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Effects of high-protein feed supplements on lamb productivity

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Abstract:
Introduction. Today's feed market offers a variety of new products of plant and animal origin that increases the productivity of young sheep. Using feed supplements can help farmers to fully realize the genetic potential of wool-and-meat genotype sheep.
Study objects and methods. We studied the effect of a whole milk replacer (skimmed powdered milk) and an ORGANIC high-protein feed supplement on the growth of young sheep and the quality of their meat. In particular, we determined the effect of starter feeds on the biochemical and morphological parameters of sheep blood at the Vtoraya Pyatiletka Breeding Farm, Stavropol Krai.
Results and discussion. Substituting starter feeds with a whole milk replacer and an ORGANIC supplement for the standard feed in the diet of sheep aged 0–4 months increased metabolic energy (by 12.5%), crude protein (by 22.4 and 25.5%, respectively), lysine (by 24.8 and 21.4%, respectively), and methionine + cystine (by 31.0%). The starter feeds also led to higher live weight (by 29.6 and 33.7% ($P \leq 0.001$)), absolute and average daily gain (by 24.6 and 29.1% ($P \leq 0.001$)), slaughter weight (by 36.5 and 42.1% ($P \leq 0.001$)), slaughter yield (by 2.50 and 2.96 abs.% ($P \leq 0.05$)), and meat marbling (by 3.6 and 11.7%). The number of muscle fibers increased by 2.1 and 3.3%, respectively. Additional profits rose from 1761.5 to 2091.5 rubles per head and the product profitability reached 50.5–57.9%.
Conclusion. The starter feeds containing a milk replacer and an ORGANIC feed supplement proved effective for sheep aged of 0–4 months in the suckling period, ensuring live weight of 39–40 kg and improving meat quality and productivity.

Keywords: Young sheep, milk replacer, ORGANIC feed supplement, slaughter and meat qualities, economic efficiency

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INTRODUCTION

Modern market conditions call for highly competitive sheep breeding, which requires specialized meat production of high quality. Sheep meat is the most expensive meat in developed countries. Its consumption depends on cultural factors and tends to increase with growing population and incomes. Major exporting countries see a decline in their sheep stocks caused by the shrinking wool market. Sheep meat production is expected to be developed by small and medium-sized farms close to their markets [1].

Today, there is an urgent need for highly productive young sheep and safe lamb meat of high-quality. The world demand for lamb is very high, both in nutritional and commercial terms. Therefore, lamb production is a priority in Russia and abroad [2].

Many studies have shown that lamb aged 0–7 months is the best type of sheep meat. Russia consumes 1.0 kg of lamb per capita, compared to 1.29 kg worldwide. Private farms account for 88.6–89.2% of sheep meat production in Russia [3].

Nutrition is one of the main factors of meat productivity alongside good maintenance conditions [4]. Selective breeding of farm animals is also gaining ground. It aims to produce new genotypes of wool-and-meat sheep for manufacturers of livestock products.

To fully realize the genetic potential of wool-and-meat sheep genotypes, we need to improve their feeding systems by adding new supplements of plant and animal origin to enhance their productivity. Adequate nutrition is the main principle of animal feeding that contributes to higher productivity. Diets should be differentiated according to production schemes and planned productivity. Rationed feeding is one of the most important indicators of nutrition that ensures normal physiological state, high productivity, good reproductive qualities, and production profitability. Nutrition enhanced with feed supplements rich in bioactive substances is the most rational way to obtain low-cost and high-quality products [5]. Radzhabov *et al.* provide a good coverage of intensive sheep raising methods based on adequate feeding [6].

By-products of starch, dairy, meat, and other industries are increasingly used as feed supplements in animal diets. However, it is important to study their composition, nutritional benefits, and possible side effects for the animal organism [7, 8]. Most changes caused by feed supplements occur at an early age, during intensive growth and development of lambs. This is a period of greatest assimilation of feed nutrients leading to the maximum increase in live weight. Feed supplements improve animal productivity, activate digestive metabolic processes, and ultimately make sheep breeding cost-effective [9, 10].

The ORGANIC supplement (patented in Russia) is a high-protein feed supplement obtained from collagen-containing solid waste of leather production. It is used to enrich feed for all types of productive animals, fish, and poultry, with a highly digestible, "protected" protein. The product has stable quality indicators, namely 82–85% of crude protein and a complete composition of essential and non-essential amino acids. It facilitates digestion and gastrointestinal functioning, which improves the digestibility and absorption of feed nutrients, as well as increases the natural resistance of the animal's body [11].

We aimed to study the effect of the ORGANIC feed supplement on the growth and development of sheep, meat productivity, and economic efficiency.

To achieve the aim, we set a number of objectives, namely to:

– formulate new starter feeds for wool-and-meat lambs aged 0–4 months based on their maintenance and feeding conditions;
– evaluate the effect of starter feeds on the growth of young sheep, as well as meat productivity and quality;
– assess the effect of starter feeds on the biochemical and morphological parameters of blood and general health of young sheep; and
– calculate feed efficiency and economic efficiency of using starter feeds in young sheep breeding.

