Research Article

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Faba beans and peas in poultry feed: economic assessment

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Abstract

BACKGROUND: Broiler diets mainly consist of cereals and protein-rich feed sources; in the EU-27, poultry farming consumes 24% of the total amount of protein-rich feedstuffs. Since the EU produces only 30% of the total quantity of protein crops used for feed, it is necessary to promote the use of traditional European protein crops (beans, peas) for feed in livestock farming. The research aim is to identify economic gains from the production of broiler chicken meat, replacing soybean meal with domestic faba beans and field peas in broiler chicken diets.

RESULTS: Adding field peas and faba beans to the broiler feed ration resulted in a significant live weight increase (5.74–11.95%) at the selling age, a decrease in the feed conversion ratio by 0.61–6.06%, and decrease in the product unit cost (15.34–37.06%) as well as an increase in the production efficiency factor (8.70–48.54), compared with the control group.

CONCLUSION: The optimum kind of legume species used in the broiler diet was peas, which were added in the amount of 200 g kg^{-1}, resulting in live weight gain, a decrease in the feed conversion ratio and an increase in the production efficiency factor.

Keywords: poultry; production efficiency; legumes in broiler diets

INTRODUCTION

A feed ration for broilers consists mainly of cereals and protein-rich feedstuffs. In the EU-27, cereals and protein-rich feedstuffs comprised, on average, 47% and 24% of the total amount; poultry farming consumes 21% of the total quantity of cereals used for feed and 24% of the total quantity of protein-rich feedstuffs.[1] Therefore, any increase in the price of cereals and protein feedstuffs in the world market undoubtedly influences the production cost of poultry meat. At the same time, the current area sown with protein crops can only partially provide livestock farming with the necessary amount of protein. The total area under protein crops occupies only 3% of the total arable area, and this industry supplies only 30% of the quantity of protein crops consumed for feed.[2]

The large imports of protein crops contribute to instability in European agriculture, and negatively affect agricultural producers, as well as causing price fluctuations. According to Food and Agriculture Organization (FAO) forecasts, the price of cereals will increase by 20% in the period 2011–2020, leading to a 30% increase in the price of meat (poultry meat).[3] According to studies by the FAO and the European Commission's responsible institutions, the use of traditional (regional) European protein crops (beans, peas) for domestic feed contributes to greater independence of the agricultural industry from feed price fluctuations in the global market and to sustainable use of the agricultural area.

In recent years, the area cropped with legumes has increased considerably in Latvia. In the period 2010–2016, the total area under faba beans (FB) rose about 24 times (from 1.3 kha to 30.9 kha), and the area under field peas (FP) increased seven times (from 1.2 kha to 8.7 kha).[4] Such a fast increase in the area under legumes was promoted by the EU's policy on the protection and improvement of biodiversity on farms. Environmentally friendly agricultural practices involve nitrogen-fixing crops (papilionaceous plants), including FP and FB,[4] that significantly reduce nitrogen compound emissions, thereby reducing greenhouse emissions and the imports and application of nitrogen fertilizers, and saving fossil energy resources used in the production of the nitrogen fertilizers.[5,6] However, from the economic perspective, a problem emerges because Latvia lacks a sufficiently developed market for selling legume seeds and there is overproduction of seeds.

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 (FC). The productivity and production cost of broilers are strongly associated with feedstuffs used, their content of crude protein (CP) and their biological value and price; overall, feed makes up about 70% of the total cost of poultry products.[7] According to an analysis of production costs, FC is the key component;[8] yet a detailed analysis indicates that the highest proportion of production costs relates to imported feed and its components, while the proportion of the domestic FC is insignificant. In view of feed price hikes,[3] the only way to reduce FC is

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to reduce the amount of expensive imported feed components in the feed ration. This means that it is necessary to seek appropriate regional feedstuffs providing higher economic efficiency, i.e. higher productivity per unit of resources used. In this aspect, FB and FP are high-yield crops whose economic role is essential. Seeds are an excellent concentrate feed for poultry and agricultural animals,[9–11] as the CP content in the dry matter of FP ranges from 185 to 264 g kg^{-1}; in FB it ranges from 269 to 317 g kg^{-1},[12–14] while soybean meal (SBM) contains approximately 506 g kg^{-1}.[14,15]

This means that FB and FP can increase the proportion of domestically produced protein-rich feedstuffs used in production and reduce the production cost of poultry products, i.e. to increase efficiency. However, the use of inappropriate proteins or an inadequate amount of protein in broiler diets can increase production costs and reduce productivity. In this aspect, the research aim is to identify economic gains from the production of broiler chicken meat, replacing soybean meal with domestic faba beans and field peas in broiler chicken diets. To achieve this aim, the following specific research tasks were set: (i) to identify the effect of the use of FB and FPs on the cost of broiler chicken feed; (ii) to assess changes in broiler chicken productivity due to FB and FP diets.

