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Original article

THE EFFECT OF A PROBIOTIC BASED ON BACILLUS AMYLOLIQUEFACIENS VKPM B-11475 ON THE COMPOSITION OF INTRAMUSCULAR FAT AND THE AMINO ACID COMPOSITION OF GOAT MEAT PROTEIN WAS STUDIED

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Abstract

Background. The article presents the results of an experimental study evaluating the effect of the probiotic strain Bacillus amyloliquefaciens VKPM B-11475, used in dosages of 4×10^9 and 4×10^7 CFU, on the metabolic profile of Zaanen goats, with an emphasis on the modulation of the composition of volatile fatty acids in intramuscular fat and the amino acid spectrum of muscle protein in the age periods of 8 months and 4 of the year. It was found that probiotic intervention induced a statistically significant modification of lipid metabolism, expressed in an increase in the proportion of saturated fatty acids by 5.22-7.23% (8 months) and 1.62% (4 years), monounsaturated – by 1.14-2.95% and 0.4-2.26%, polyunsaturated – by 0.67-1.53% and 0.46–0.81%, as well as an increase in the level of linoleic acid by 0.83-1.13% and 0.05-0.24%, with a concomitant decrease in the concentration of linolenic acid by 0.19-0.49% and 0.04-0.17%, respectively. The data obtained highlight the potential of B. amyloliquefaciens as a functional additive for targeted correction of the nutritional status of productive animals.

Purpose. To study the effect of the probiotic *Bacillus amyloliquefaciens* on the amino acid composition of goat meat

Materials and methods. A probiotic based on *Bacillus amyloliquefaciens* VKPM B-11475 (*B. amyloliquefaciens*) was produced in the research laboratory of the individual entrepreneur and head of the farm “Tsirulev Evgeny Pavlovich”. The preparation is a light-brown liquid with an average concentration of 4×10^9 CFU. An experimental study was conducted at the goat milk production and processing farm of Semkina O.V. in the Privolzhsky District, Samara Region. Kids were selected as matched pairs, 10 animals per group, at 2 months of age. Three groups of animals, 10 animals each, were created for the experiment. The control group included young kids on a basic feeding ration. Goats in the first experimental group received a probiotic at a dose of 4×10^9, while those in the second experimental group received 4×107 30 minutes before feeding, one capsule per head once daily for one month, administered using a bolus dispenser. Animals were slaughtered at the age of 8 months. A similar experiment was conducted with animals aged 4 years; they were also given the probiotic annually for 2 months. The experiment examined the effect of the probiotic on the fatty acid composition of intramuscular fat (studied using FT-MIR spectroscopy) and the amino acid composition of meat protein (studied using the method described in GOST 34132-2017, method for amino acid analysis).

Results. A significant quality indicator is not only the fat content but also the fatty acid composition of its lipid fraction. Animal fats contain essential polyunsaturated fatty acids, such as linoleic and linolenic acids, which play a vital role in metabolic processes. Like essential amino acids, they are not synthesized in the body, or are synthesized to a limited extent. A prolonged lack of polyunsaturated acids in the diet leads to growth retardation, necrotic skin lesions, and changes in capillary permeability.

Conclusion. The use of a probiotic based on *Bacillus amyloliquefaciens* VKPM B-11475 in raising Saanen goats demonstrates a positive effect on the lipid and amino acid composition of meat. In the short term (8 months), an increase in the proportion of saturated fatty acids by 5.22-7.23%, monounsaturated fatty acids by 1.14-2.95%, and polyunsaturated fatty acids by 0.67-1.53% was observed, including an increase in linoleic acid content by 0.83-1.13%, while linolenic acid decreased by 0.19–0.49%. In the long-term experiment (4 years), the changes persist, but are more pronounced: an increase in saturated fatty acids by 1.62%, monounsaturated by 0.4-2.26%, polyunsaturated by 0.46-0.81% and linoleic acid by 0.05-0.24%, as well as a decrease in the content of linolenic acid by 0.04-0.17%.

