Effectiveness of extracts of medicinal plants included in poultry diet

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Abstract. A large number of papers have explored the use of phytobiotics in the diet of farm animals and poultry in recent years. This study area is much addressed, since vegetable feed additives can be an alternative to feed antibiotics. They have a pronounced growth-stimulating and immune-modulating effect on the body of young birds, and are essential for manufacturing organic products of animal origin. The aim of our study was to evaluate the effect of water-ethanol extracts of sarepta mustard on chicken meat performance, and the effect of mountain ash extracts on egg performance of laying hens. A scientific and economic experiment was performed, where broilers from the experimental groups received the sarepta mustard extract at doses of 10, 30, 50, 70, and 90 mg/kg of feed, and laying hens received the mountain ash extract at doses of 30, 40, 50, 60 and 70 mg/kg of body weight. It was found that the optimal dose of the sarepta mustard extract for broiler chickens was 70 mg/kg of feed. The average daily weight gain exceeded the control indicators by 3.0%, and the European production efficiency factor and the Russian production efficiency factor for chicken meat by 33.2 and 7.2 units, respectively. For laying hens, the optimal dose of the mountain ash extract attained 70 mg/kg of body weight. It increased the egg production rates for the hen housed and middle hen by 12.2 and 10.4%, respectively, compared to the control, and exceeded that of the European egg production index and the Russian egg production factor for laying hens by 1.53 and 10.34 units, respectively.

1 Introduction

Part of the complex measures aimed at replacing the use of antibiotics for preventive purposes in the cultivation of poultry is the use of feed additives in its diets with antibacterial, anti-

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inflammatory and other effects that contribute to the normalization of body homeostasis, the functions of the microbiota of the gastrointestinal tract, and increase the natural resistance and productivity of poultry. These means include plant feed additives - phytobiotics, or phytogenics. At the same time, the use of phytobiotics in poultry farming is of increased interest as a supplier of the most significant food products in terms of volume and available to the population.

2 Materials and methods

Experimental studies to evaluate the effectiveness of the use of the sarepta mustard extract in feeding broiler chickens were performed on the poultry farm in Kuzbass, Kemerovo region. The experiments involved broiler chickens of the ISA F15 cross.

The extract was tested using a cage system for growing poultry by the method of analogous groups in one control and five experimental groups of one-day-old broiler chickens grouped with respect to their sex and body weight. Each group included 35 heads. The groups were formed in accordance with conventional methods [1].

During the experiment, the chickens from the control were fed a complete feed (CF) in line with phases of poultry growing with inclusion of antibiotic growth promoters; in addition to the compound feed free of antibiotic, broiler chickens from the experimental groups were given the sarepta mustard extract in different doses according to the experimental scheme (Table 1).

Table 1. Scheme of the scientific and economic experiment on broiler chickens

Group	Number of birds, heads	Feeding conditions
Control	35	CF + feed antibiotic
Experimental group 1	35	CF+ mustard extract at a dose of 10 mg/kg feed
Experimental group 2	35	CF+ mustard extract at a dose of 30 mg/kg feed
Experimental group 3	35	CF+ mustard extract at a dose of 50 mg/kg feed
Experimental group 4	35	CF+ mustard extract at a dose of 70 mg/kg feed
Experimental group 5	35	CF+ mustard extract at a dose of 90 mg/kg feed

Extracts of medicinal plants are produced by water-ethanol extraction using low temperature vacuum drying.

The amount of biologically active compounds in the extracts of medicinal plants meets the requirements of regulatory documents [2].

The doses of medicinal plant extracts supplemented to the complete feed for broiler chickens and laying hens were calculated with respect to the main biologically active compounds by the methodology proposed by V.A. Tutelyan and B.P. Sukhanov [3].

Observations of broiler chickens and recording of experimental data were performed for 42 days. The sarepta mustard extract was supplemented to the feed of broiler chickens in the following growth phases: 1–6 days – prestart, 7–20 days – start, 21–28 days – growth, 29–33 days – finish 1.

