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Differences in the serum lipid profile of goats with varying autonomic nervous system tone

Bogdan Boychuk*
Postgraduate Student
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0009-0000-6169-004X

Valentyn Karpovskyi
Doctor of Veterinary Sciences, Professor
National University of Life and Environmental Sciences of Ukraine
03041,15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-3858-0111

Ihor Hryshchuk
Doctor of Philosophy
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-2571-6876

Valentyn Karpovskyi
PhD in Veterinary Sciences
Odesa State Agrarian University
65012, 13 Panteleimonivska Str., Odesa, Ukraine
https://orcid.org/0009-0003-9848-1411

Andrii Hryshchuk
PhD in Veterinary Sciences, Associate Professor
Luhansk Taras Shevchenko National University
36000, 3 Koval Str., Poltava, Ukraine
https://orcid.org/0000-0002-4608-337X

Abstract. Goat farming is a promising branch of animal husbandry, as statistics show a rapid increase in global demand for goat milk and meat products. To meet market demand, new methodological approaches are needed to improve animal productivity while maintaining the quality of the raw

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*Corresponding author

materials. In this context, this study aims to determine the impact of autonomic nervous system tone on lipid metabolism in goats. The study involved Saanen goats, with the experimental groups formed based on the results of variation-pulsometric study and electrocardiography, followed by the determination of autonomic nervous system tone using the Baevsky method. The serum lipid profile of goats was studied using a LabLine-010 spectrophotometer. The following indicators were biochemically analysed in serum samples: content of triacylglycerols, cholesterol, high-density, low-density, and very-low-density lipoproteins, and the atherogenic index was calculated. It was established that the content of triacylglycerols was 23% lower ($P < 0.05$) in sympathotonic animals and 41% lower ($P < 0.001$) in vagotonic animals compared to normotonic animals. The level of low-density lipoproteins in the blood serum of sympathotonic animals decreased by 40% ($P < 0.05$), and in vagotonic animals – by 76% ($P < 0.01$), relative to normotonic animals. The content of high-density lipoproteins in sympathotonic animals increased by 36% ($P < 0.001$), relative to normotonic animals. The level of cholesterol in the blood serum of goats differed by 16% ($P < 0.01$) in sympathotonic animals and 15% ($P < 0.01$) in vagotonic animals compared to normotonic animals. A significant influence of autonomic nervous system tone on the processes of maintaining lipid homeostasis in goats was determined. Taking into account the individual features of the influence of the autonomic nervous system on lipid metabolism when distributing animals will contribute to the effective adjustment of diets. After all, each animal has a different tone of the autonomic nervous system, which significantly affects the features of substance transformation in its body

Keywords: lipid metabolism; cholesterol; lipoproteins of varying density; atherogenic index; autonomic regulation

Introduction

L. Wang *et al.* (2024) noted that goat farming holds a prominent position in global livestock production. This is attributed to farms producing milk and meat products with high protein content and a shorter reproductive cycle than cattle. As a result, goats are better adapted to various environmental changes and exhibit accelerated growth rates.

According to S. M'hir *et al.* (2024), the growing popularity of goat products in the consumer market can be attributed to these advantages. Furthermore, a positive aspect of goat farming is the increasing consumer preference for goat products over cow products, especially milk. Contemporary statistics reveal that a growing number of people are experiencing food allergies when consuming cow's milk. Notably, goat's milk contains a higher content of unsaturated fatty acids, making it a more desirable dietary option. This issue is being actively researched as the ratio of saturated to unsaturated fatty acids in human diets is increasing each year, playing a significant role in lipid metabolism.

S.A. Allaoua *et al.* (2021) demonstrated that society is increasingly interested in evaluating what they consume and their preferences, particularly regarding fatty acids such as omega-3 and omega-6. Scientists are paying growing attention to lipid metabolism and methods for its regulation. The main challenge lies in increasing the fat content of milk while enriching it specifically with omega-3 and omega-6 fatty acids. It is also important to note that when altering the concentration of these fatty acids, it is essential to maintain their balanced ratio, as failing to do so can disrupt lipid metabolism.

H.T. Faisal *et al.* (2022) found that increasing the unsaturated fatty acid content in goats is achieved through the use of various dietary supplements, which positively affect fatty acid content. However, changes in diet do not always yield the desired improvements in indicators. The range of results often shows minimal differences or only slight variations. As a result, when these figures are consolidated, they lead to significant errors in the average values.

Z. Antunović *et al.* (2020) demonstrated that this trend persists primarily when attempts are made to adjust baseline lipid metabolism indicators without considering the factors that regulate metabolism in the body. It should also be noted that each animal has individual characteristics, which are reflected in its overall metabolism. As a result, the effectiveness of certain dietary supplements will vary, and when deriving an overall numerical outcome, there can be significant discrepancies. To address this issue, attention should be paid to the body systems that directly regulate homeostasis. Among the complex mechanisms of neurohumoral regulation, there is a framework for understanding individual characteristics that can improve approaches to regulating lipid metabolism. According to T. LeBouef *et al.* (2023), the autonomic nervous system is a key factor in analysing the body's metabolism. Its primary role is to maintain homeostasis and to provide an active response to external influences that may negatively affect metabolic processes.