Keywords: B. amyloliquefaciens preparation; volatile fatty acids; amino acids; Zaanen goat breed; muscle tissue

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Научная статья

ВЛИЯНИЕ ПРОБИОТИКА НА ОСНОВЕ BACILLUS AMYLOLIQUEFACIENS ВКПМ B-11475 НА СОСТАВ ВНУТРИМЫШЕЧНОГО ЖИРА И АМИНОКИСЛОТНЫЙ СОСТАВ БЕЛКА КОЗЛЯТИНЫ

Г.В. Молянова, М.М. Орлов

Аннотация

Обоснование. В статье представлены результаты экспериментального исследования по оценке влияния пробиотического штамма *Bacillus amyloliquefaciens* ВКПМ B-11475, применяемого в дозировках 4×10^9 и 4×10^7 КОЕ, на метаболический профиль зааненских коз, с акцентом на модуляцию состава летучих жирных кислот во внутримышечном жире и аминокислотный спектр мышечного белка в возрастные периоды от 8 месяцев до 4 лет. Было установлено, что применение пробиотика вызвало достоверные изменения показателей липидного обмена: увеличение насыщенных жирных кислот на 5,22-7,23% (8 месяцев) и 1,62% (4 года), мононенасыщенных – на 1,14-2,95% и 0,4-2,26%, полиненасыщенных – на 0,67-1,53% и 0,46-0,81%, а также повышение уровня линолевой кислоты на 0,83-1,13% и 0,05-0,24%, с сопутствующим снижением концентрации линоленовой кислоты на 0,19-0,49% и 0,04-0,17% соответственно. Полученные данные подчеркивают потенциал *B. amyloliquefaciens* в качестве функциональной добавки для целенаправленной коррекции пищевого статуса продуктивных животных.

Цель. Изучить влияние пробиотика *Bacillus amyloliquefaciens* на жирнокислотный и аминокислотный состав мяса коз.

Материалы и методы. В научно-исследовательской лаборатории индивидуального предпринимателя, главы крестьянского хозяйства «Цирулев Евгений Павлович» был произведен пробиотик на основе *Bacillus amyloliquefaciens* ВКПМ B-11475 (B. amyloliquefaciens). Препарат представляет собой жидкость светло–коричневого цвета, средняя концентрация составляет 4×10^9 КОЕ (КОЕ - колониеобразующая единица). Научно-производственный опыт проводился на ферме по производству и переработке козьего молока фермерского хозяйства «Семкина О.В.» Приволжского района Самарской области. Козлята были отобраны по принципу пар-аналогов по 10 голов в группе в возрасте 2 месяцев. Для проведения эксперимента были созданы три группы животных по 10 голов в каждой. В контрольную группу вошли козлята-молодняк с базовым рационом кормления. Козы I опытной группы принимали пробиотик в дозе $4{\times}10^9$, II опытной группы - $4{\times}10^7$ за 30 минут до кормления по 1 капсуле на голову 1 раз в день в течение месяца с использованием болюсного дозатора. Убой животных проводили в возрасте 8 месяцев. Аналогичным образом был проведен эксперимент с животными в возрасте 4 лет, им также назначали пробиотик в течение 2 месяцев ежегодно. В ходе эксперимента изучалось влияние исследуемого пробиотика на состав жирных кислот во внутримышечном жире (изучалось с помощью FT-MIR спектроскопии), а также на аминокислотный состав мясного белка (изучалось методом, описанным в ГОСТ 34132-2017).

Результаты. Значимым показателем качества является не только содержание жира, но и жирнокислотный состав его липидной фракции. В составе животных жиров присутствуют незаменимые полиненасыщенные жирные кислоты, играющие важную роль в обменных процессах: линолевая и линоленовая. Подобно незаменимым аминокислотам, они в организме не синтезируются или синтезируются ограниченно. Длительное отсутствие в рационе полиненасыщенных кислот приводит к прекращению роста, некротическим поражениям кожи, изменениям проницаемости капилляров.

Заключение. Использование пробиотика на основе *Bacillus amyloliquefaciens* ВКПМ В-11475 при выращивании зааненских коз демонстрирует положительное влияние на липидный и аминокислотный состав мяса. В краткосрочной перспективе (8 месяцев) наблюдается увеличение доли насыщенных на 5,22–7,23%, мононенасыщенных на 1,14-2,95% и полиненасыщенных на 0,67-1,53% жирных кислот, в том числе увеличение содержания линолевой кислоты на 0,83-1,13%, при этом линоленовая кислота снижается на 0,19-0,49%. В долгосрочном эксперименте (4 года) изменения сохраняются, но более выражены: увеличение насыщенных жирных кислот на 1,62%, мононасыщенных на 0,4-2,26%, полинасыщенных на 0,46-0,81% и линолевой кислоты на 0,05-0,24%, а также по мере снижения содержания линоленовой кислоты на 0,04-0,17%.