STUDY OBJECTS AND METHODS

We aimed to test new starter feeds for wool-and-meat lambs aged 0–4 months of the Russian Meat Merino breed. Experimental studies were conducted at the Vtoraya Pyatiletka Breeding Farm (Stavropol Krai, Russia).

Its sheep breeding technology involves stall and pasture maintenance; weaning (at the age of 120 days); shearing (May – June); grazing (on pastures with kosher basic feeding technology); artificial insemination (September – October); and lambing (February – March). When in the stalls, sheep receive coarse, juicy, and concentrated feeds.

Diets for young sheep were determined by such factors as age, live weight, and productivity [9]. We used three diets, namely: standard feed (control), starter feed with 5% of skimmed powered milk as a whole milk replacer (experiment), and starter feed with 3% of the ORGANIC supplement (experiment). The composition of starter feeds and their nutritional value are shown in Table 1.

Compared to standard feed (Formula 1), starter feed with the whole milk replacer (MR) (Formula 2), and starter feed with the ORGANIC supplement (OS) (Formula 3) had higher values of total nutritional value (by 4.7 and 6.6%, respectively), crude protein (by 19.8 and 27.3%, respectively), digestible protein (by 7.6 and 15.1%, respectively), lysine (by 23.7 and 18.6%, respectively), methionine + cystine (by 32.7%), threonine (by 23.1 and 21.2%, respectively), and crude fat (by 83.4 and 82.7%, respectively) (Table 1).

The formulated starter feeds (Table 1) were tested on three groups of ewes (12 heads in each) with single ram lambs (aged from 2 days to 4 months) based on the analogous pair principle (Table 2).

As we can see in Table 2, the control ram lambs (Group I) received alfalfa hay and standard feed (Formula 1) based on the formulation of the All-Russian Research Institute of Animal Husbandry. For the rams in the experimental groups, the standard feed was replaced with starter feed with the milk replacer and starter feed with the ORGANIC supplement, respectively.

Feed samples were analyzed at the Feed and Metabolism Laboratory, Stavropol State Agrarian University. Total nitrogen (crude protein) was determined on a UDK-142 protein (nitrogen) analyzer, crude fat – on a SER-148 fat analyzer, macro- and microelements – on a Spectroscan MAX GV universal analyzer, vitamins – on a LCMS-10 EV liquid chromatograph, crude fiber – on a FIVE fiber analyzer, and total feed moisture – on an AD-4714 A moisture analyzer.

The guidelines by Dmitrik *et al.* were used to determine the morphological composition of lamb carcasses and conduct a microstructural analysis of the *Longissimus dorsi* muscle [12]. The animals' internal homeostasis was assessed on the basis of morphological and biochemical blood analyses [13, 14]. The counting of erythrocytes and leukocytes was performed in the Goryaev chamber. The leukocyte formula was based on a blood smear stained using the Romanowsky-Giemsa technique. The results were biometrically processed using statistical methods (Microsoft Excel).

Table 1 Feed formulations for lambs aged 0–4 months

Indicator	Feed formulations		
	Formula 1*	Formula 2**	Formula 3***
Feed composition, %			
Barley	29.00	14.00	15.00
Oats	28.0	–	–
Wheat	10.00	14.00	15.93
Wheat Bran	10.00	11.33	15. 0
Corn	–	20.00	15.00
Peas	10.0	–	–
Sunflower cake (crude protein 34%, crude fiber 20)	10.00	19.97	20.00
Alfalfa flour (crude protein 14.0 %)	–	10.00	10.00
ORGANIC feed supplement	–	–	3.00
Skimmed milk powder	–	5.00	–
Feed yeast (crude protein 42%)	–	3.00	3.00
Feed chalk	–	0.58	0.35
Monocalcium phosphate	1.00	0.50	1.03
P61-1 premix for calves	1.00	0.80	0.80
Table salt	0.70	0.82	0.89
Components			
Energy feed units	1.06	1.11	1.13
Metabolic energy, MJ	10.6	11.1	11.3
Dry matter, g	880.0	891.8	890.6
Crude protein, g	149.3	178.8	190.0
Digestible protein, g	131.5	141.5	151.4
Lysine, g	5.9	7.3	7.0
Methionine + cystine, g	4.9	6.5	6.5
Threonine, g	5.2	6.4	6.3
Crude fat, g	28.3	51.9	51.7
Crude fiber, g	79.7	90.1	93.8
Sugar, g	37.7	35.6	33.4
Ca, g	3.26	8.0	8.6
P, g	7.21	6.7	6.9
Mg, g	2.6	2.3	2.5
Table salt, g	1.4	10.0	10.0
Fe, mg	78	20.0	20.0
Cu, mg	5.2	4.0	4.0
Zn, mg	31.4	32.0	32.0
Mn, mg	35.5	40.0	40.0
Co, mg	2.0	2.0	2.0
I, mg	1.0	1.2	1.2
Se, mg	0.11	0.16	0.16
Vitamins			
A, thousand IU	4.8	16.0	16.0
D_3, thousand IU	0.01	3.20	3.20
E, mg	12.5	56.0	56.0
B_1, mg	3.5	2.4	2.4
B_2, mg	1.1	8.0	8.0
B_3, mg	9.3	16.0	16.0
B_5, mg	13.0	8.0	8.0
B_{12}, mg	–	0.016	0.016