EXPERIMENTAL

Broilers and diets

The experiment was done using cross Ross-308 broilers aged 1–42 days, i.e. up to the selling age. The broilers were kept on the floor, meeting animal welfare standards. The stocking density complied with Council Directive 2007/43/EC of 28 June 2007, laying down minimum rules for the protection of chickens kept for meat production;[16] the live weight density was 33 kg m^{-2} or 12 chicks m^{-2}. During the first week, the temperature at the broiler house was maintained at 31 °C. In the second week the temperature was gradually decreased to 28 °C. The broilers had constant lighting and free access to feed and water.

At the age of 1 day, the broilers ($N = 240$) were divided into eight groups ($n = 30$), ensuring an equal number of broilers of both sexes in each group. In terms of crude protein (CP), crude fat (CF), Ca, P and amino acids, the composition of the diet for all groups was balanced and appropriate for the growth intensity of the broilers and the needs of their organisms: starter feeds (at the age of 0–10 days), grower feeds (11–26 days) and finisher feeds (from the age of 27 days to the selling age) in accordance with the standards for the cross Ross-308.[17] The basic feed for broilers was prepared according to a relevant feed recipe for industrial production of broilers to gain a live weight of 1.7–2.4 kg at the age of 42 days,[17] providing CP 247 ± 23.6 g kg^{-1} and metabolizable energy (ME) 3120 ± 48.4 kcal kg^{-1} in the grower period feed. To achieve the maximum live weight, in the finisher period feed CP was decreased to 219 ± 19.2 g kg^{-1}, while ME was increased to 3200 ± 37.5 kcal kg^{-1}. The diet for the control group comprised 5.3% crude fat, 6.1–6.6% crude ash, 4.9–6.1% fibre, 1.1–1.2% calcium, 0.6–0.7% phosphorus, 1.09–1.43% lysine and 0.41–0.51% methionine.

The chemical composition of the examined cultivars of FP and FB contained equal amounts of CP, ME, crude fat, fibre, crude ash, calcium and phosphorus (Table 1). In the experimental feed, the CP content of peas was 251–264 g kg^{-1}, which also contained the irreplaceable amino acid lysine 1.4–1.6 g 100 g^{-1}, as well as methionine 0.20–0.22 g 100 g^{-1}; the CP content of beans was 294 g kg^{-1}, including lysine 1.7 g 100 g^{-1} and methionine 0.22 g 100 g^{-1}.

Table 1. Chemical composition of peas, faba beans and soybeans

Items	FPB	FPV	FBL	SBM
DM (%)	88.0	88.3	88.9	87.4
CP (% DM)	26.4	25.1	29.4	50.6
CFA (% DM)	1.2	1.3	1.6	1.6
CFB (% DM)	7.1	6.9	6.5	3.6
CAsh (% DM)	2.9	2.9	3.4	7.8
ST (% DM)	52.1	53.0	44.5	10.6
Ca (% DM)	0.1	0.1	0.1	0.4
P (% DM)	0.4	0.4	0.6	0.7
ME (kcal kg^{-1})	3217	3174	3019	3305
LYS (% DM)	1.50	1.40	1.71	2.80
MET (% DM)	0.22	0.20	0.21	0.61

SBM, soybean meal; FPB, field peas 'Bruno'; FPV, field peas 'Vitra'; FBL, faba beans 'Lielplatone'; DM, dry matter; CP, crude protein; CFA, crude fat; CFB, crude fibre; CAsh, crude ash; ST, Starch; Ca, calcium; P, potassium; ME, metabolizable energy; LYS, lysine; MET, methionine.

In the experimental feed, part of the soybean meal incorporated in the basic feed was replaced with different amounts of faba beans (*Vicia faba minora* var. 'Lielplatone') (FBL) and field peas (*Pisum sativum* var. 'Bruno') (FPB) and var. 'Vitra' (FPV) (Table 2). The other feedstuffs and their amounts in the diet were the same for all the broiler groups. The feed components were blended and formed into pellets appropriate for the growth stage: starter and grower 1.6–2.4 mm diameter, 4.0–7.0 mm length; finisher 3.0–4.0 mm diameter, 5.0–8.0 mm length.

The most important development processes take place in the bird organism in the first days of life, which form and develop the appetite of the bird. For this reason, at the starter stage the broilers of all the groups were fed a starter feed of the same composition. From the 11th day of life onwards (the grower stage), the experimental broiler groups (groups 2–8) were fed a mixture with different amounts of FPB, FPV and FBL, partly replacing soybean meal in the basic feed (Table 2). Different amounts of FPB, FPV and FBL provided 14.7–52.8 g protein, and SBM 53.2–115.2 g kg^{-1} feed (Table 2).