Ключевые слова: B. amyloliquefaciens; летучие жирные кислоты; аминокислоты; козы зааненской породы; мышечная ткань

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Introduction

Agriculture, acting as a system-forming sector of the economy, plays a critically important role in ensuring global food security, socio-economic development and maintaining ecological balance. In the context of population growth, projected to reach 9 billion people by 2050, and the intensification of climate change, the agricultural sector faces the need not only to increase food production, but also to radically improve its quality, nutritional value and accessibility. The economic importance of the industry is reflected in the creation of employment opportunities, especially in developing countries, stimulating related sectors (processing, logistics, trade) and improving the standard of living of rural communities. At the same time, modern agriculture is being transformed towards sustainable and high-tech practices that minimize the ecological footprint, promote biodiversity conservation and ecosystem restoration, which underlines its key role in achieving sustainable development goals and adapting to anthropogenic challenges [1].

Goat breeding, being a strategically important branch of the agro-industrial complex of Russia and other countries, demonstrates a high adaptive potential in the face of various climatic and economic challenges. The actualization of the sector is driven by the growing consumer demand for natural and organic products, where goat's milk and meat occupy a niche of functional nutrition due to their unique biochemical properties. Comparative analysis shows the superiority of goat's milk over cow's milk in terms of calcium (13-15% higher) and B vitamins (B2 by 18-20%, B12 by 8-10%), as well as the presence of an alternative form of casein, which reduces the risk of allergic reactions by 40-60% in sensitized individuals. These characteristics correspond to the trend of conscious consumption, stimulating farmers to introduce resource-saving technologies and form new market niches, which ultimately contributes to the diversification of agriculture and strengthening food security [2; 3].

In addition, goat breeding has a lower negative impact on the environment compared to cattle. Goats are less demanding of resources and can successfully graze on less fertile lands, making them ideal for sustainable agriculture. This attracts the attention of not only consumers, but also public and private investors interested in supporting environmentally friendly industries. In general, the growing interest in natural and organic products creates favorable conditions for the development of goat breeding and contributes to the formation of a new culture of consumption focused on health and a sustainable future [4].

In the article by T.L. Krasovskaya, S.I. Novopashina (2012), the goats were fed, in addition to the main diet, the feed additive Humival at a dosage of 50 mg dv/ kg. There was a 40% reduction in the number of sick animals. Increase the safety of young animals by 10%. Bactericidal activity increased by 3.55%, lysozyme activity by 4.74% [5].

Under the influence of the LactoMin supplement (at a dosage of 50 g /head / day), the average daily milk yield increased by 11.7%, protein by 0.08%, fat content by 0.15%. Under the action of the LactuVet additive (at a dosage of 50 g / head / day), there was an increase in indicators compared to the control: average daily milk yield by 8.5%, protein by 0.02%, and fat content by 0.07% [6]. Feed additive "Plantarum" in a dosage of 0.8 ml / kg of body weight per day. There was an increase in such indicators as: productivity by 3.27%, protein mass fraction by 3.33%; fat mass fraction by 3.22% [7]. When sapropel feed additive was introduced into the main diet (0.6 g / kg of live weight + hongurin 0.20 g / kg of live weight + Kempendyai salt 10 g), there was an increase in live weight in 6 months by 4.38%, in 8 months by 6.69%, in 10 months by 6.88%, in 12 months. by 7.78%. Absolute growth increased by 18.12%, profitability by 8.51% [4]. Additives "YODDAR-ZN" (100 mg per 1 kg of concentrated feed) and DAFS-25 (1.6 mg per 1 kg) increase the index of albumins (by 0.45 and 1.21%), phosphorus (by 8.53 and 20.12%, respectively). Reduction of globulins (by 0.51 and 1.21%), creatinine (by 13.43 and 17.21%, respectively [8]. Algavet feed additive (in a dosage of 40 ml per animal) provides an increase in productivity (by 24.55%), fat mass fraction (by 0.26%), protein mass fraction (by 0.28%), SOMO (by 0.27%), density (by 0.09%), milk caloric content (by 8.10%) [9]. The Plantarum feed additive (at a dosage of 0.8 mg/kg) provides an increase in such indicators as: absolute increase (by 3.12%), average daily increase (by 2.80%), live weight (by 18.2%), relative increase (decreased by 0.6%) [10]. The use of a feed additive from ginger seeds (ginger estrudate) led to an increase in the mass fraction of fat (by 0.43%), mass fraction of protein (by 0.10%), SOMO (by 0.02%), average daily milk yield (by 17.52%) [11]. Under the influence of the feed additive Zhomstevia (5 g / kg of live weight) There was an increase in productivity (by 19.20%), acidity (by 0.69%), density (by 0.09%), fat mass fraction (by 0.28%), protein mass fraction (by 0.24%), SOMO (by 0.26%), casein (by 0.33%). The content of whey proteins decreased by 0.09% [12]. The probiotic drug Celobacterin (at a dosage of 1 g of the drug per 1 kg of feed) provides a 33% increase in milk yield, and a 32% reduction in the cost of dry matter for milk synthesis [13]. The introduction of 150 g + sodium acetate into the main diet of soy meal (at a dosage of 90 g per head per day) led to an increase in the average daily milk yield (by 14.67%), fat (by 6.25%), protein (by 18.99%), lactose (by 12.35%) [14].