*Formula 1 – standard feed used at the Vtoraya Pyatiletka Breeding Farm

** Formula 2 – starter feed with 5% of milk replacer (New Compound Feeds Company)

*** Formula 3 – starter feed with 3% of ORGANIC feed supplement (New Compound Feeds Company)

Table 2 Diets of suckling lambs aged 0–4 months (n = 12)

Group	Diet description
I (control)	Normal diet (ewe milk, alfalfa hay, mineral feed) + standard farm feed (Formula 1)
II (experimental)	Normal diet + starter feed with whole milk replacer (Formula 2)
III (experimental)	Normal diet + starter feed with ORGANIC supplement (Formula 3)

Table 3 Actual feed intake by sheep aged 0–4 months

Indicator	Group		
	I (control)	II (experimental)	III (experimental)
Alfalfa hay	0.30	0.36	0.36
Standard farm feed (Formula 1)	0.41	–	–
Starter feed with the whole milk replacer (Formula 2)	–	0.42	–
Starter feed with the ORGANIC supplement (Formula 3)	–	–	0.42
Table salt, g	6.0	6.0	6.0
Felucen mineral salt, g	5.0	5.0	5.0
Disodium phosphate, g	4.9	4.9	4.9
Components			
Energy feed units	0.64	0.72	0.72
Metabolic energy, MJ	6.4	7.2	7.2
Dry matter, g	0.60	0.70	0.70
Crude protein, g	98	120	123
Digestible protein, g	79	90	93
Lysine, g	4.20	5.24	5.10
Methionine + cystine, g	2.90	3.80	3.80
Crude fiber, g	112	134	134
Sugar, g	23	23	23
Ca, g	5.2	8.0	7.9
P, g	5.8	4.6	5.1
Mg, g	1.51	1.51	1.57
NaCl, g	6.7	6.3	6.3
Fe, mg	82.3	69.2	68.4
Cu, mg	5.80	5.71	5.66
Zn, mg	22.0	24.6	24.3
Mn, mg	35.7	42.4	41.9
Co, mg	0.9	1.0	0.9
I, mg	0.41	0.52	0.52
Vitamins			
A, mg	12	34	34
D_3, thousand IU	31	1376	1360
E, mg	37	62	61

Table 4 Feed consumption by sheep during the suckling period

Group	Diet			
	Ewe milk	Alfalfa and legume hay	Feed	Total
Standard farm feed (control):				
– feed weight, kg	136.0	10.8	24.4	171.2
– energy feed units	40.80	4.97	31.70	77.47
– digestible protein, g	4488	443	3684	8615
Starter feed with whole milk replacer:				
– feed weight, kg	136.0	11.2	25.8	173.0
– energy feed units	40.80	5.15	33.50	79.45
– digestible protein, g	4488	459	3947	8894
Starter feed with ORGANIC supplement:				
– feed weight, kg	136.0	10.9	25.7	172.6
– energy feed units	40.80	5.00	33.40	79.20
– digestible protein, g	4488	447	5110	10045

RESULTS AND DISCUSSION

Adequate feeding, especially during intensive growth and development, is highly important for the animals' productivity. In our study, the lambs' needs for basic nutrients were determined by their health and growth indicators.

Substituting the standard feed (Formula 1) for starter feeds containing the milk replacer (Formula 2) and the ORGANIC supplement (Formula 3) in the diets of sheep (Table 3) aged 0–4 months increased their metabolic energy (by 12.5%), crude protein (by 22.4 and 25.5%, respectively), lysine (by 24.8 and 21.4%, respectively), methionine + cystine (by 31.0%), and vitamins A, D, E (1.6–44.3 times).

Table 4 shows the total feed consumption by the experimental lambs during the suckling period. Over 120 days of growth, the control group consumed 77.47 energy feed units and 8.62 kg of digestible protein. In the experimental groups, energy feed units were lower by 1.98 and 1.73 and digestible protein by 0.279 and 1.430 kg, respectively. As we know, ewes produce plenty of milk (1.2–1.5 liters) during lactation to meet their lambs' nutritional needs. However, its amount significantly reduces in the months following lactation. For this reason, we formulated starter feeds containing the milk replacer (WMR) and the ORGANIC supplement (OS).

Feeding starter feeds to suckling lambs for four months affected their live weight (Fig. 1). Compared