By means of FP, FB and SBM, for experimental groups MEI 979–1236 kcal kg^{-1} was provided in the grower period and 752–1012 kcal kg^{-1} in the finisher period, exceeding the MEI provided for the control group by 54–331 kcal kg^{-1}, which may be explained by four to five times higher starch (ST) content of FP and FB compared with SBM (Table 2).

Economic analysis

The economic efficiency of FP and FB in broiler diets was evaluated in terms of the most important productivity indicators: change in live weight, live weight gain, feed consumption, product unit cost and productivity index.

The economic efficiency of consumption of feed by broilers was identified using the feed conversion ratio, which can be calculated using the following formula:

$$\mathrm{FCR} = \frac{\text{Total feed consumed}}{\text{Total live weight}} \quad (1)$$

where FCR is feed conversion ratio.[17]

However, the economic indicators of broiler productivity and growth were calculated using the production efficiency factor. This

Table 2. Basic and conditioned feeds evaluated in the broiler chicken feeding experiment

Item	1[a]	2	3	4	5	6	7	8
SBM[b] (g kg^{-1})	280	228	175	230	180	251	221	201
SBM[c] (g kg^{-1})	210	158	105	160	110	181	151	130
FPB (g kg^{-1})	–	100	200	–	–	–	–	–
FPV (g kg^{-1})	–	–	–	100	200	–	–	100
FBL (g kg^{-1})	–	–	–	–	–	50	100	50
CPI from SBM[b] (g kg^{-1})	141.7	115.2	88.6	116.3	90.92	126.8	111.9	101.5
CPI from SBM[c] (g kg^{-1})	106.3	79.7	53.2	80.9	55.5	91.4	76.5	66.0
CPI from FP and FB (g kg^{-1})	–	26.4	52.8	25.1	50.2	14.7	29.4	39.8
MEI[b] (kcal kg^{-1})[d]	925 ± 23	1074 ± 15	1222^S ± 25	1077 ± 31	1236^S ± 19	979 ± 22	1033 ± 16	1149 ± 19
P-value	–	0.232	0.008	0.437	0.005	0.978	0.918	0.411
MEI[c] (kcal kg^{-1})[d]	694 ± 16	842 ± 21	991^S ± 29	859 ± 19	1012^S ± 33	752 ± 22	810 ± 18	917 ± 31
P-value	–	0.069	0.035	0.209	0.041	0.170	0.424	0.113
LYSI[b] (g)[d]	6.9 ± 0.2	6.9 ± 0.1	6.9 ± 0.1	6.9 ± 0.1	6.9 ± 0.3	7.0 ± 0.2	6.9 ± 0.1	6.9 ± 0.4
P-value	–	0.736	0.563	0.538	0.114	0.228	0.215	0.748
LYSI[c] (g)[d]	5.1 ± 0.1	5.2 ± 0.3	5.2 ± 0.1	5.1 ± 0.2	5.1 ± 0.4	5.2 ± 0.1	5.2 ± 0.2	5.2 ± 0.3
P-value	–	0.930	0.444	0.638	0.335	0.160	0.443	0.152
METI[b] (g)[d]	1.49 ± 0.02	1.41 ± 0.02	1.32 ± 0.01	1.40 ± 0.01	1.31 ± 0.02	1.43 ± 0.01	1.37 ± 0.01	1.34 ± 0.02
P-value	–	0.268	0.864	0.154	0.462	0.246	0.098	0.112
METI[c] (g)[d]	1.12 ± 0.02	1.03 ± 0.01	0.95 ± 0.01	1.03 ± 0.01	0.94 ± 0.02	1.06 ± 0.01	0.99 ± 0.01	0.97 ± 0.01
P-value	–	0.224	0.068	0.322	0.461	0.968	0.211	0.136

[a] Control group; [b] growing stage; [c] finishing stage; [d] sum from SBM, beans and peas. Data are presented as means ± standard deviation; S, significant differences ($P < 0.05$). SBM, soybean meal; FPB, field peas 'Bruno'; FPV, field peas 'Vitra'; FBL, faba beans 'Lielplatone'; CPI, crude protein intake; MEI, metabolizable energy intake; LYSI, lysine intake; METI, methionine intake.

takes into account the live weight, age and survival of broilers and their feed conversion, and can be calculated using the following formula:

$$\text{PEF} = \frac{\text{Livability (\%)} \times \text{Live weight (kg)}}{\text{Age (days)} \times \text{FCR}} \times 100 \qquad (2)$$

where PEF is production efficiency factor. This best shows the productivity of broilers and economic returns from raising them.[17]

Statistical analysis

Data on performance of broiler productivity were subjected to analysis of variance (ANOVA) with $P < 0.05$ significance level. Significant differences were accepted if $P < 0.05$.[18,19] All statistical analyses were performed using SPSS for Windows version 20.0.