Y. Huang *et al.* (2023a) argued that the study of lipid metabolism is a crucial issue in the development of goat farming. According to him, these animals, during foetal development, early lactation, and periods of intensive milk production, expend a significant amount of energy-rich substances. Such intense metabolism, without certain adjustments in the diet, can lead to an imbalance in energy, which, as a consequence, will result in economic losses. An example of this, according to Y. Huang (2023b), is the low birth weight of newborn kids. A deficiency of high-energy compounds during the period of active foetal growth often leads to the birth of newborn kids with reduced weight. In the future, these animals will have a lower survival rate at a young age and, as adults, will be prone to metabolic disorders.

D. Wang *et al.* (2023) noted that the active growth of young animals and their productivity largely depend on sufficient levels of amino acids and lipids in the body. Based on their own research, the authors assert that the rates of development vary depending on the individual characteristics of goats, as evidenced by the metabolic profile of their blood. Analysis of lipid metabolism is crucial as it can facilitate effective modulation and improve the quality of milk and meat. J. Wu *et al.* (2023a; 2023b) in their research highlighted the significant importance of goat milk as a source of bioactive components in the form of polyunsaturated fatty acids and emphasised the importance of studying lipid metabolism to better regulate the mechanisms of synthesis of these same fatty acids. Given this, the value of goat products is increasing daily, prompting scientists to seek methods to increase the productivity of these animals and improve the quality of goat products.

To enhance productivity and balance lipid metabolism, researchers have employed various methods. For instance, Y. Zhang *et al.* (2023) supplemented goat diets with copper to improve weight gain in meat breeds by influencing lipid metabolism. According to their hypothesis, copper supplementation in goat diets reduces the content of mRNA for enzymes involved in the oxidation of long-chain fatty acids. F. Zamuner *et al.* (2020) utilised infusions of glucose, insulin, and adrenocorticotropin to stimulate milk production and improve metabolic transformations. S. Liu *et al.* (2021) investigated the effects of soybean oil as a supplement to enhance milk production in goats. Specifically, the use of this supplement provided an increase in lipid content in goats while simultaneously increasing the fat percentage in milk, and evaluated the animals' ability to counteract heat stress by compensating for energy expenditure under its influence. The application of plant-based lipid supplements with a high content of polyunsaturated fatty acids to improve goat productivity by stimulating fat accumulation in the mammary gland, leading to an increase in its percentage and the consumer value of dairy products, has been explored.

This study aimed to investigate the sympathovagal balance in goats to better understand metabolic processes, particularly lipid metabolism. This understanding is essential for the formation of technological groups of animals based on their individual characteristics.

Materials and Methods

The biological material for this study was obtained from Saanen goats at a farm in the village of Knyahynynok, Lutsk District, Volyn Region, during the years 2023-2024. Samples were taken from animals in experimental groups, with 5 animals in each group. The formation of these groups was based on the results of the variation-pulsometric study conducted using the methodology of R.M. Baevsky *et al.* (2001). Based on the results obtained, three experimental groups of animals were formed: normotonics, sympathotonics, and vagotonics. During the experimental studies, all manipulations with the goats involved in the study were carried out following the basic principles of bioethics, in compliance with the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (1986) and the Procedure for Conducting Research and Experiments on Animals by Scientific Institutions (2012).

For the biochemical analysis, blood serum was obtained by allowing native blood samples to stand and incubating them for one hour in a thermostat at 37°C.

A LabLine-010 spectrophotometer (Austria) was used to determine cholesterol content. A test system from LLC "Granum Laboratory", Kharkiv, was used to determine total protein content. Measurement conditions: wavelength 505 (500-550) nm, cuvette with an optical path length of 1 cm, temperature 15-25°C.

The obtained results were calculated using the formula:

$$C_{exp} = \frac{E_{exp}}{E_{std}} \times C_{std}, \qquad (1)$$

where C_{exp} is the cholesterol concentration in the experimental sample, mmol/L; E_{exp} is the optical density of the experimental sample, ODU; E_{std} is the optical density of the standard, ODU; C_{std} is the cholesterol content in the standard, 5.16 mmol/L.

Determination of triacylglycerol content in blood serum using a LabLine-010 (Austria) spectrophotometer. Measurements were taken at a wavelength of 490-550 nm in 1 cm cuvettes.

The obtained results were calculated using the formula:

$$C_{exp} = \frac{E_{exp}}{E_{std}} \times C_{std}, \qquad (2)$$

where C_{exp} is the triglycerides concentration in the experimental sample, mmol/L; E_{exp} is the optical density of the experimental sample, ODU; E_{std} is the optical density of the standard, ODU; C_{std} is the triglycerides content in the standard, 2.25 mmol/L.