In the study of I.F. Gorlov, A.A. Korotkova et al. (2013), in addition to the basic diet, the goats of the II experimental group were fed the feed additive "YODDAR-ZN" (100 mg per 1 kg of concentrated feed), and the III experimental group, in addition to O.R., were fed the selenium-organic drug DAFS-25 (1.6 mg per 1 kg). There was an increase in such indicators as milk yield by 10.87% (II experimental group) and 14.78% (III experimental group); fat mass fraction by 0.21 and 0.78%; protein mass fraction by 0.05 and 0.10%; live weight by 3.06 and 3.85%; lactation coefficient by 7.57 and 10.53%; lactation constancy coefficient 3.43 and 3.95%. Erythrocyte count by 0.71 and 1.17%; leukocytes (decreased) by 2.5% (experimental group III), and (increased) by 5.69% (experimental group II); hemoglobin by 1.25 and 2.5%; total protein by 5.46 and 7.33%; glucose by 2.56 and 4.27%; calcium 0.75 and 1.35%; urea 11.34 and 6.58% respectively [15].

Under the influence of feed additives Lactovet-1 (at a dosage of 0.5% by weight of concentrates) and Cumelact -1 (at the same dosage), erythrocyte counts increase (by 4.98 and 9.53%), hemoglobin (by 2.17 and 3.41%), total protein (by 4.69 and 7.59%), albumins (by 2.18 and 32.83%), urea (by 8.88 and 19.28%), glucose (by 8.98 and 11.23 %), calcium (by 8.64 and 20.57 %), phosphorus (by 4.45 and 19.74%), bilirubin (by 2.03%) (when using Cumelact-1, the indicator was equal to the control group). ALT (by 2.80 and 11.92%), AST (by 0.46 and 1.20%), lysozyme activity (by 12.32 and 14.63%). The number of phagocytic neutrophils increased by 4.26 and 5.72%, the phagocytic index by 0.44 and 0.79%. Milk yield increased by 5.41 and 6.49%, fat by 0.28 and 0.30%. Titrated acidity increased by 0.29 and 0.82%, respectively. The following indicators decreased: leukocytes by 2.00 and 0.72%, globulins by 0.92 and 2.17%, creatinine by 10.40 and 16.93%, respectively [16].

The drug "Em Kurunga" (in a dosage of 0.01 g of concentrate per 1 kg of live weight) provides an increase in body weight by 12.1%, and a change in the physique index in terms of: legginess by 3.5%, elongation (decrease) by 8.6%, downness by 13%, overgrowth (decrease) by 0.6%, massiveness by 3%, bony by 1.1%, big-headed by 2%, broad-browed (decrease) by 6.6% [17].

Materials and methods

A probiotic based on *Bacillus amyloliquefaciens* VKPM B-11475 (*B. amyloliquefaciens*) was produced in the research laboratory of an individual entrepreneur, the head of a Peasant (Farmer) Farms "Tsirulev Evgeny Pavlovich" [18]. The preparation is a light-brown liquid with an average concentration of 4×10^9 CFU.