RESULTS

An analysis of the experimental diets and live weights revealed that the largest live weight at the age of 42 days and, accordingly, the largest live weight gain was specific to group 3 (2747.3 ± 335.8 g) and group 5 (2808.74 ± 410.3 g) (Table 3), which were fed a diet comprising 200 g kg^{-1} FPB and 200 g kg^{-1} FPV (Table 2). The live weight of broilers from these groups significantly exceeded ($P < 0.05$) that from the control group at the selling age (by 238.4 g or 9.50%, and 299.8 g or 11.95%, respectively) (Table 3).

A slightly lower live weight of broilers was observed in group 7, which was fed a diet with 100 g kg^{-1} FBL. At the selling age, the live weight of broilers in this group was, on average, 2725.1 ± 299.5 g (Table 3) or by 216.2 g (8.62%) larger than that of the control group broilers; yet, significant statistical ($P > 0.05$) differences were not identified (Table 3).

The FC for the control group, which contained SBM, was, on average, 0.48 EUR kg^{-1} at the grower stage and 0.44 EUR kg^{-1} at the finisher stage. If adding FP and FB to the diet (groups 2–8), the cost of feed ranged from 0.360 EUR to 0.443 EUR kg^{-1} at the grower stage and was within the range of 0.280–0.392 EUR kg^{-1} at the finisher stage. This means that, if replacing SBM with FB and FP in the diet of broilers, FC decreased by 0.06–0.12 EUR kg^{-1} at the grower stage and by 0.08–0.16 EUR kg^{-1} at the finisher stage for all the experimental groups (Table 4).

An important indicator to measure efficiency in the use of feed is feed consumption per broiler or the amount of feed intake (FI) by a broiler until the selling age. In the experiment 4.26–4.40 kg of wholesome feed was used to raise a broiler. The lowest total feed intake (TFI) per broiler was observed in group 3 broilers (4.26 kg), whose diet contained 200 g kg^{-1} FPB (Table 3). In contrast, the highest TFI (4.40 kg) was specific to the group 7, whose diet contained 100 g kg^{-1} FBL; content of CP and ME were also higher than that of the control group broilers.

The FCR for all the broiler groups was in the range of 1.55–1.65. Overall, the FCR decreased for the experimental groups by 0.61–6.06% compared with the control group (Table 4); the best performance was presented by group 3 (1.55 ± 0.13 kg kg^{-1}), group 5 (1.55 ± 0.16 kg kg^{-1}) and group 6 (1.60 ± 0.24 kg kg^{-1}). The highest feed conversion was observed in the control group (1.65 ± 0.11 kg kg^{-1}) and group 8 (1.64 ± 0.18 kg kg^{-1}). This indicates that such a combination of 100 g kg^{-1} FPV and 50 g kg^{-1} FBL for the bird organism was not as efficient as if feeding only one kind of legume, i.e. 200 g kg^{-1} FP. At the same time, the highest MEI was observed in groups 3 and 5 as well as in group 8 (Table 2). This indicates that the conversion of feed in the intestinal tract of broilers was more intensive in groups 3 and 5 than in the other experimental groups.

Table 3. Change in live weight and daily live weight gain for broilers

Item	1[a]	2	3	4	5	6	7	8
IBW (g) ± SD	284.8 ± 21.4	268.1 ± 24.0[S]	276.2 ± 23.2	276.3 ± 16.1	285.0 ± 29.1	290.9 ± 27.2	288.2 ± 19.2	271.5 ± 22.1[S]
GBW (g) ± SD	1503.9 ± 171.5	1647.6 ± 162.3[S]	1632.7 ± 168.2[S]	1463.9 ± 159.2	1735.6 ± 181.5[S]	1725.1 ± 237.1[S]	1706.2 ± 173.6[S]	1657.8 ± 185.3[S]
FBW (g) ± SD	2508.9 ± 284.7	2685.7 ± 283.4	2747.3 ± 335.8[S]	2652.8 ± 302.3	2808.7 ± 410.3[S]	2690.6 ± 298.1	2725.1 ± 299.5	2660.5 ± 312.2
FBW to control (%)	–	+7.1	+9.5	+5.7	+11.9	+7.2	+8.6	+6.0
P-value[A]	–	0.002	0.006	0.379	0.000	0.000	0.000	0.002
P-value[B]	–	0.317	0.027	0.101	0.043	0.308	0.140	0.517

[a] Control group. Data are presented as means ± standard deviation (SD). IBW, initial body weight at day 10; GBW, grower body weight at day 27; FBW, final body weight at day 42; *P*-value[A], to define differences in comparison of control group at 28 days of age; *P*-value[B], to define differences in comparison of control group at 42 days of age; S, significant differences ($P < 0.05$) between control group (1) and experimental groups (2–8).