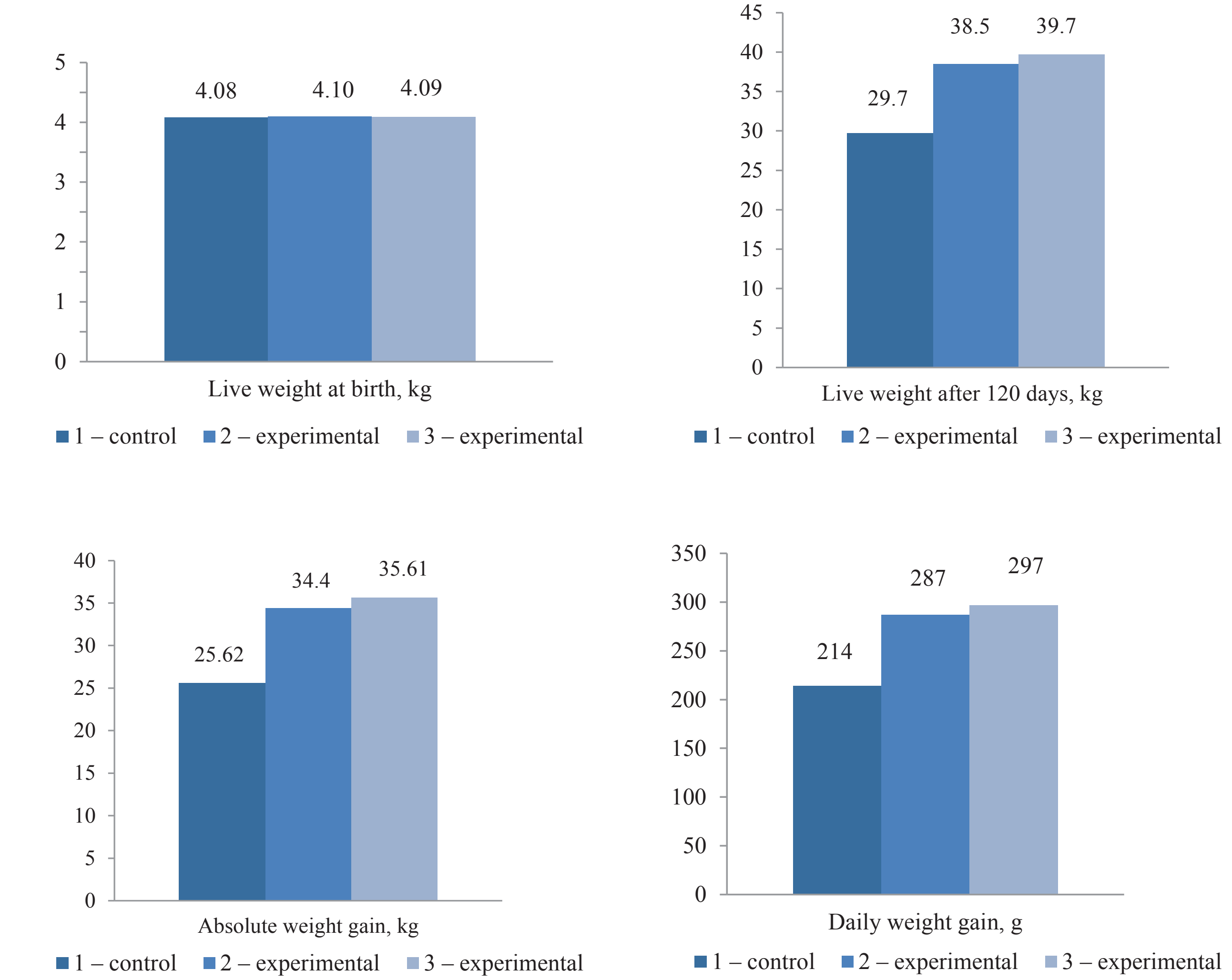


Figure 1 Live weight and live weight gain of young sheep that received: 1 – standard feed (control); 2 – starter feed with the whole milk replacer, 3 – starter feed with the ORGANIC supplement; n = 12

to the control lambs, live weight of the experimental lambs aged 120 days in the groups that received starter feeds with the WMR and OS increased by 8.8 kg, or 29.63% ($P \leq 0.001$), and 10.0 kg, or 33.67% ($P \leq 0.001$), respectively. The average daily gain rose by 73.0 g, or 34.11% ($P \leq 0.001$), and 83 g, or 38.78% ($P \leq 0.001$), respectively, with 100% animal safety.

Therefore, we found that the use of starter feeds with the WMR and the OS instead of standard feed was zootechnically justified. These feeds contributed to a better palatability of the diet feed and a greater intake of nutrients.

Lamb production needs to be increased to enhance the economic efficiency of sheep breeding. The meat from sheep aged up to one year is easily digestible and has a low fat content. For this reason, it is recommended for dietetic diet. Scientists have also established that the most intensive weight gain occurs in the first six months.

For the next stage of our study, we carried out a control slaughter of lambs at the age of four months. This age was due to intensive protein deposition in the first six months. Adipose tissue accumulating more intensively in the later period of life affects the biological value of meat and the economic efficiency of lamb production.

Hematological parameters show a complete picture of the organism's development. We found that the blood parameters of 4-month-old lambs of the experimental and control groups were within the physiological norms (Fig. 2).

The contents of erythrocytes and hemoglobin were within the physiological norms, indicating the absence of anemia (Fig. 2). Compared to the control group, the blood of the experimental lambs that received starter feeds with the MR and the OS had a slight increase in hemoglobin, namely by 2.6 ($P > 0.1$) and 4.7% ($P < 0.05$), respectively, and in erythrocytes, by 5.6 and 11.1% ($P < 0.05$), respectively. This contributed to a more intensive metabolism. The contents of leukocytes were almost identical, with a difference of 2.9 and 5.9%, respectively.