The content of low-density lipoproteins (LDL) was determined using the LabLine-010 (Austria). Measurements were taken at a wavelength of 590-700 nm in 1 cm cuvettes.

The obtained results were calculated using the formula:

$$C_{exp} = \frac{E_{exp}}{E_{std}} \times C_{std}, \quad (3)$$

where C_{exp} is the low-density lipoproteins concentration in the experimental sample, mmol/L; E_{exp} is the optical density of the experimental sample, ODU; E_{std} is the optical density of the standard, ODU; C_{std} is the low-density lipoproteins content in the standard, 5.17 mmol/L.

The determination of high-density lipoproteins (HDL) was carried out using the LabLine-010 (Austria). Measurements were taken at a wavelength of 550-650 nm in 1 cm cuvettes.

$$C_{exp} = \frac{E_{exp}}{E_{std}} \times C_{std}, \quad (4)$$

where C_{exp} is the high-density lipoproteins concentration in the experimental sample, mmol/L; E_{exp} is the optical density of the experimental sample, ODU; E_{std} is the optical density of the standard, ODU; C_{std} is the high-density lipoproteins content in the standard, 2.585 mmol/L.

The content of very low-density lipoproteins (VLDL) was determined using Friedewald's formula:

$$VLDL = TotalChol - (HDL + LDL). \quad (5)$$

The atherogenic index was calculated using the formula:

$$AI = (TotalChol - HDL)/LDL. \quad (6)$$

Reagents from LLC "Granum Laboratory", Kharkiv, were used to determine the above-mentioned lipid metabolism parameters.

Statistical analysis of the obtained results was carried out using Microsoft Excel software. The probability of the difference between the obtained indicators was calculated using Student's t-test. Differences between the compared indicators were considered significant at a significance level of $P < 0.05$, $P < 0.01$, $P < 0.001$.

Results and Discussion

According to the results of the biochemical analysis of the blood serum of goats, the lipid profile indicators for the vagotonic experimental group were established (Table 1).

Table 1. Lipid profile indicators of blood serum of vagotonic goats

Indicator	NVO	SE	Mdn.	SD	Asym.	Min.	Max.
Triglycerides, mmol/L	5	0.01	0.26	0.02	-0.08	0.23	0.28
VLDL, mmol/L	5	0.01	0.13	0.02	-0.58	0.10	0.14
LDL, mmol/L	5	0.02	0.44	0.03	-0.04	0.4	0.47
HDL, mmol/L	5	0.02	1.22	0.04	-0.41	1.16	1.27
Cholesterol, mmol/L	5	0.02	1.79	0.04	0.27	1.76	1.84
Atherogenic index	5	0.02	0.47	0.04	-1.34	0.39	0.50

Note: *NVO – number of valid observations, SE – standard error, Mdn. – median, SD – standard deviation, Asym. – asymmetry, Min. – minimum value, Max. – maximum value*
Source: *authors' development*

According to the study results, the triglyceride levels in the blood serum of vagotonic goats displayed minimal variation between the minimum and maximum values, amounting to 0.05 mmol/L, which ensured low standard deviation and standard error values. The concentration of very low-density lipoproteins in animals with a predominance of the parasympathetic nervous system showed a difference of 0.04 mmol/L between the minimum and maximum values, accompanied by low standard deviation and standard error.

The low-density lipoproteins in this group of animals exhibited a range difference of 0.07 mmol/L, with similarly low standard deviation and standard error values. The concentration of high-density lipoproteins in the goats characterised by a predominance of the parasympathetic nervous system indicated a range difference of 0.11 mmol/L between minimum and maximum values, with low standard deviation and standard error. The cholesterol level in the blood serum of vagotonic goats fluctuated between minimum and maximum values by 0.08 mmol/L, also accompanied by low standard deviation and standard error. The atherogenic index in the vagotonic animals revealed a difference of 0.11 mmol/L between the minimum and maximum values, with low standard deviation and standard error.

According to the results of the biochemical analysis of the blood serum of goats, the lipid profile indicators for the normotonic experimental group were established (Table 2).

Table 2. Lipid profile indicators of blood serum of normotonic goats

Indicator	NVO	SE	Mdn.	SD	Asym.	Min.	Max.
Triglycerides, mmol/L	5	0.01	0.42	0.02	0.60	0.40	0.47
VLDL, mmol/L	5	0.01	0.16	0.02	-0.08	0.14	0.19
LDL, mmol/L	5	0.01	0.26	0.03	-1.67	0.21	0.27
HDL, mmol/L	5	0.01	1.15	0.03	-1.34	1.10	1.17
Cholesterol, mmol/L	5	0.01	1.56	0.03	-0.04	1.52	1.59
Atherogenic index	5	0.02	0.36	0.04	2.00	0.34	0.44

Note: *NVO – number of valid observations, SE – standard error, Mdn. – median, SD – standard deviation, Asym. – asymmetry, Min. – minimum value, Max. – maximum value*
Source: *authors' development*