Table 4. Effects of peas and beans on the feed intake, feed conversion ratio and production efficiency factor for broilers

Item	1[a]	2	3	4	5	6	7	8
TFI per broiler (kg)	4.30	4.32	4.26	4.33	4.36	4.30	4.40	4.36
to control (%)	–	+0.46	−0.03	+0.69	+1.39	0	+2.32	+1.39
P-value	–	0.436	0.215	0.360	0.421	0.298	0.075	0.231
FCR ± SD	1.65 ± 0.11	1.61 ± 0.02	1.55[S] ± 0.13	1.63 ± 0.22	1.55[S] ± 0.16	1.60[S] ± 0.24	1.61 ± 0.23	1.64 ± 0.18
to control (%)	–	−2.42	−6.06	−1.21	−6.06	−3.03	−2.42	−0.61
P-value	–	0.106	0.008	0.326	0.012	0.040	0.205	0.362
PEF ± SD	339.19 ± 0.51	357.79 ± 0.35	379.66[S] ± 0.46	348.28 ± 0.32	387.73[S] ± 0.64	360.54 ± 0.29	361.66 ± 0.18	347.89 ± 0.53
to control	–	+18.60	+40.47	+9.09	+48.54	+21.34	+22.47	+8.70
P-value	–	0.519	0.000	0.140	0.006	0.320	0.104	0.182

[a] Control group. Data are presented as means ± SD. TFI, total feed intake; FCR, feed conversion ratio; PEF, production efficiency factor; *P*-value, to define differences in comparison of control group at 42 days of age; S, significant differences ($P < 0.05$).

The highest economic return or PEF, 387.73 ± 0.64 and 379.66 ± 0.46, was observed in the groups 5 and 3, respectively – the PEF was significantly ($P < 0.05$) higher (by 48.54 and 40.47) than that for the control group (339.19 ± 0.51). Overall, the PEF for the experimental groups was higher by 8.70–48.54 than that for the control group (Table 4). A higher PEF evidences that the FP and FB used in the experiment, which replaced SBM, are appropriate for the broiler organism and provide it with all the necessary nutrients and energy requirements, foster the growth of broilers, increase live weight gains and reduce FI per kilogram live weight gain.

Raising one broiler during the experiment required, on average, 4.26–4.40 kg feed, which cost in the range of 1.363–1.978 EUR kg^{-1}. Accordingly, the FC per kilogram live weight gain was in the range of 0.50–0.79 EUR kg^{-1}. The FC for the control group was the highest at 0.79 EUR kg^{-1}, as the feed contained SBM. Different amounts of peas and beans added to the broiler diet reduced the FC per kilogram live weight gain by 0.12–0.29 EUR kg^{-1} if compared with the control group (Table 5). Adding 200 g kg^{-1} FPB and 200 g kg^{-1} FPV to the diet for the experimental groups (groups 3 and 5) resulted in a lower cost per kilogram live weight gain than that for the control group. The use of 100 g kg^{-1} FPV and 50 g kg^{-1} FBL in the broiler diet (group 8) also considerably reduced the cost per kilogram live weight gain, by 0.21 EUR kg^{-1}, compared with the control group (Table 5).

The highest revenue from selling broiler meat was gained from group 7 (diet comprised 100 g kg^{-1} FBL), at EUR 102.04 and group 8 (diet comprised 50 g kg^{-1} FBL and 100 g kg^{-1} FPV), at EUR 99.63, outperforming the control group by 20.7% and 17.8%, respectively, which may be explained by 100% broiler survival in these groups. However, group 5, which had the highest broiler live weight, generated a revenue of EUR 94.66 from selling the broiler meat – only 11.9% more than the control group.

The difference in the cost of feed consumed was determined by differences in the amount and cost of crude protein in SBM and in the experimental feed: FPB, FPV and FBL (Table 6). The market price of FP grown in Latvia is approximately 0.30 EUR kg^{-1}, FB costs 0.29 EUR kg^{-1}, and SBM costs 0.65 EUR kg^{-1}. The market price of a wholesome feed for broilers aged between 10 and 26 days is 0.48 EUR kg^{-1} and for broilers aged over 27 days it is 0.44 EUR kg^{-1}. At present, SBM – by 0.35 EUR kg^{-1} – is more expensive than FP and FB; yet the cost of 1 kg CP in various feedstuffs plays an important role. The price of 1 kg CP from SBM – by EUR 0.12–0.36 – is higher than that from FPB, FPV and FBL.