Higher total protein in the serum of the experimental lambs indicated more intensive protein digestion and absorption of amino acids in the intestine, as

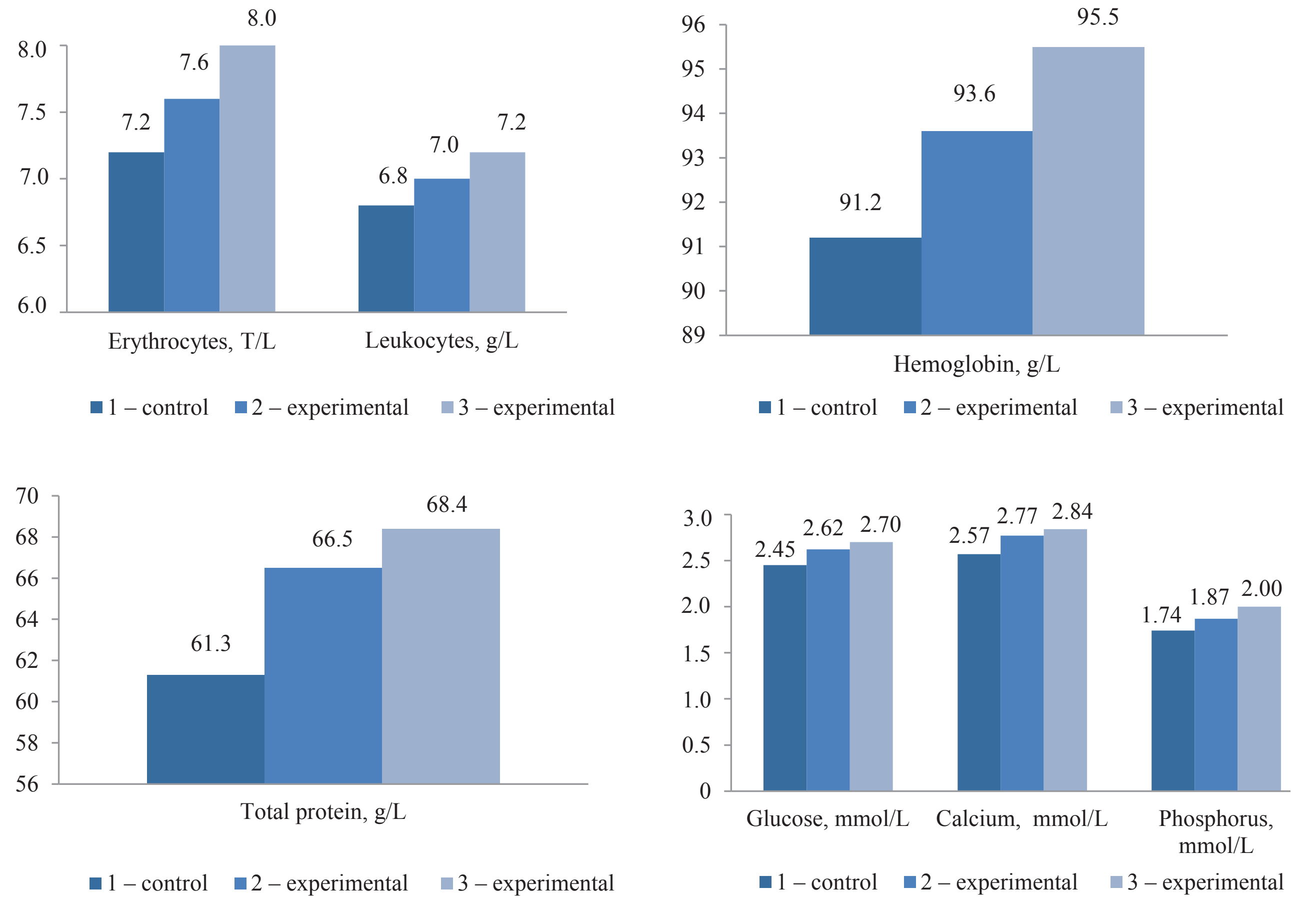


Figure 2 Hematological and biochemical parameters of young sheep that received: 1 – standard feed (control); 2 – starter feed with the whole milk replacer, 3 – starter feed with the ORGANIC supplement

well as protein synthesis in the liver. This finding was confirmed by the live weight gain indicators. In particular, total protein in the experimental groups that received the MR and the OS was 8.5 and 11.6% ($P < 0.05$) higher in comparison with the control group. Glucose contents were higher by 6.9 ($P < 0.05$) and 10.2% ($P < 0.05$), respectively, indicating a better supply of body cells with energy. Similar results were reported by Khompodoeva and Pashtetskaya *et al.* [15, 16].

Figure 3 Carcasses of young sheep

Calcium was significantly higher in the blood serum of experimental lambs, namely by 7.8 ($P < 0.05$) and 10.5% ($P < 0.05$) in the groups that received the MR and the OS, respectively. A similar trend was observed in the amount of phosphorus: it was 7.5 ($P < 0.05$) and 14.9% ($P < 0.01$) higher in the experimental groups, compared to the control. This was indicative of better saturation of the bone tissue and stronger bones.

The control slaughter (Fig. 3) proved a possibility of obtaining high-quality dietetic meat from lambs aged 4 months.