A scientific and production experiment was carried out at the goat milk production and processing farm of Semkina O.V. of the Privolzhsky district of the Samara region. The goats were selected according to the principle of pairs of analogues of 10 heads in a group of 2 months of age. To conduct the experiment, three groups of animals were created, including 10 heads each [18]. The control group included baby goats with a basic feeding diet. The goats of the experimental group I took probiotic at a dose of 4×10^9, experimental group II 4×10^7 30 minutes before feeding, 1 capsule per head 1 time per day for a month using a bolus dispenser. The slaughter of animals was carried out at the age of 8 months. Similarly, an experiment was conducted with animals aged 4 years, they were also prescribed a probiotic for 2 months annually.

During the experiment, the effect of the probiotic under study on the composition of fatty acids in intramuscular fat (studied using FT-MIR spectroscopy), as well as on the amino acid composition of meat protein (studied by the method described in GOST 34132-2017).

The digital data obtained in the experiments were subjected to statistical processing using the Microsoft Office Excel 2010 computer application and analyzed in accordance with the norms of variation statistics. Statistical reliability was determined by the Student's criterion.

Results

A significant indicator of quality is not only the fat content, but also the fatty acid composition of its lipid fraction. The composition of animal fats contains essential polyunsaturated fatty acids that play an important role in metabolic processes: linoleic and linolenic. Like essential amino acids, they are not synthesized in the body or are synthesized in a limited way. Prolonged absence of polyunsaturated acids in the diet leads to cessation of growth, necrotic skin lesions, changes in capillary permeability. The results of the study of the content of fatty acid are presented in Tables 1-2, amino acid composition in tables 3-4.

Table 1.

Fatty acid composition of intramuscular fat in 8-month-old goats, %

Indicator	Groups of animals		
	Control group	First experimental group	Second test
Saturated fatty acids	50.47±1.258	57.70±1.437***	55.69±1.387***
Monounsaturated fatty acids	42.89±1.065	45.84±1.142***	44.03±1.093***
Polyunsaturated fatty acids	4.65±0.113	3.12±0.078***	3.98±0.097***
Linoleic acid	2.89±0.072	4.02±0.096***	3.72±0.087***
Linolenic acid	1.08±0.027	0.59±0.012***	0.89±0.018***

Here and further note: *** – $p\leq0.001$ – relative to the control data.

Analysis of the data presented in Table 1 demonstrates that changes in the diet of goats (experimental groups) had a statistically significant ($p<0.001$) effect on the profile of fatty acids in intramuscular fat compared with the control group. There is a marked tendency to increase the proportion of saturated fatty acids (from 50.47% in the control to 57.70% and 55.69% in the first and second experimental groups, respectively) and monounsaturated (from 42.89% to 45.84% and 44.03%), while the content of polyunsaturated fatty acids decreased significantly (from 4.65% to 3.12% and 3.98%). It is noteworthy that, contrary to this general trend, the level of linoleic acid increased (from 2.89% to 4.02% and 3.72%), while the content of linolenic acid, on the contrary, showed the sharpest decrease (by 1.8 and 1.2 times – from 1.08% to 0.59% and 0.89%), indicating a complex and multidirectional the influence of experimental factors on the metabolism of various classes of PUFA. From the point of view of physiology and biochemistry, the observed changes are probably due to the modification of lipid metabolism in the rumen of animals under the influence of a new diet. A sharp decrease in the level of linolenic acid (C18:3 n-3) and a general decrease in the proportion of PUFA (polyunsaturated fatty acids) with a simultaneous increase in SFA (saturated fatty acids) and MUFA (monounsaturated fatty acids) indicates an increased biohydrogenation process in the rumen, during which microorganisms saturate the free double bonds of fatty acids supplied with feed, converting polyunsaturated acids into monounsaturated (for example, into oleic acid) and further in saturated (primarily stearin C18:0). The paradoxical increase in linoleic acid (C18:2 n-6) despite a general decrease in PUFA may be explained by an initially linoleic-acid–rich diet and ruminal metabolic pathways (e.g., partial biohydrogenation to conjugated linoleic acid) that could cause transient accumulation in tissues.

Table 2.