The growth rates of broiler chickens was analyzed via individual weighing of the body of the entire number of chickens at the beginning and end of the experiment, and by the absolute and average daily body weight gains obtained by conventional methods. Daily consumption of feed was recorded to calculate feed consumption per 1 kg of body weight gain, and daily chicken mortality was monitored to calculate the livestock safety relative to the initial number of birds for the entire period [1].

For estimation of quality indicators of bird's carcasses, anatomical cutting of six birds from each group was performed [1]. The recorded weight included preslaughter weight, the weight of the uneviscerated and eviscerated bird, and the weight of internal organs (liver, heart, gizzard). The obtained values were used to calculate the slaughter yield.

Chemical analysis of chicken meat was performed for an average sample of the pectoral and femoral muscles in compliance with the following methods: moisture content – in compliance with GOST 9793-2016, protein – in compliance with GOST 25011-81, fat – in compliance with GOST 23042-2015, ash – in compliance with GOST 31727-2012.

Efficiency factors were used to evaluate the efficiency of chicken meat production. The international express method for calculating the European Efficiency Factor (EEF) was used:

$$\mathrm{EEF} = \frac{\mathrm{Bw} \times \mathrm{Ls}}{\mathrm{Dg} \times \mathrm{Fc}} \times 100, \qquad (1)$$

where EEF is the European efficiency factor; Bw is the body weight of the broiler chicken at the end of growing, kg; Ls is livestock safety, %; Dg is the duration of growing, days; Fc is feed consumed per 1 kg of body weight gain, kg.

To quickly determine the advantages of a certain group of broiler chickens and production profitability, we determined the Russian production efficiency factor (RPEF) for chicken meat, calculated using the express method by A.Sh. Kavtarashvili and R.V. Karapetyan [4]:

$$\mathrm{RPEF} = \frac{\mathrm{M} \times \mathrm{Pm}}{\mathrm{Cf} \times 100 : \mathrm{Sf}} \times 100 \qquad (2)$$

where RPEF is the meat production factor; M is gross meat yield in slaughter weight, kg, Pm is average price of 1 kg of meat, rub., Cf is total cost of feed, rub., Sf is the share of feed in meat cost (in slaughter weight), %.

Experimental studies to determine the effectiveness of the use of the mountain ash extract in the production of chicken eggs were performed on laying hens of the Hisex White cross on an industrial poultry farm.

To study the effect of the extract, one control and five experimental groups of 49-week-old laying hens were formed using the method of analogous groups, 50 heads in each group.

Laying hens were selected with respect to their age and body weight in accordance with conventional methods [1]. The chickens from the control group were fed a complete feed; in addition to the complete feed, the chickens from the experimental groups were given the mountain ash extract at different doses in accordance with the experimental scheme (Table 2).

Table 2. Scheme of the scientific and economic experiment on laying hens

Group	Number of birds, heads	Feeding conditions
Control	50	CF
Experimental group 1	50	CF+ mountain ash extract in a dose of 30 mg/kg feed
Experimental group 2	50	CF+ mountain ash extract at a dose of 40 mg/kg feed
Experimental group 3	50	CF+ mountain ash extract at a dose of 50 mg/kg feed
Experimental group 4	50	CF+ mountain ash extract at a dose of 60 mg/kg feed
Experimental group 5	50	CF+ mountain ash extract at a dose of 70 mg/kg feed

The observation period of laying hens and experimental data recording lasted for 6 months.

The mountain ash extract was tested with regard to egg production for the hen housed and middle hen, egg production intensity, average egg weight, feed consumption, feed costs per

10 eggs and 1 kg of egg weight, the percentage of culling of eggs with damage (check, breakage), survival, and morphological composition of eggs in accordance with conventional methods [1].

The quality of chicken eggs was chemically analyzed in an average sample in accordance with conventional methods for moisture, protein, fat, and ash content in compliance with GOST 31469-2012.

The efficiency of egg production was assessed by the international method for calculating the European efficiency factor (EEF) (3):

$$EEF = (1.4 \times \text{egg weight per 1 head, kg}) - (0.35 \times \text{feed conversion, kg}) \quad (3)$$

where EEF is the European efficiency factor.