According to the results of the lipid profile analysis of the serum in normotonic goats, the concentration of triacylglycerols ranged between the minimum and maximum values of 0.07 mmol/L, which indicated low values of standard deviation and standard error. The concentration of very low-density lipoproteins in animals with a balanced influence of the sympathetic and parasympathetic nervous systems demonstrated a difference in the range of values between the minimum and maximum indicators of 0.05 mmol/L, also ensuring low parameters of standard deviation and standard error. The levels of low-density lipoproteins in normotonic animals showed a difference between the minimum and maximum values of 0.06 mmol/L, which again reflected low values of standard deviation and standard error. The concentration of high-density lipoproteins in goats with a balanced influence of the sympathetic and parasympathetic nervous systems was characterised by a difference between the minimum and maximum values of 0.07 mmol/L, ensuring low values of standard deviation and standard error. The cholesterol level in the serum of normotonic animals revealed a difference between the minimum and maximum values of 0.07 mmol/L, which also indicated low values of standard deviation and standard error. The atherogenic index exhibited a difference between the minimum and maximum values of 0.10 mmol/L, confirming low values of standard deviation and standard error.

According to the results of the biochemical analysis of the blood serum of goats, the lipid profile indicators for the sympathotonic experimental group were established (Table 3).

Table 3. Lipid profile indicators of blood serum of sympathotonic goats

Indicator	NVO	SE	Mdn.	SD	Asym.	Min.	Max.
Triglycerides, mmol/L	5	0.01	0.34	0.02	0.24	0.32	0.37
VLDL, mmol/L	5	0.01	0.15	0.02	0.59	0.13	0.18
LDL, mmol/L	5	0.01	0.35	0.02	-0.01	0.33	0.37
HDL, mmol/L	5	0.01	0.84	0.02	-0.55	0.82	0.86
Cholesterol, mmol/L	5	0.02	1.35	0.04	-1.53	1.27	1.38
Atherogenic index	5	0.02	0.59	0.04	0.17	0.54	0.63

Note: *NVO – number of valid observations, SE – standard error, Mdn. – median, SD – standard deviation, Asym. – asymmetry, Min. – minimum value, Max. – maximum value*
Source*: authors' development*

According to the results of the lipid profile analysis of serum in sympathotonic goats, the concentration of triacylglycerols showed a difference between the minimum and maximum values of 0.05 mmol/L, which resulted in low values of standard deviation and standard error. The concentration of very low-density lipoproteins in animals with a predominance of the sympathetic nervous system exhibited discrepancies between the minimum and maximum values of 0.05 mmol/L, which accounted for low values of standard deviation and standard error. The levels of low-density lipoproteins in sympathotonic goats displayed differences between the minimum and maximum values of 0.05 mmol/L, again ensuring low values of standard deviation and standard error. The concentration of high-density lipoproteins in animals with a predominance of the sympathetic nervous system corresponded to a difference between the minimum and maximum values of 0.04 mmol/L, which provided low parameters of standard deviation and standard error. The cholesterol concentration in the serum of sympathotonic goats was characterised by differences between the minimum and maximum values of 0.11 mmol/L, reflecting low values of standard deviation and standard error. The atherogenic index in this group of animals exhibited differences between the minimum and maximum values of 0.09 mmol/L, ensuring low values of standard deviation and standard error.

When comparing the concentration of triacylglycerols in the serum of goats from different experimental groups with varying autonomic nervous system tones, some differences were identified. In comparison with the normotonic experimental group, it was found that the concentration of triacylglycerols in sympathotonic goats was 23% lower ($P < 0.05$), while in the vagotonic experimental group, it was 41% lower ($P < 0.001$). Consequently, the normotonic experimental group had higher triacylglycerol levels, reflecting the intensity of fatty acid metabolism in the goats (Fig. 1).

When analysing the concentration of low-density lipoproteins, it was established that, in relation to the normotonic experimental group, characterised by a balanced sympathovagal balance, sympathotonic goats exhibited values that were 40% higher ($P < 0.05$), while the animals in the vagotonic experimental group had values that were 76% higher ($P < 0.01$) (Fig. 2).

The levels of high-density lipoproteins in the normotonic experimental group of goats were found to be 36% higher ($P < 0.001$) when compared with the sympathotonic goats, which exhibited a predominance of the sympathetic nervous system. In relation to the vagotonic experimental group, characterised by a predominance of the parasympathetic nervous system, the levels of high-density lipoproteins showed minor differences compared to the normotonic group (Fig. 3).