Fatty acid composition of intramuscular fat in 4-year-old goats

Indicator	Groups of animals		
	Control group	First experimental group	Second experimental group
Saturated fatty acids	64.68±1.613	63.06±1.572**	63.96±1.587**
Monounsaturated fatty acids	32.70±0.815	34.96±0.871***	33.10±1.822
Polyunsaturated fatty acids	3.31±0.267	3.77±0.093	4.12±0.116**
Linoleic acid	1.79±0.081	2.03±0.049***	1.84±0.048
Linolenic acid	1.36±0.031	1.19±0.026***	1.32±0.031

The data for the 4-year period revealed significant but less contrasting changes in the fatty acid profile compared to the 8-month experiment. The content of saturated fatty acids in the experimental groups (63.06% and 63.96%) decreased significantly ($p<0.01$) compared with the control (64.68%), while the proportion of monounsaturated acids increased significantly only in the first experimental group (34.96% versus 32.70% in the control, $p<0.001$). There is a tendency to increase polyunsaturated fatty acids, which reached statistical significance in the second experimental group (4.12% vs. 3.31%, $p<0.01$). The content of linoleic acid significantly increased only in the first group (2.03% vs. 1.79%, $p<0.001$), and the level of linolenic acid, on the contrary, significantly decreased in the same group (1.19% vs. 1.36%, $p<0.001$), which indicates a long-term adaptation of metabolism and possible compensatory regulation of biochemical pathways, leveling the initial effect of a change in diet. From a physiological and biochemical point of view, the changes observed over 4 years indicate a long-term adaptation of the rumen microbiome and lipid metabolism of animals to the experimental diet. A decrease in the proportion of saturated fatty acids (NLCs) and an increase in monounsaturated (MNFA) and polyunsaturated (PUFA) acids compared to earlier results suggests partial compensation and increased efficiency of assimilation of dietary lipids, possibly due to an adaptive shift in the rumen microbial population towards communities with less intensive biohydrogenation activity. This adaptation leads to a higher bypass of unsaturated fatty acids from the rumen for deposition in tissues. The stabilization of linolenic acid levels in the second near control values group (1.32% vs 1.36%) against the background of its reduction in the first group indicates a complex regulation of omega-3 acid metabolism, which may depend on the exact composition of the diet and individual characteristics of animals, including the activity of tissue desaturases, elongases and specific peroxisomal β-oxidizing enzymes.

According to the data, dietary modification in goats led to selective but statistically significant changes in the content of some essential amino acids in muscle protein after 8 months of the experiment. There was a significant increase in the concentration of lysine (from 6.1 g/100 g of protein in the control to 6.6 and 6.3 in the first and second experimental groups, respectively, $p < 0.001$), isoleucine (from 3.3 to 3.7, $p < 0.001$ and 3.4, $p < 0.01$) and the amount of phenylalanine and tyrosine (from 5.4 to 5.8, $p < 0.05$ and 5.7, $p < 0.001$).

At the same time, the levels of histidine, leucine, methionine with cysteine, threonine, tryptophan, and valine remained statistically unchanged, indicating a targeted effect of diet on the metabolism of specific amino acids without disrupting the overall amino acid balance of the protein matrix.

Table 3.

Amino acid composition of essential amino acids of goat meat proteins 8 months, %

Amino acid	Amino acid content, g/100 protein		
	Control group	First experimental group	Second experimental group
Histidine	2.5±0.061	2.6±0.065	2.6±0.063
Isoleucine	3.3±0.079	3.7±0.087***	3.4±0.081**
Leucine	6.7±0.162	6.9±0.169	6.8±0.164
Lysine	6.1±0.149	6.6±0.163***	6.3±0.153***
Methionine+cysteine	2.8±0.064	2.9±0.068	2.9±0.068
Phenylalanine+ tyrosine	5.4±0.132	5.8±0.139*	5.7±0.137***
Threonine	2.5±0.061	2.6±0.062	2.5±0.056
Tryptophan	0.087±0.001	0.091±0.001	0.089±0.001
Valin	4.6±0.112	4.8±0.117	4.7±0.112

A significant quality indicator is not only fat content but also the fatty acid composition of its lipid fraction. The observed increase in the content of specific essential amino acids (lysine, isoleucine, phenylalanine, and tyrosine) while maintaining the overall amino acid balance indicates a selective effect of diet composition on metabolic pathways. It is likely that experimental feed additives contained an increased number of precursors of these amino acids or stimulated the activity of key enzymes of their synthesis in the rumen microbiota, such as aminotransferases and dehydrogenases. At the same time, the absence of changes in the concentration of other essential amino acids indicates a high degree of metabolic homeostasis and regulatory compensation provided by the mechanisms of feedback inhibition of biosynthetic pathways, which prevents imbalance and maintains the stability of the muscle tissue proteome.