Economic efficiency was determined using the Russian egg production factor (EPF) [4]:

$$EPF = \frac{(E \times Pe)+(M \times Pm)}{(Cf \times 100:Sf)+Crch} \times 100 \quad (4)$$

where EPF is the egg production factor; E is the gross output of eggs, pieces, Pe is the average price of 1 egg, rub., M is gross meat yield in slaughter weight, kg, Pm is the average price of 1 kg of meat, rub., Cf is the total cost of feed for the productive period, rub., Sf is the share of feed in the cost of eggs, %, Crch is the cost of rearing replacement chicks, rub.

3 Results

3.1 Results for the sarepta mustard extract used in feeding of broiler chickens

The results obtained for the sarepta mustard extract supplemented at the studied doses to the feed of broiler chickens are presented in Table 3.

Table 3. Growth indicators for broiler chickens, g

Indicator	Group					
	control	experimental group 1	experimental group 2	experimental group 3	experimental group 4	experimental group 5
Body weight at the beginning of the experiment	46.31 ± 0.08	46.26 ± 0.09	46.36 ± 0.11	46.19 ± 0.12	46.11 ± 0.13	46.23 ± 0.16
Body weight at the end of the experiment	2765.72 ±52.90	2754.91 ± 58.07	2710.74 ± 50.55	2746.65 ± 52.52	2847.91 ± 39.92	2738.20 ± 51.39
Absolute growth	2719.38 ± 52.91	2708.68 ±58.08	2664.40 ±50.57	2700.46 ±52.53	2801.76 ±39.92	2691.97 ±51.36
Average daily gain	64.75 ± 1.26	64.49 ±1.38	63.44 ± 1.20	64.30 ± 1.25	66.71 ± 0.95	64.09 ± 1.22

At the end of the experiment (42-day-old chickens), the average body weight of chickens from experimental group 4 increased by 3.0%, and that of chickens from experimental groups 1, 2, 3 and 5 slightly decreased by 0.4, 2.0, 0.7 and 1.0%, respectively, compared to the control.

The absolute and average daily weight gain of chickens receiving feed supplemented with sarepta mustard extract was greater by 3.0% in chickens from experimental group 4, by 0.4%

in chickens from experimental group 1, by 2.0% in chickens from experimental group 2, by 0.7% in chickens from experimental group 3, and by 1.0% in chickens from experimental group 5, compared to the control (Table 3).

Analysis of the consumption of complete feed by broiler chickens (Table 4) showed that broilers from experimental groups 1–4 consumed less feed per head by 0.2, 0.9, 2.2 and 2.4%, and broilers from experimental group 5 consumed more feed per head by 0.7% compared to the control.

Table 4. Feed consumption and survival of experimental broiler chickens

Indicator	Group					
	control	experimental group 1	experimental group 2	experimental group 3	experimental group 4	experimental group 5
Feed consumption within the experimental period, kg	160.90	156.00	157.80	157.50	156.81	162.01
Feed consumption per 1 head, kg	4.60	4.59	4.56	4.50	4.49	4.63
Feed costs per 1 kg of gain, kg	1.69	1.69	1.71	1.67	1.60	1.72
Survival, %	97.1	97.1	94.3	100.0	97.1	100.0

Supplementation of feed with the sarepta mustard extract at doses of 50 and 70 mg/kg of feed decreased its feed efficiency ratio by 1.2 and 5.3% (experimental groups 3 and 4) relative to the control. At doses of 30 and 90 mg/kg of feed, this increased its feed efficiency ratio by 1.2 and 1.8% (experimental groups 2 and 5) compared to the control.

It should be noted that the survival rate of broiler chickens from experimental group 3, which received the mustard extract supplemented at a dose of 50 mg/kg of feed, was high and amounted to 100.0%, which is 2.9% more compared to the control. The survival of broiler chickens from the control, and from experimental groups 1 and 4 was 97.1%, and in experimental group 2, this indicator was 2.8% less compared to the control (Table 4).