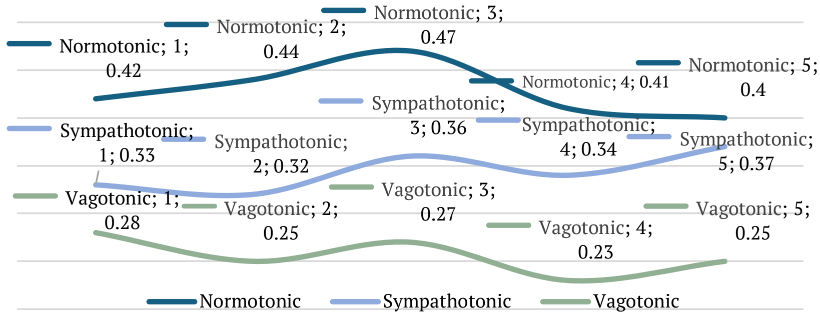

Figure 1. The concentration of triacylglycerols in the serum of goats with different autonomic nervous system tones, mmol/L

Note: *colours indicate different tones of the autonomic nervous system, respectively*

Sourse: *authors' development*

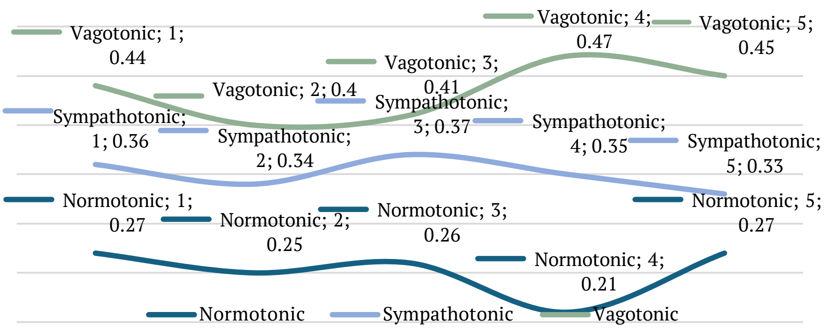

Figure 2. The concentration of low-density lipoproteins in the serum of goats with different autonomic nervous system tones, mmol/L

Note: *colours indicate different tones of the autonomic nervous system, respectively*

Sourse: *authors' development*

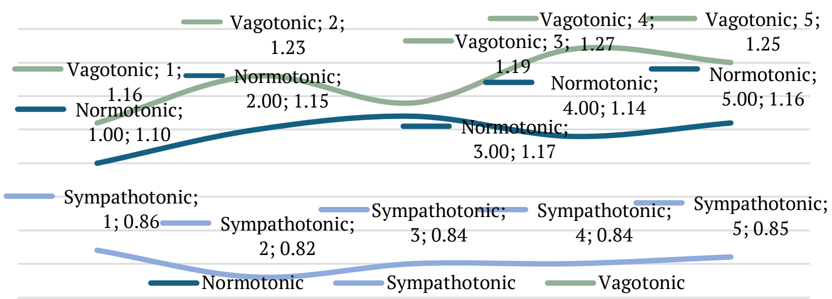

Figure 3. The concentration of high-density lipoproteins in the serum of goats with different autonomic nervous system tones, mmol/L

Note: *colours indicate different tones of the autonomic nervous system, respectively*

Sourse: *authors' development*

The total cholesterol concentration in the serum of normotonic goats was 16% higher ($P < 0.01$) compared to that of sympathotonic goats. When comparing the cholesterol levels between the normotonic animals and the vagotonic experimental group, it was established that the concentration in vagotonic goats was 15% higher compared to the normotonic goats ($P < 0.01$) (Fig. 4).

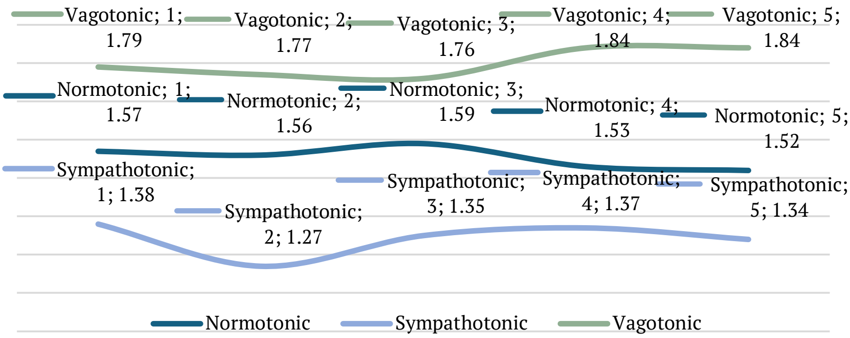

Figure 4. The concentration of cholesterol in the serum of goats with different autonomic nervous system tones, mmol/L

Note: *colours indicate different tones of the autonomic nervous system, respectively*
Sourse: *authors' development*

Analysis of the atherogenic index revealed that in normotonic goats, compared to sympathotonic goats with a predominance of the sympathetic nervous system, the atherogenic index was 38% lower ($P < 0.01$). In relation to the vagotonic experimental group, the values of the atherogenic index showed minor differences when compared with the normotonic group (Fig. 5).