DISCUSSION

It is known that the productivity of broilers has been developed as a genetic feature,[20] and an increase in production efficiency and a low production cost of poultry meat are achieved by a short production cycle and crosses of fast-growing broilers; yet feedstuffs used as well as the content of protein in the feed significantly affect the productivity of broilers.[8,21] The key focus in the composition of broiler feed is placed on CP, as it comprises most of any broiler diet, which, together with the other nutrients, considerably affects the health and productivity of the poultry.[22] If a diet is deficient in CP, broilers lose their appetite, poorly absorb their feed, their live weight decreases and their meat quality deteriorates. If there is too much protein in a poultry diet, part of the excess protein turns into fat, which is stored in their bodies,

Table 5. Feed costs for broilers and returns per slaughter weight

Item	1[a]	2	3	4	5	6	7	8
Grower stage FC (EUR kg^{-1})	0.48	0.42	0.36	0.42	0.37	0.44	0.41	0.39
to control (EUR kg^{-1})	–	−0.06	−0.12	−0.06	−0.11	−0.04	−0.07	−0.09
to control (%)	–	12.46	24.93	11.68	23.33	7.71	15.00	19.17
Finisher stage FC (EUR kg^{-1})	0.44	0.36	0.28	0.36	0.28	0.39	0.35	0.32
to control (EUR kg^{-1})	–	−0.08	−0.16	−0.08	−0.16	−0.05	−0.09	−0.12
to control (%)	–	36.36	17.27	36.14	10.91	21.36	27.95	18.18
Average feed costs (EUR kg^{-1})	0.46	0.39	0.32	0.39	0.33	0.42	0.38	0.35
Total FC for raising one bird (EUR)	1.98	1.69	1.36	1.71	1.42	1.80	1.66	1.54
to control (%)	–	14.82	31.08	13.75	28.47	9.24	16.14	22.30
FC per kg live weight (EUR kg^{-1})	0.79	0.63	0.50	0.64	0.50	0.67	0.61	0.58
to control (%)	–	−20.25	−36.70	−18.97	−36.70	−15.19	−22.78	−26.58
Returns per slaughter weight sold per group (EUR per group)	84.55	97.22	99.45	89.40	94.66	94.03	102.04	99.63
to control (%)	–	14.98	17.61	5.74	11.95	11.21	20.68	17.82

[a] Control group. Data are presented as means ± SD. FC, feed costs. Market price on fresh broilers is 157.98 EUR 100 kg^{-1}.

Table 6. Costs of crude protein from peas, beans and soybean meal

Item	SBM	FPB	FPV	FBL
Trading price (EUR kg^{-1})	0.65	0.30	0.30	0.29
Protein content (g kg^{-1} feed)	442.24	232.32	221.63	261.37
Cost of CP (EUR kg^{-1})	1.47	1.29	1.35	1.11
Cost of CP relative to SBM (EUR kg^{-1})	–	−0.18	−0.12	−0.36

SBM, soybean meal; FPB, field peas 'Bruno'; FPV, field peas 'Vitra'; FBL, Faba beans 'Lielplatone'; DM, dry matter; CP, crude protein.

while part of the protein is excreted, as well as vitamins A and D, and minerals Ca and P are poorly absorbed.[23] In poultry farming, lysine and methionine are among the most limiting amino acids, which are important for the growth of the organism and in the balance of nitrogen; deficiency in lysine causes blood circulation problems, a lower level of haemoglobin as well as leading to smaller muscles and bone deterioration;[24] consequently, the death rate of broilers increases and an increase in the weight of their muscles is lower, which can cause considerable economic losses.

Researchers from various countries point out that the incorporation of FP and FB into broiler diets provides not only an adequate amount of protein but also enhances the composition of amino acids in the feed,[25] yet the amino acid content of the FP and FB used in the experiment is much lower than that of SBM (Table 1). However, replacing SBM with FP and FB according to the amount of protein, the real amount of the FP and FB (g) in the experimental feed was higher; therefore, the intakes of lysine and methionine by the control and experimental group broilers did not significantly differ ($P > 0.05$) (Table 2).

A number of research studies have pointed out that the amount of ME in feed plays an important role in the rational use of the feed. González *et al.*[26] showed that, in relation to energy use, grain legumes were the most efficient protein sources, with 41–77 g protein MJ^{-1} energy use; at the same time, Farrell *et al.*[27] and Perween *et al.*[28] indicated that broilers consume less feed, of higher ME content. Yet our research showed that no significant differences ($P > 0.05$) in TFI were observed between the control and experimental groups (Table 4). However, a higher live weight was observed in the groups (3 and 5) whose diets provided a higher ME content, i.e. the diets with 200 g kg^{-1} FPB and 200 g kg^{-1} FPV. The groups that were provided with a higher ME content also had a significantly higher ($P < 0.05$) FCR and PEF. Similar findings were made in a research study by Perween *et al.*,[28] which revealed that a higher crude protein and energy level positively affected live weight gains in Varanaja chicken. Similar results were achieved by Muniz *et al.*,[29] who reported that the increase in ME provided better feed conversion in meat quails.

