *Nutrition Research Reviews* **12**(2) 203–230. doi: 10.1079/095442299108728938

Volpelli, L.A., Valusso, R., Morgante, M., Pittia, P. & Piasentier, E. 2003. Meat quality in male fallow deer (*Dama dama*): Effects of age and supplementary feeding. *Meat Science* **65**(1) 555–562.

Wanapat, M., Kang, S. & Polyorach, S. 2013. Development of feeding systems and strategies of supplementation to enhance rumen fermentation and ruminant production in the tropics. *Journal of Animal Science and Biotechnology* **4**(32), 1–11.

Watson, C.A., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C.F.E., Vanhatalo, A., Zander, P., Murphy-Bokern, D. & Stoddard, FL. 2017. Grain Legume Production and Use in European Agricultural Systems. *Advances in Agronomy* **144**, 235–303. doi: 10.1016/bs.agron.2017.03.003

Wegi, T., Tolera, A., Wamatu, J., Animut, G. & Rischkowsky, B. 2018. Effects of feeding different varieties of faba bean (*Vicia faba L.*) straws with concentrate supplement on feed intake, digestibility, body weight gain and carcass characteristics of Arsi-Bale sheep. *Asian-Australasian journal of animal sciences* **31**(8) 1221–1229. doi: 10.5713/ajas.17.0736

White, C.L., Young, P., Phillips, N.P. & Rodehutscord, M. 2000. The effect of dietary protein source and protected methionine (Lactet) on wool growth and microbial protein synthesis in Merino wethers. *Australian Journal of Agricultural Research* **51**(2), 173–84. doi: 10.1071/AR99093