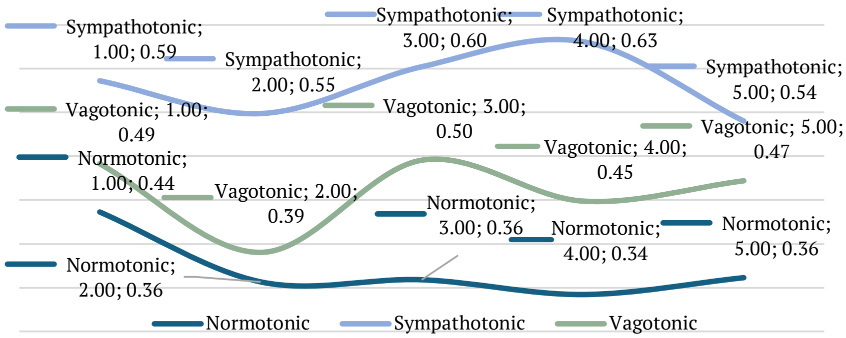

Figure 5. Atherogenic index values in goats with different autonomic regulation tones

Note: *colours indicate different tones of the autonomic nervous system, respectively*
Sourse: *authors' development*

The atherogenic index values in the sympathotonic experimental group were characterised by high values, indicating a low level of high-density lipoproteins relative to total cholesterol parameters. The normotonic goats had the lowest atherogenic index values, reflecting a higher concentration of high-density lipoproteins relative to total cholesterol concentration.

Analysis of the lipid composition in goats is crucial. For high-yielding animals, a deficiency in energy-rich substances can become a key factor in the further development of their organism, which will be reflected in future productivity. In addition, it is worth conducting a risk assessment for these ruminants. The issue of the stress factor is always relevant due to its diversity and frequency of occurrence. Even though, at first glance, the threat of a stressful state of an animal carries insignificant shifts in the body, over time this problem can grow, which will be reflected in lipid metabolism and, as a consequence, in productivity. The question of improving metabolism in this case is quite relevant since with an increase in the content of energy-rich substances, an acceleration of the growth and development of goats will be noted, which will subsequently be reflected in productivity (Fougère *et al.*, 2021).

To improve lipid metabolism, researchers have developed various approaches primarily focused on adjusting the levels of fats and fatty acids in the body through different dietary supplements. The aim of introducing additional nutrients into the diet is to influence the enzymatic pathway, provide an additional source of lipids, and correct the antioxidant system, among other factors. Q. Li *et al.* (2024) analysed the biochemical composition of goat serum at different stages of their development. Their study found that from the age of 180 days, the intensity of lipid metabolism in goats was significantly lower compared to other periods of young animal development. It is important to note that the aforementioned authors emphasised the significance of lipid metabolism for ensuring adequate growth and development in goats. Analysing the data obtained by these researchers, it can be noted that the lipid profile indicators are similar, but due to the distribution of animals according to the tone of the autonomic nervous system, the error of the data in the presented material is significantly reduced. This will substantially enhance the analysis of lipid metabolism research results for scientists, as the obtained indicators have a smaller margin of error and take individual characteristics into account.

A. Ianni *et al*. (2021) conducted a study investigating the effects of an olive leaf dietary supplement on the lipid profile of goats. The experimental group of goats fed a diet supplemented with olive leaves, had a 9% lower cholesterol content in their milk compared to the control group. More significantly, the blood cholesterol content was 20% lower in the experimental group compared to the control. However, these results had a considerable margin of error, which adversely affected the values of the variation error. Such findings indicated that the animals were not categorised according to their individual characteristics, resulting in disparate indicators with significant errors. The results of this study highlight the necessity of distributing animals according to their individual traits, which would facilitate a more accurate analysis of lipid metabolic transformations.

Y. Shen *et al.* (2022) conducted a study involving the addition of resveratrol supplements to the diet of goats to enhance animal growth and improve lipid metabolism. The biochemical analysis of the blood serum revealed the impact of the resveratrol dietary supplement on the levels of triglycerides, as well as high-density and low-density lipoproteins. Compared to the control group, it was found that the triglyceride content significantly decreased by 55% in goats receiving a high concentration of resveratrol, with a dosage of 600 mg per kilogram of body weight. The levels of high-density lipoproteins increased by 1.5 times in animals receiving this dietary supplement relative to the control group, while the low-density lipoprotein levels decreased by 2.5 times compared to the control group. There was also an increase in the atherogenic index. Despite these significant differences, it is worth noting that during the study, the methodology for correcting lipid metabolism and improving lipid levels exhibited considerable discrepancies in the results. Consequently, there was a lack of variation in the triglyceride levels and LDL ($P > 0.05$), as well as a weak correlation when comparing the total cholesterol and HDL ($P < 0.05$). In comparing these results, it can be concluded that distinguishing the experimental groups of animals according to the activity of the autonomic nervous system would enhance the effectiveness of the biochemical analysis of lipid metabolism and reduce the initial error in the statistical data.