We established (Fig. 4) that starter feeds enriched with the milk replacer and the ORGANIC supplement, increased the slaughter weight by 36.5 and 42.05% ($P \leq 0.001$) and slaughter yield by 2.50 and 2.96 abs.%, respectively, compared to the control.

Next, we studied the morphological composition of animal carcasses to assess meat productivity. For this, we deboned the carcasses and analyzed various meat characteristics, especially the meat coefficient (the ratio of the weight of meat to the weight of bones and tendons) (Fig. 5).

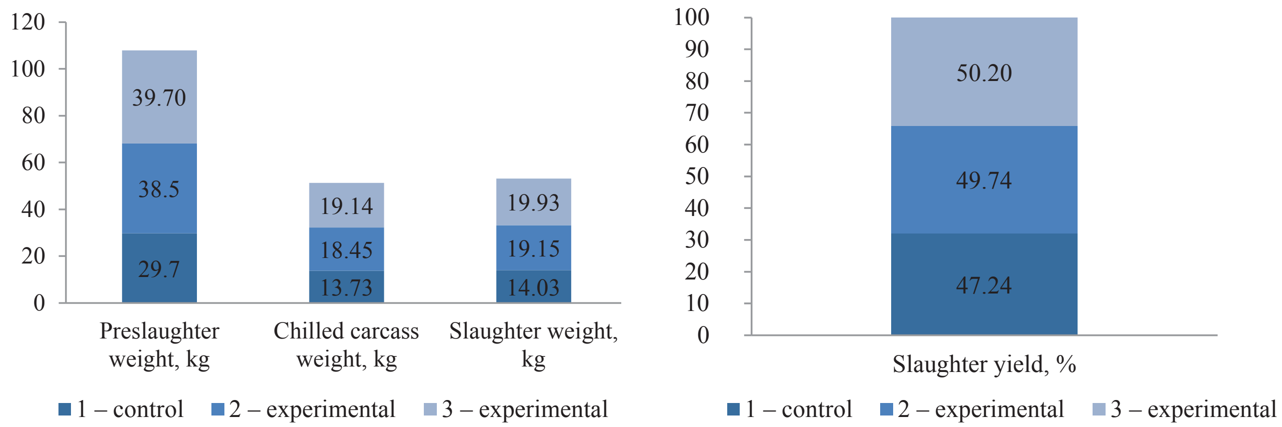


Figure 4 Slaughter characteristics of ram lambs that received: 1 – standard feed (control); 2 – starter feed with the whole milk replacer, 3 – starter feed with the ORGANIC supplement; n = 3

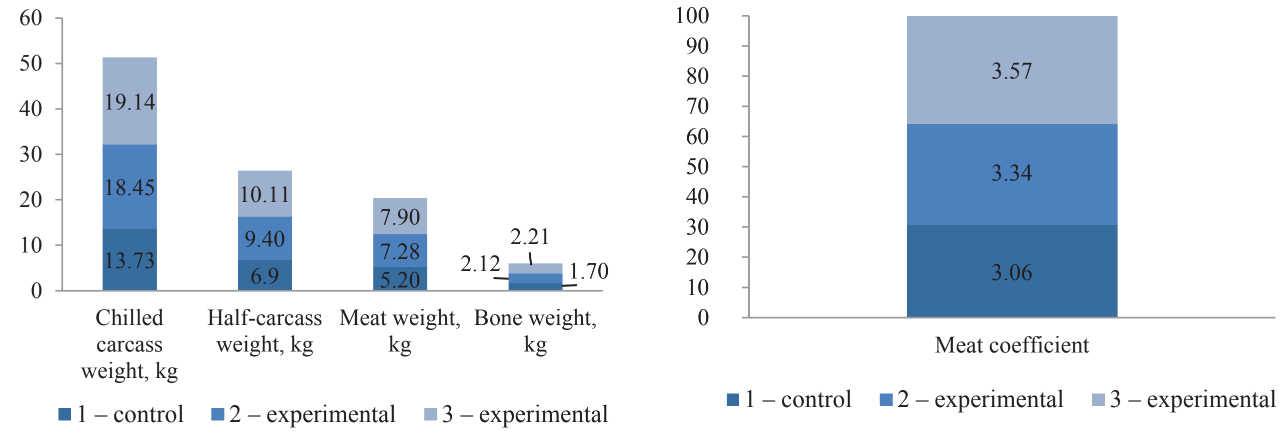


Figure 5 Morphological composition of lamb carcasses aged 4 months that received: 1 – standard feed (control); 2 – starter feed with the whole milk replacer, 3 – starter feed with the ORGANIC supplement; n = 3

The ratio of muscle, bone, and connective tissues in the body of sheep affects the nutritional and biological value of carcasses. However, if sheep had different live weight, the nutritional value of their carcasses can vary greatly [17].

Apparently, higher feed intake and better assimilation of nutrients in the experimental groups contributed to a more uniform deposition of subcutaneous fat and the formation of muscle mass.

We found maximum meat weight in the carcasses of lambs that received feed with the milk replacer and the ORGANIC supplement, respectively. Particularly, their meat weight was 40.0 and 51.9% ($P \leq 0.001$) higher than in the control group, with a meat coefficient of 3.34 and 3.57, respectively. Our data were consistent with those reported by Khayitov and Dzhuraeva [18].