Every feedstuff added to the broiler diet has specific effects, as they represent biological and chemical substances that, if added to the diets for broilers and laying hens, are transformed in the metabolic processes of the bird organism and contribute to feed absorption and the growth and development of the organism, while resulting in quality products and higher efficiency. Positive effects are made through achieving better feed conversion and higher organism vitality, stimulating the immune system, regulating the digestive tract's microflora, etc.; consequently, economic efficiency increases.[30]

Although the genetic features of broilers allow achieving an earlier slaughter age and maximally meet the growing demand for poultry meat,[31] it is necessary to provide the broilers with protein sources that allow achieving a certain live weight within a shorter period and reaching a higher productivity level. At the same time, it is important to ensure that protein crops needed for feed are grown and are available in the nearest region,[32] which results in lower protein source costs. According to the targets set by the European Commission in respect to protein crop self-sufficiency, the EU has to reduce its soybean imports by 50% until 2040 and to promote the use of traditional European protein crops (beans, peas) for feed, as the domestic feed contributes to greater independence of the agricultural industry from feed price fluctuations in the global market.

A number of research studies have proved the positive effect of FP and FB in broiler diets. However, the amount of FP and FB in the animal diet is limited by tannins and alkaloids[33] present in these legumes, which are antinutritive compounds that influence the taste and the digestive system,[10] thereby decreasing the productivity of broilers. This means that FP and FB cannot fully replace SBM in standard poultry feed mixtures because of a lower CP content and presence of antinutritive compounds. However, Gous[34] points out that the process of granulation of pulses involves sufficient thermal treatment that inactivates antinutritive compounds, and no additional thermal treatment is required for the pulses,[34] which also decreases feed production costs. In the current study the feed components were blended and pelleted, thereby decreasing the antinutritive compounds of the feed.

According to the literature, a broiler diet may maximally comprise 300 g kg^{-1} peas of the total amount of feed.[10] When analysing the effects of different amounts of peas used in layer hens' diet on egg production and feed conversion in the laying hens, Igbasan and Guenter[35] found that a diet comprising 200–400 g kg^{-1} peas was equivalent to a diet with wheat and soybeans. However, a diet with 600 g kg^{-1} peas resulted in a lower laying intensity, lower egg weight and a lower FCR. The production of broiler meat differs from that of eggs in the production cycle length; the former is shorter. In the present experiment, the broiler production cycle was 42 days. Regarding poultry age in the production cycle, a number of researchers have pointed out that the maximum amount of peas to be incorporated into the poultry diet ranges from 200 to 300 g kg^{-1}. In their research investigations, Castell *et al.*[36] and Koivunen[37] have pointed out that up to 200–300 g kg^{-1} peas may be added to the broiler diet without causing negative effects on the productivity and health of broilers. According to Perez-Maldonado *et al.*[38] and Nalle *et al.*,[13] adding 200 g kg^{-1} beans to the broiler diet until the age of 21 days resulted in faster growth and a higher FCR. In their experiment, Metayer *et al.*[39] fed broilers a diet comprising 200 and 250 g kg^{-1} beans. It was observed that during the first 14 days the live weight of broilers that were fed beans was higher than that of broilers that were fed soybean flour. In the experiment, the diets where SBM was partly replaced with FP (40–160 g kg^{-1} during the starter period, 60–240 g kg^{-1} during the grower period and 120–480 g kg^{-1} during the finisher period) resulted in similar productive performance,[40] which to some extent may be explained by the incorporation of FP in the diets in the starter period when the broilers' digestive organs that process feed were very sensitive and still not adapted to a coarse fibrous feed.

Based on the above-mentioned research findings on physiologically adequate amounts of legumes in the poultry diet, in the present experiment the amounts of FP, FB and a combination of both legumes incorporated in the diet for the experimental groups ranged from 50 to 200 g kg^{-1} (Table 2).