M. Zheng *et al.* (2021) investigated the impact of zinc supplements, including zinc sulphate, zinc methionine, and zinc glycinate, on lipid metabolism. The aim of their study was to determine the effects of these dietary supplements on the performance indicators of goats during the growth period. The highest lipid content in blood serum was observed in animals fed zinc sulphate and zinc glycinate supplements. The lowest lipid content was noted in goats that consumed zinc methionine. It is worth noting that although differences in indicators were found in the three experimental groups of animals, not all the results obtained showed a correlation between lipid metabolism indicators and the additional administration of zinc supplements to these animals. This indicates a significant discrepancy in the obtained results, which confirms the need to divide the experimental groups of animals according to their individual characteristics. This can be ensured by taking into account the tone of the autonomic nervous system, as confirmed by the results described in this material.

L. Min *et al*. (2023) investigated the impact of dietary supplements consisting of *Aquilaria sinensis* leaves on lipid metabolism in goats. The aim of their research was to improve productivity, specifically meat quality and weight gain. Their research suggests that diets supplemented with *Aquilaria sinensis* leaves offer a viable alternative for improving lipid metabolism and meat quality. This affordable ingredient promotes balanced weight gain in goats and enriches their bodies with polyunsaturated fatty acids, thereby enhancing the quality of the meat. The use of this dietary supplement also contributed to a decrease in blood cholesterol levels and an increase in high-density lipoprotein levels in goats. An analysis of the data from the study suggests the need to categorise animals based on the influence of the divisions of the autonomic nervous system. This is because not all lipid metabolism indicators showed significant results when comparing animals from the experimental group with the control group. It is worth noting that, according to the results obtained, animals have different intensities of lipid metabolism under different tones of the autonomic nervous system, which provides new information for studying the improvement of organic substance metabolism.

S. Liu *et al*. (2021) used dietary supplements in the form of flaxseed oil and heated flaxseed. This resulted in a decrease in total levels of triacylglycerols, cholesterol, and low-density lipoproteins in goats, which was significantly lower compared to diets using flaxseed oil alone. However, when assessing the reliability of the results, it was found that although the obtained indicators showed some changes in plasma lipids, the difference between the values in the experimental and control groups was quite insignificant. Comparing with the results described in this research, it should be noted that the informativeness of such indicators significantly depends on the body systems that control and directly influence metabolism. To obtain reliable results, it is recommended that animals be divided into experimental groups according to their sympathovagal balance, which would simplify the analysis of the results for scientists.

Having analysed various studies on improving lipid metabolism in goats, it is evident that the data showing changes in serum lipid profiles exhibit significant numerical discrepancies. This is corroborated by statistical analysis results, which lie at the lower boundary of acceptability (Rawat *et al.,* 2021). Several factors can account for these discrepancies. Firstly, the formation of experimental and control groups can be a significant issue. Farmers do not always consider the individual characteristics of each animal, which is crucial as metabolic processes vary from one organism to another. These oversights can lead to significant discrepancies in biochemical analysis results. Secondly, different animals may react differently to changes in feeding strategies. The introduction of various dietary supplements can have both positive and negative effects, as alterations in diet composition can modify metabolic processes. This once again highlights the need to consider individual animal characteristics (Singh *et al.,* 2023).

An analysis of serum lipid profiles in goats with varying autonomic nervous system tones revealed differences between animals in different experimental groups. These differences reflect the metabolic processes occurring at different intensities. The activity of the sympathetic and parasympathetic nervous systems is a key factor in this study. Each animal has a specific sympathovagal balance, characterised by varying activity of the divisions of the autonomic nervous system (Metz *et al.,* 2022). By classifying goats based on individual characteristics, three groups were formed: normotonics, vagotonics, and sympathotonics. Each group of animals was characterised by the different activity of the sympathetic and parasympathetic nervous systems, and consequently different intensities of metabolic processes. This is confirmed by the research results, which showed high levels of triacylglycerols in normotonic animals, high levels of low-density lipoproteins in vagotonic animals, and low levels of high-density lipoproteins in sympathotonic animals. Considering this, it becomes possible to better understand the picture of lipid metabolism in goats.

By incorporating these characteristics in methods to improve lipid metabolism in goats, scientists will gain an additional reference point. This is because, according to the obtained data, there are already differences in the content of cholesterol, lipoproteins of various densities, and triacylglycerols without the addition of dietary supplements. These indicators are quite important in assessing not only lipid metabolism but also overall metabolic processes and goat productivity. Therefore, considering this criterion when forming experimental animal groups will help scientists better evaluate the obtained results. This can elevate the value of dietary supplements used to improve lipid metabolism to a new level.

Considering environmental factors, an animal can be subjected to a stressor at any given time. Primarily, under these circumstances, the stability of the body's homeostasis will suffer, as it will significantly mobilise energy reserves to counteract these changes. One of the main systems that respond to stress is the autonomic nervous system, which, depending on individual characteristics, will have a different tone (Durosaro *et al.,* 2023). As a result, metabolic processes in each goat will shift differently. Consequences of this, if left unaddressed, may include decreased productivity and economic losses.