Histological studies of the *Longissimus dorsi* muscle showed better microstructural characteristics in the meat of experimental lambs (Table 5).

The meat of young sheep from the experimental groups that received the MR and the OS had smaller muscle bundles, but it contained more fibers than the meat of the control animals, namely by 8.45 pcs./1 mm^2 (2.1%) and 13.34 pcs./1 mm^2 (3.3%), respectively. The marbling coefficient of meat in the group that received the OS exceeded that of meat in the groups fed on standard feed and the OS feed by 11.7 and 7.9% ($P \leq 0.05$), respectively.

The microstructural analysis of muscle tissue samples (Fig. 6) showed that the *Longissimus dorsi* muscle of lambs had a greater number of muscle fibers of a smaller diameter with fatty layers, indicative of high nutritional and commercial qualities.

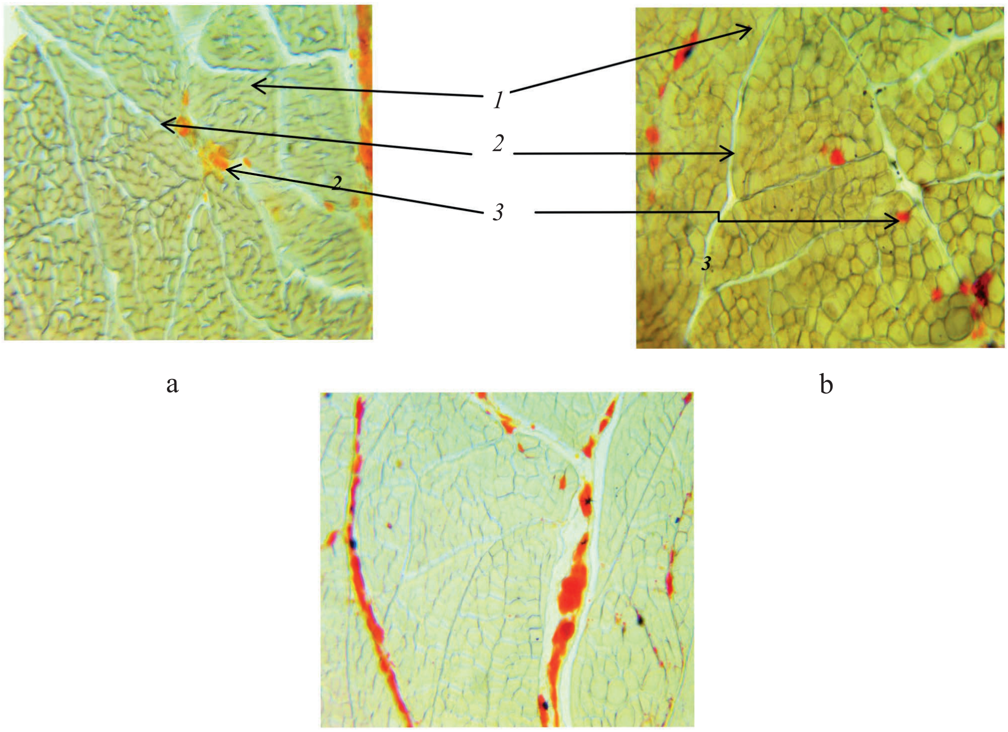
The biological value is the main indicator of the product's nutritional value.

The chemical composition of muscle tissue largely depends on fatness and productivity type (wool-and-meat or other). In our study (Fig. 7), the muscle tissue of the experimental lambs in the groups fed on the MR and OS feeds contained less moisture (by 4.52–6.47 abs.% ($P \leq 0.05$)), but more dry matter (by 1.47–4.52 abs.%), fat (by 0.58–0.80 abs.%), and protein (by 0.87–3.67 abs.% ($P \leq 0.05$)), compared to the control. Our data were consistent with those of Bogatirevet *et al.* [19].

Table 5 Microstructural analysis of the *Longissimus dorsi* muscle in sheep aged 4 months that received various diets (n = 3)

Indicator	Group		
	Standard feed (control)	Starter feed with whole milk replacer (experiment)	Starter feed with ORGANIC supplement (experiment)
Number of muscle fibers, pcs.	401.33 ± 7.22	409.78 ± 7.38	414.67 ± 7.47
Muscle fiber diameter, μm	28.45 ± 0.51	25.84 ± 0.46	25.34 ± 0.35*
"Marbling" assessment, score	28.95 ± 0.52	29.99 ± 0.54	32.35 ± 0.58*
Connective tissue, %	8.00 ± 0.14	7.60 ± 0.13	7.20 ± 0.11*