After four years, the amino acid composition showed a stable and statistically significant improvement in the profile of essential amino acids in the experimental groups compared with the control. In the first experimental group, there was a significant increase in all key amino acids: histidine (2.4±0.04 vs 2.0±0.02, $p<0.001$), isoleucine (3.5±0.07 vs 3.1±0.02, $p<0.001$), leucine (6.6±0.01 vs 6.2±0.04, $p<0.001$), lysine (6.4±0.09 vs 6.1±0.05, $p<0.01$), methionine+cysteine (2.7±0.05 vs 2.5±0.07, $p<0.01$), phenylalanine+tyrosine (5.6±0.03 vs 5.0±0.08, $p<0.001$) and valine (4.6±0.07 vs 4.1±0.06, $p<0.001$). In the second experimental group, the changes were less pronounced, but also significant: histidine (2.2±0.05, $p<0.01$), isoleucine (3.4±0.07, $p<0.01$), leucine (6.6±0.08, p<0.001), lysine (6.2±0.06, p<0.05), phenylalanine+tyrosine (5.2±0.05, p≤0.01) and valine (4.3±0.05, p≤0.001).

Table 4.

Amino acid composition of essential amino acids of goat meat proteins 4 years old. %

Amino acid	Amino acid content. g/100 protein		
	Control group	First experimental group	Second experimental group
Histidine	2.0±0.02	2.4±0.04***	2.2±0.05**
Isoleucine	3.1±0.02	3.5±0.07***	3.4±0.07**
Leucine	6.2±0.04	6.6±0.01***	6.6±0.08***
Lysine	6.1±0.05	6.4±0.09**	6.2±0.06*
Methionine+ cysteine	2.5±0.07	2.7±0.05**	2.6±0.03
Phenylalanine+ tyrosine	5.0±0.08	5.6±0.03***	5.2±0.05**
Threonine	2.4±0.08	2.5±0.06	2.4±0.03
Tryptophan	0.083±0.001	0.088±0.001	0.085±0.001
Valin	4.1±0.06	4.6±0.07***	4.3±0.05***

The content of threonine and tryptophan remained unchanged in both groups, which indicates a long-term positive effect of the experimental diet on the protein composition of meat while maintaining metabolic balance. Long-term use of experimental diets for 4 years led to a significant improvement in the amino acid composition of goat meat, which indicates a deep metabolic adaptation of animals. There was a statistically significant increase in the content of histidine (from 2.0 to 2.4 and 2.2 g/100 g of protein), isoleucine (from 3.1 to 3.5 and 3.4), leucine (from 6.2 to 6.6 in both groups), lysine (from 6.1 to 6.4 and 6.2), methionine with cysteine (from 2.5 to 2.7) and valine (from 4.1 to 4.6 and 4.3) while maintaining unchanged levels of threonine and tryptophan. These changes are explained by the optimization of the synthetic activity of the scar microflora and improved utilization of nutrients, while the stability of individual amino acids indicates the preservation of metabolic homeostasis due to the mechanisms of enzymatic regulation.

Conclusion

The use of a probiotic based on *Bacillus amyloliquefaciens* VKPM B-11475 in the cultivation of Saanen goats demonstrates a positive effect on the lipid and amino acid profile of meat. In the short term (8 months), there is an increase in the proportion of saturated (by 5.22–7.23%), monounsaturated (by 1.14–2.95%) and polyunsaturated (by 0.67–1.53%) fatty acids, including an increase in linoleic acid (by 0.83–1.13%), while linolenic acid decreases (by 0.19-0.49%). In the long–term experiment (4 years), the changes persist, but are more pronounced: an increase in NLC (by 1.62%), MNFA (by 0.4–2.26%), PUFA (by 0.46–0.81%) and linoleic acid (by 0.05-0.24%), as well as a decrease in linolenic acid (by 0.04–0.17%). The amino acid composition of the protein improves significantly: after 8 months, there is an increase in all essential amino acids, including isoleucine (by 3.03–12.12%), lysine (by 3.17–8.19%) and valine (by 2.17–4.34%), and after 4 years the effect increases for histidine (by 10-20%), isoleucine (by 9.67–12.9%) and valine (by 4.87–12.19%), which confirms the stability of the metabolic changes induced by the probiotic.

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