The results of the anatomical cutting of broiler chickens are shown in Figure 1. It was found that the weight of the uneviscerated poultry was greater in the experimental groups: by 1.2% in group 1, by 3.9% in group 2, by 2.3% in group 3, by 3.1% in group 4, and by 0.4% in group 5 compared to the control. The weight of the eviscerated broiler chickens was also higher in the experimental groups: by 1.7% in group 1, by 5.2% in group 2, by 2.9% in group 3, by 4.0 % in group 4, and by 0.7% in group 5 compared to the control.

The slaughter yield of broiler chickens from experimental groups 1–5 was higher by 1.3, 6.0, 3.4, 1.2 and 2.0% compared to the control.

Broiler chickens, which received feed supplemented with the mustard extract, showed the following changes in the absolute weight of internal organs relative to the control (Figure 2):

1. Heart weight reduced by 11.2, 29.6 ($p<0.05$), 15.5, 22.5 ($p<0.05$) and 4.2% in chickens from experimental groups 1–5.

2. Liver weight reduced by 3.1, 9.3, 5.1, 7.2 and 1.0% in chickens from all experimental groups.

3. Gizzard weight increased by 5.5, 17.8, 9.2, 13.5 and 1.2% in chickens from all experimental groups.

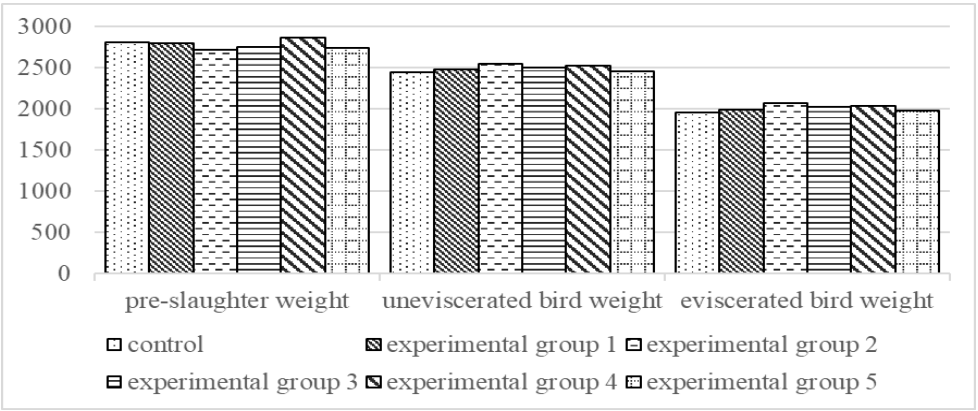

Fig. 1. Results of the anatomical cutting of broiler chickens, g

In the relative weight of the internal organs, no significant difference could be observed compared to the control for broiler chickens, which received feed supplemented with different doses of the mustard extract. It should be noted that in chickens from experimental group 2, the relative weight of the gizzard increased most significantly compared to other birds from the experimental groups (by 0.21%), and the relative weight of the liver and heart decreased most significantly (by 0.07 and 0.11%) relative to the control.

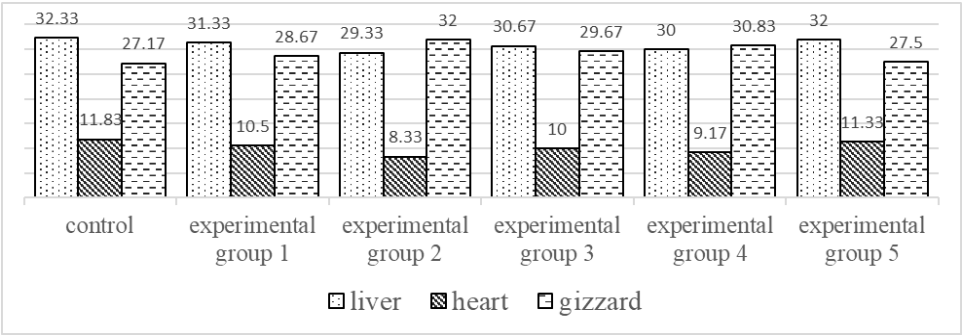

Fig. 2. Weight of internal organs of broiler chickens, g

The study results on the chemical composition of broiler chicken meat are shown in Figure 3.