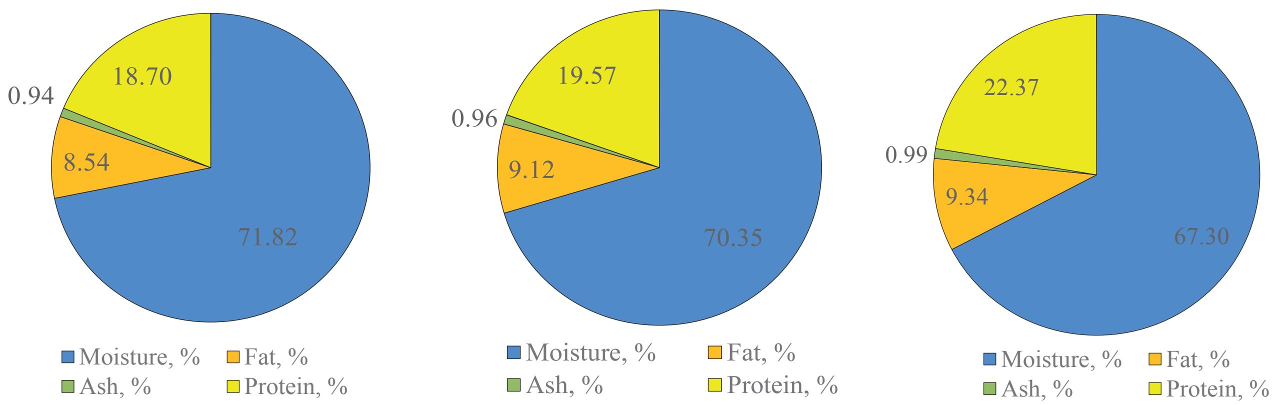
* – significant difference from the control group ($P \leq 0.05$)



c

1 – muscle fibers; *2* – connective tissue; *3* – fatty interfiber and interfascicular inclusions ("marbling")

Figure 6 Histosection of the longissimus dorsi muscle tissue of young sheep (colored with hematoxylin-eosin, magnification ×500): a) group fed on standard feed (control); b) group fed on starter feed with whole milk replacer (experiment); c) group fed on starter feed with ORGANIC supplement (experiment)



a b c

Figure 7 Chemical composition of muscle tissue of young sheep that received a) – standard feed (control); b) – starter feed with the whole milk replacer, c) – starter feed with the ORGANIC supplement; n = 3

Table 6 Economic efficiency of lamb production (per head, in 2021 prices)

Indicator	Group		
	Standard feed (control)	Starter feed with whole milk replacer (experiment)	Starter feed with ORGANIC supplement (experiment)
Weight gain during experimental period, kg	25.62	34.40	35.61
Additional gain, kg	–	8.78	9.99
Average daily gain, g	214	287	297
Costs per 1 kg of gain: energy feed units	3.02	2.31	2.22
digestible protein, g	336	259	282
Cost of 1 kg of live weight gain, rubles	189.0	145.5	138.7
Total costs, rubles	4842.2	5005.2	4939.1
including feed supplements, rubles	–	161.3	96.3
Selling price of 1 kg of live weight gain, rubles		219.0	
Sales proceeds, rubles	5610.8	7533.6	7798.6
Profit, rubles	768.6	2528.4	2859.5
Additional profit, v	–	1761.5	2091.5
Level of profitability, %	15.8	50.5	57.9
Return on 1 rbl. of feed supplement costs, rubles	–	10.9	21.7

Thus, the morphological and microstructural analyses of the longissimus dorsi muscle tissue revealed higher quality indicators in the lamb fed on the OS feed, compared to the groups that received standard feed and the MR feed. Particularly, it had the largest number of muscle fibers of a smaller diameter, a higher marbling score, and a lower content of connective tissue. Therefore, the meat in the group fed on the OS feed was characterized as tender and juicy. The most nutritious and valuable were those animal carcasses which had a greater content of muscle tissue, since connective tissue contains fatty tissue that make meat a high-calorie product and give it a characteristic taste, color, and aroma.

The economic analysis (Table 6) proved the efficiency of using starter feeds with the high-protein milk replacer of the ORGANIC supplement when growing wool-and-meat lambs up to 4 months of age.

Particularly, the absolute increase in live weight of lambs in the experimental groups that received the MR and the OS feeds amounted to 8.8 and 10.0 kg or 34.27 and 38.99% ($P \leq 0.001$), respectively.

The additional costs of the milk replacer and the ORGANIC feed supplement for the experimental groups were 161.3 and 96.3 rubles, respectively. The same selling price of 219.0 rubles per 1 kg of live weight allowed for an extra profit of 1761.5 and 2091.5 rubles respectively. The level of profitability of lamb production increased by 34.7 and 42.1%, respectively. The return on one ruble of feed supplement costs amounted to 10.9 and 21.7 rubles, respectively.

CONCLUSION

Including starter feeds enriched with 5% of skimmed powered milk as a whole milk replacer or 3% of the ORGANIC feed supplement in the diet of sheep aged up to four months enhanced their nutritional value, namely metabolic energy (by 4.7 and 6.6%), raw protein (by 19.8 and 27.3%), lysine (by 23.7 and 18.6%), methionine + cystine (by 32.7%), and threonine (by 23.1 and 21.2%). By the age of four months, the lambs had an increase in live weight (8.8 and 10.0 kg) and average daily weight gain (73.0 and 83.0 g). The supplements also improved the quality of meat, as well as feed efficiency (by 0.71 and 0.98 energy feed units) and the profitability of lamb production.

CONTRIBUTION

The authors were equally involved in writing the manuscript and are equally responsible for plagiarism.

CONFLICT OF INTEREST

The authors declare no conflict of interest regarding the publication of this article.

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