In the production of broiler meat, just as in any industry, economic efficiency is characterized by the efficient use of resources for better performance.[41] The most important indicators showing the economic efficiency of poultry farming are broiler live weight gain, survival rate, FCR, production cycle duration, unit production cost and PEF.[7,20,42,43]

Compared with other agricultural animals, broilers can absorb the feed consumed to increase their live weight in the best way. The research showed (Tables 3 and 4) that TFI for the experimental groups with the highest live weight characteristics at the selling age was very different. In the trial, TFI ranged from 4.26 to 4.40 kg to reach a live weight in the range of 2652.84–2808.74 g. This means that TFI per kilogram live weight gain depends on the absorption of feed nutrients in the bird's organism. Therefore, from the economic aspect, the largest role is played by TFI per kilogram live weight gain or FCR. FCR can be defined as the amount of TFI per unit weight gain, and is a composite trait of starting and ending body weight and TFI.[44] It has to be as low as possible, as FCR is a measure of how well a flock converts feed intake into live weight and provides an indicator of management performance, and also profit at any given feed cost. FCR increases as the bird gets older;[20] therefore, it is important to take into consideration the selling age of poultry. The standard in broiler performance is achievement of 2.5 kg live weight with FCR of 1.72 at the 42nd day of age.[45] The present research shows that, if incorporating legumes up to 200 g kg^{-1} into the broiler diet, the FCR was in the range of 1.55–1.65, which is consistent with the research studies done by Creswell.[45]

Economic efficiency and variability in energy required for body weight maintenance that contributes to FI are not accounted for in FCR, according to Willems *et al.*;[46] therefore, Nabizadeh,[42] Marcu *et al.*,[7] and Szőllősi and Szőcs[43] suggested calculating the PEF to express the efficiency of production in one indicator, which better shows economic efficiency than energy efficiency.[42,43,47] PEF calculations take into account poultry live weight at the selling age, broiler age, survival rate and FCR. This can more comprehensively show broiler productivity and the economics of raising poultry.

The productivity of cross Ross-308 broilers was analysed in terms of PEF, which indicates the economic aspect that takes into account live weight gain, survival rate, FCR and the length of the production period. During the experiment, the survival rate was 93.3–100%. The higher the PEF, the higher the productivity of broilers and economic returns. The research showed that adding FP and FB to the broiler diet yielded positive results, and the PEF for the experimental groups was by 8.70–48.54 units higher than for the control group. The higher PEF evidences that the feedstuffs comprising FP and FB used in the diet, which replaced SBM, are appropriate for the broiler organism and provide it with all the necessary nutrients, foster the growth of broilers, increase their live weight gain and reduce their TFI per kilogram live weight gain.

An analysis of the economic indicators acquired in the present experiment showed that the most efficient diet was the one comprising 200 g kg^{-1} FP, which was fully consistent with a research study done by Koivunen.[37] As pointed out by Perez-Maldonado *et al.*[38] and Olkowkski *et al.*,[11] the maximum amount of peas to be used in the broiler diet is 300 g kg^{-1}, which increases the productivity of the broilers without causing any harm to their health; yet the present experiment allows conclusion that, economically, such an amount of peas lowers productivity. Increasing the amount of peas and beans in the broiler diet above 200 g kg^{-1}, the live weight of broilers is smaller compared with the experimental groups, which were not fed a diet comprising peas more than 200 g kg^{-1} in the feed. However, a combination of legumes – peas and beans – used in the broiler diet was economically less efficient than a diet comprising only one kind of legume. For example, a diet with 100 g kg^{-1} FBL (fed to group 7 broilers) resulted in a higher average live weight – 2725.1 ± 299.5 g – which was higher than the live weight for group 6 (2690.6 ± 298.1 g), a diet with 50 g kg^{-1} FBL, and group 8 (2660.5 ± 312.2 g), which were fed diets comprising a mixture of 100 g kg^{-1} FPV and 50 g kg^{-1} FBL.

CONCLUSIONS

The research examined the effects of peas and beans grown in Latvia, and included in poultry diets in different amounts, on the productivity of poultry from the economic aspect.

Compared with the control group:

- a significantly ($P < 0.05$) larger live weight gain at the age of 42 days was specific to group 3 (2747.3 ± 335.8 g) and group 5 (2808.7 ± 410.3), exceeding the control group's performance by 9.5% and 11.9%, respectively;

- the lowest feed consumption per kilogram live weight gain or feed conversion ratio was presented by group 3 (1.55 ± 0.13 kg kg^{-1})and group 5 (1.55 ± 0.16 kg kg^{-1}), which were lower by 6.06%;
- the highest economic return (PEF 387.73 ± 0.64) was observed in group 5 – the PEF for this group was higher by 48.54 than that for the control group (339.19 ± 0.51);
- a significant decrease in cost per unit of products produced was observed in groups 3 (36.70%), 5 (36.70%) and 8 (26.58%) compared with control.

The research results indicate that the recommended amount of peas in the diet is 200 g kg^{-1}, which ensures an increase in live weight gain and a decrease in the feed conversion ratio and, accordingly, lower feed consumption and a lower production cost per unit of products produced.

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