The moisture content in chicken meat samples from all experimental groups increased by 0.01, 0.24, 0.13, 0.21 and 0.33%, respectively, compared to the control.

The protein mass fraction in the muscle tissue of broiler chickens from experimental groups 3, 4 and 5 was higher by 0.17, 0.21, and 0.32%, and that of broiler chickens from experimental groups 1 and 2 was lower by 0.04 and 0.05% compared to the control. The fat mass fraction decreased by 0.22, 0.03 and 0.02% in the chicken meat samples from experimental groups 2, 4 and 5, and increased by 0.12 and 0.09% in experimental groups 1 and 3 compared to the control. The ash content in chicken meat samples from all experimental groups was lower by 0.04% in group 1, by 0.07% in group 2, by 0.02% in group 3, by 0.07 % in group 4 and by 0.07% in group 5 compared to the control.

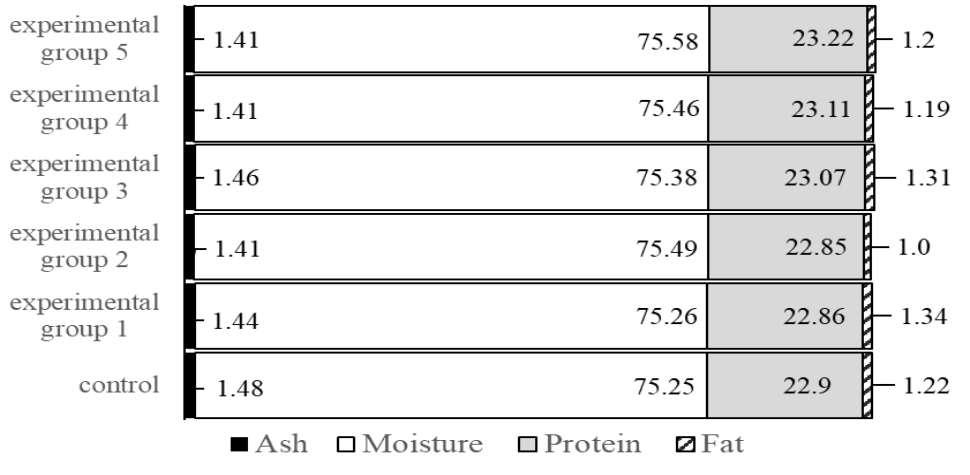

Fig. 3. Chemical composition of broiler chicken meat, %

The energy value of the meat of broiler chickens from experimental groups 1, 3, 4, and 5 was higher by 1.0, 1.5, 0.6, and 1.0%, and in experimental group 2, it was lower by 2.1% compared to the control.

The data on the chicken meat production factors are shown in Table 5. Thus, the European efficiency factor was higher by 13.3 units in experimental group 3, by 33.2 units in experimental group 4, and by 0.8 units in experimental group 5; it was lower by 1.5 units in experimental group 1, and by 22.4 units in experimental group 2 compared to the control.

Table 5. Chicken meat production efficiency factors

Factor	Group					
	control	**experimental group 1**	**experimental group 2**	**experimental group 3**	**experimental group 4**	**experimental group 5**
European production efficiency factor (EPEF)	378.2	376.7	355.8	391.5	411.4	379.0
Production efficiency factor (PEF) for chicken meat	106.8	111.7	112.1	116.4	114.0	110.2

The production efficiency factor for chicken meat was higher by 4.9 units in experimental group 1, by 5.3 units in experimental group 2, by 9.6 units in experimental group 3, by 7.2 units in experimental group 4, and by 3.4 units in experimental group 5 compared to the control.

The calculation of integral indicators showed that the use of the sarepta mustard extract at a dose of 70 mg/kg of feed in our studies caused the greatest increase in the economic efficiency of chicken meat production.