Conclusions

The influence of autonomic nervous system tone on serum lipid profiles in goats has been established. Differences in lipid metabolism indicators in these animals have been determined depending on the different tones of the autonomic nervous system: normotonics, vagotonics, or sympathotonics. In particular, in the serum lipid profile of goats, differences have been found in indicators such as cholesterol content, high-density and low-density lipoproteins, triacylglycerols, and atherogenic index values with different autonomic nervous system tones.

It was determined that the content of triacylglycerols in the blood serum of normotonic goats was the highest compared to the experimental groups of sympathotonic animals ($P < 0.05$) and vagotonic animals ($P < 0.001$). It was established that the level of low-density lipoproteins was lowest in normotonic animals compared to the experimental groups of sympathotonic ($P < 0.05$) and vagotonic ($P < 0.01$) animals. It was determined that the content of high-density lipoproteins was the lowest in goats of the sympathotonic experimental group compared to the normotonic experimental group ($P < 0.001$). It was established that the values of total cholesterol in the blood serum of normotonic animals were higher compared to the experimental group of sympathotonic animals ($P < 0.01$) and lower when compared to the experimental group of vagotonic animals ($P < 0.01$). The value of the atherogenic index in the experimental group of normotonic animals was the lowest compared to the experimental group of sympathotonic animals ($P < 0.01$) and animals of the vagotonic experimental group ($P < 0.05$). It was established that depending on the individual characteristics of the goat's organism, reflected in the form of sympathovagal balance, in which the influence of the sympathetic or parasympathetic nervous system predominates or there is a balanced interaction of the sympathetic and parasympathetic nervous systems, lipid metabolism processes differ.

The prospect of further research involves the use of dietary supplements in goat feed, formulated based on the tone of the autonomic nervous system. This approach is expected to significantly enhance the effectiveness of these supplements and contribute to improving lipid metabolism in goats, ultimately leading to increased productivity.

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None.

Conflict of Interest

None.

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Відмінності ліпідограми сироватки крові кіз із різним тонусом автономної нервової системи

Богдан Бойчук
Аспірант
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0009-0000-6169-004X

Валентин Карповський
Доктор ветеринарних наук, професор
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0003-3858-0111

Ігор Грищук
Доктор філософії
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0003-2571-6876

Валентин Карповський
Кандидат ветеринарних наук
Одеський державний аграрний університет
65012, вул. Пантелеймонівська, 13, м. Одеса, Україна
https://orcid.org/0009-0003-9848-1411

Андрій Грищук
Кандидат ветеринарних наук, доцент
Луганський національний університет імені Тараса Шевченка
36000, вул. Коваля, 3, м. Полтава, Україна
https://orcid.org/0000-0002-4608-337X

Анотація. Козівництво є перспективною галуззю тваринництва, оскільки за статистикою попит на споживання молочної і м'ясної продукції кіз на світових ринках стрімко зростає. Для насичення ринку необхідною кількістю продукції потрібні нові методичні підходи з покращення продуктивності тварин зі збереженням якості вихідної сировини. У зв'язку з цим, метою дослідження було визначення впливу тонусу автономної нервової системи на обмін ліпідів в організмі кіз. Для дослідження використовували тварин породи Зааненська, формування дослідних груп проводилось з урахуванням результатів варіаційно-пульсометричного дослідження і даних електрокардіографії з подальшим визначенням тонусу автономної нервової системи за методикою Баєвського. Дослідження ліпідограми сироватки крові кіз здійснювали за допомогою спектрофотометра LabLine-010. У зразках сироватки крові здійснювали біохімічний аналіз наступних показників: вмісту триацилгліцеролів, холестеролу, ліпопротеїнів високої, низької і дуже низької щільності та розраховували величину індексу атерогенності. Встановлено, що вміст триацилгліцеролів набував значень менших на 23% ($P < 0{,}05$) у симпатотоніків та на 41% ($P < 0{,}001$) в тварин ваготоніків порівняно з нормотоніками. Рівень ліпопротеїнів низької щільності у сироватці крові симпатотоніків зменшувався на 40% (Р < 0,05), а у ваготоніків – на 76% (Р < 0,01), відносно нормотоніків. Уміст ліпопротеїнів високої щільності у симпатотоніків збільшувався на 36% (Р < 0,001), відносно нормотоніків. Рівень холестеролу в сироватці крові кіз відрізнявся значеннями вищими на 16% (Р < 0,01) у симпатотоніків та на 15% (Р < 0,01) у ваготоніків порівняно з нормотоніками. Визначено істотний вплив тонусу автономної нервової системи на процеси підтримання ліпідного гомеостазу в організмі кіз. Врахування індивідуальних особливостей впливу автономної нервової системи на метаболізм ліпідів при розподілі тварин сприятиме ефективному коригуванню раціонів. Адже кожна тварина має різний тонус автономної нервової системи, що істотно впливає на особливості перетворення речовин в її організмі

Ключові слова: обмін ліпідів; холестерол; ліпопротеїни різної щільності; коефіцієнт атерогенності; автономна регуляція