3.2 Results on the effect of the mountain ash extract on the performance of laying hens

The study results on the effect of different doses of the mountain ash extract on the performance of laying hens are shown in Table 6 and Figure 4.

Table 6. Lifestock of laying hens receiving feed supplemented with the mountain ash extract

Indicator	Group					
	control	experimental group 1	experimental group 2	experimental group 3	experimental group 5	experimental group 6
Gross output of eggs, pcs.	7345	7271	7463	7262	7872	8241
Egg production per hen housed, pcs.	146.90	145.42	149.26	145.24	157.44	164.82
Egg production per middle hen, pcs.	149.90	146.89	150.77	145.82	159.03	165.48
Egg production intensity, %	81.91	80.27	82.39	79.68	86.90	90.43
Feed consumption per group, kg	1125.00	1103.02	1155.40	1045.90	1047.30	1051.72
Feed consumption per 1 head, kg	22.96	22.28	23.34	21.00	21.16	21.12
Feed conversion per 10 eggs, kg	1.53	1.52	1.55	1.44	1.33	1.28
Feed conversion per 1 kg of egg mass, kg	2.46	2.40	2.42	2.12	2.01	2.04
Egg culling, %	1.51	2.22	3.67	1.97	2.08	2.68
Survival, %	94.0	96.0	96.0	98.0	96.0	98.0

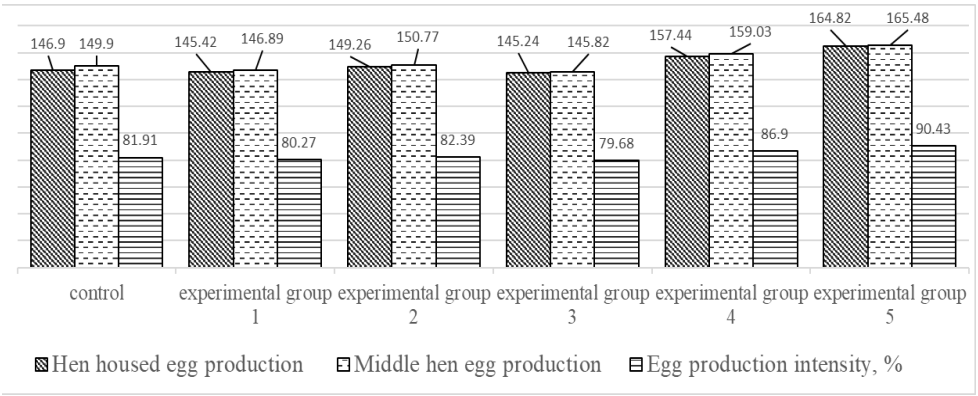

Fig. 4. Lifestock indicators of laying hens

Tests with the mountain ash extract showed an increased egg production for the hen housed and middle hens in some experimental groups: by 1.6 and 0.6% in group 2, by 7.2 and 6.1 % in experimental group 4, and by 12.2 and 10.4% in experimental group 5 compared to the control. In experimental groups 1 and 3, these indicators were lower by 1.0 and 2.0%, 1.1 and 2.7%, respectively, relative to the control. The egg production intensity, the total number of eggs laid by hens during a certain period, was higher by 0.5, 5.0 and 8.5% in experimental groups 2, 4, and 5, and lower by 1.6 and 2.2% in experimental groups 1 and 3 compared to the control.

Laying hens from the experimental groups unequally consumed complete feed: feed consumption of hens from experimental groups 1, 3, 4, and 5 was lower by 3.0, 8.5, 7.8, and 8.0%, and that of hens from experimental group 2 was higher by 1.7% compared to the control. At the same time, feed costs per 10 eggs in these experimental groups decreased by 0.7, 5.9, 13.1, and 16.3% relative to the control; in experimental group 2, on the contrary, feed costs increased by 1.3%. Feed conversion per 1 kg of egg weight was lower for the mountain ash extract at all the studied doses – by 2.4, 1.6, 13.8, 18.3, and 17.1% compared to the control. However, the proportion of body-checked eggs and broken eggs increased compared to the control: by 0.71% in experimental group 1, by 2.16% in experimental group 2, by 0.46% in experimental group 3, by 0.57% in experimental group, and by 1.17% in experimental group 5.

The survival of laying hens in all experimental groups remained high during the entire study period, and was higher by 2.0, 2.0, 4.0, 2.0, and 4.0% compared to the control.

Table 7 summarizes the study results on the morphological parameters of eggs for hens fed with different doses of the mountain ash extract.

The average weight of eggs of laying hens was observed to increase by 1.2, 2.4, 8.8, 5.9 ($p<0.05$) and 0.2% in all experimental groups compared to the control. The largest weight of eggs (67.88 g) was found in hens fed with the mountain ash extract at a dose of 50 mg/kg of body weight.

Consumption of the mountain ash extract showed a tendency to reduce the eggshell thickness by 1.0% in experimental groups 1 and 2, and by 1.5% in experimental group 3; the eggshell thickness increased by 4.2% in experimental group 3 and by 1.0% in experimental group 5 compared to the control.

In eggs of hens from all experimental groups, which received feed supplemented with different doses of the mountain ash extract, the relative content of albumen increased by 1.8, 2.4, 2.9, 3.5, and 4.0%, the relative content of yolk decreased by 1.8, 2.3, 2.9, 3.4 ($p<0.05$), and 4.0% ($p<0.05$) and that of eggshell decreased by 0.04, 0, 05, 0.08, 0.10, and 0.13%, the

albumen-to-yolk ratio increased by 9.4, 13.1, 17.3, 21.5 ($p<0.05$), and 26.2 % ($p<0.05$) compared to the control.

Table 7. Morphological parameters of eggs, %

Parameter	control	experimental group 1	experimental group 2	experimental group 3	experimental group 4	experimental group 5
Average egg weight, g	62.37 ±0.98	63.14 ±0.91	63.89 ±0.98	67.88 ±3.70	66.05 ±0.89*	62.47 ±1.64
Eggshell thickness, mm	0.403 ±0.009	0.399 ±0.003	0.399 ±0.003	0.420 ±0.007	0.397 ±0.004	0.407 ±0.004
Relative content, %:						
albumen	57.11 ±0.99	58.91 ±0.87	59.47 ±1.05	60.01 ±1.28	60.57 ±1.53	61.08 ±1.80
yolk	30.19 ±0.92	28.42 ±0.86	27.86 ±0.97	27.30 ±1.13	26.75 ±1.32*	26.21 ±1.52*
egg shell	11.09 ±0.46	11.13 ±0.23	11.14 ±0.20	11.17 ±0.21	11.19 ±0.26	11.22 ±0.31
Albumen/yolk ratio	1.91 ±0.09	2.09 ±0.10	2.16 ±0.11	2.24 ±0.14	2.32 ±0.17*	2.41 ±0.20*

Figure 5 presents the results of study of the chemical composition of eggs of hens fed with different doses of the mountain ash extract.

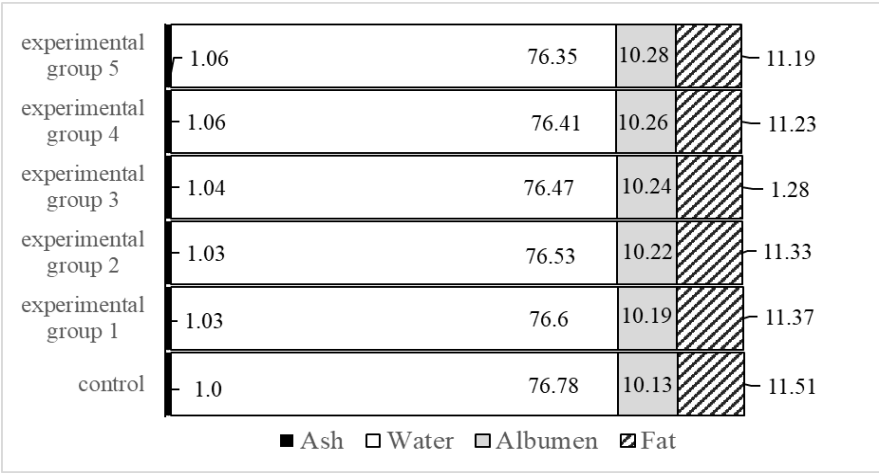

Fig. 5. Chemical composition of eggs, %

When feeding laying hens with the mountain ash extract, the mass fraction of ash in the eggs of hens from the experimental groups was observed to increase in proportion to an increase in the extract dose by 0.03, 0.03, 0.04, 0.05, and 0.06% compared to the control. The mass fraction of albumen was found to proportionally increase in eggs of hens from all experimental groups by 0.06, 0.09, 0.11, 0.13, and 0.15%, respectively. The content of fat and water in eggs of hens fed with the mountain ash extract at doses of 30, 40, 50, 60, and 70 mg/kg of body weight was proportional to the amount of the extract. It was lower by 0.14, 0.18, 0.23, 0.28, and 0.32% (fat), and by 0.18, 0.25, 0.31, 0.37, and 0.43% (water) compared to the control.

Table 8 summarizes the results of calculation of the egg performance of hens fed with the mountain ash extract.

Table 8. Egg production performance

Indicator	Group					
	control	experimental group 1	experimental group 2	experimental group 3	experimental group 4	experimental group 5
EEPF	12.23	12.14	12.63	13.12	14.00	13.76
EPF	100.82	99.61	97.69	102.17	107.80	111.16

The European egg production factor (EPEF) was observed to increase by 0.4, 0.89, 1.77, and 1.53 units for hens from experimental groups 2–5 fed with the mountain ash extract supplemented at doses of 40, 50, 60, and 70 mg/kg of body weight. However, the egg production efficiency factor for laying hens was higher by 1.35, 6.98, and 10.34 units compared to the control only for hens receiving the mountain ash extract at doses of 50, 60, and 70 mg/kg of body weight (experimental groups 3–5).

Therefore, the calculation of production efficiency factors showed that the mountain ash extract included in the diet of laying hens at a dose of 70 mg/kg of body weight increased the economic efficiency of egg production.

4 Discussion

Our conclusions are similar to those of M. J. Adegbeye et al. [5], in which supplementation of mustard seed to Arbor Acres broilers increased chick body weight towards the end of fattening, and J. Moyosore et al. [6], in which feeding mustard seed powder to broiler chickens increased their weekly growth rate.

The observed effects of feeding the extract of mountain ash can be explained by the influence of biologically active compounds of its fruits. Mountain ash bioflavonoids (substances with P-vitamin action) are the most powerful antioxidants with capillary-strengthening, anti-inflammatory and hypolipidemic properties [7].

Mountain ash polyphenols prevent the depletion of the antioxidant defense system, reducing the load on it due to its effects. These substances are able to act as a buffer, eliminate hyperprotonemia and tissue hypoxia. Polyphenols relieve oxidative stress by inhibiting the processes of lipid peroxidation [8].

5 Conclusions

1. The paper discusses the effectiveness of introducing different doses of extracts of medicinal plants, namely, sarepta mustard and mountain ash, into the diet of broiler chickens and laying hens. The indicators of meat production of broilers and egg productivity of hens, as well as the European and Russian production efficiency factors for broiler meat and chicken eggs were determined. It was shown that certain doses of the studied extracts had a positive effect on the performance of experimental hens and increased the production efficiency indices of meat and eggs.

2. Supplementation of the diet of broiler chickens with the sarepta mustard extract at a dose of 70 mg/kg of feed increased the growth rates of hens by 3.0% compared to the control, and the European and Russian production efficiency factors for broiler chickens increased by 33.2 and 7.2 units, respectively.

3. Laying hens fed with the mountain ash extract at a dose of 70 mg/kg of body weight dominated by 12.2 and 10.4% over hens from the control in egg production per hen housed and middle hen, by 1.53 units relative to the European egg production factor, and by 10.34 units relative to the Russian egg production factor.

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