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Influence of autonomic nervous system tone on the content of unsaturated fatty acids in blood lipids in goats

Bożena Króliczewska*
PhD in Technical Sciences, Associate Professor
Wrocław University of Environmental and Life Sciences
50375, 31 C.K. Norwida Str., Wrocław, Poland
https://orcid.org/0000-0002-0291-3562

Bohdan 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

Valentin 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
Postgraduate Student
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0003-2571-6876

Andriy Hryshchuk
PhD in Veterinary Sciences, Associate Professor
Luhansk Taras Shevchenko National University
36003, 3 Kovalya Str., Poltava, Ukraine
https://orcid.org/0000-0002-4608-337X

Abstract. The relevance of this study lies in the need to determine the role of the autonomic nervous system in the metabolism of unsaturated fatty acids, especially essential ones, in the

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**Corresponding author*

body of goats, which will improve the understanding of individual metabolic characteristics in these animals. The use of established blood markers will make it possible to analyse the state of lipid metabolism in the body of goats and ensure an increase in the effectiveness of methods of its correction. The purpose of this study was to determine the specific features of the autonomic nervous system influence on the relative content of unsaturated fatty acids in goat plasma lipids. The experiment involved goats of the Zaanenska breed, of which, using electrocardiographic analysis according to the Baevsky method and depending on the tone of the autonomic nervous system, three experimental groups were formed: normotonics, sympathotonics, and vagotonics. The method of gas-liquid chromatography was used to determine the percentage of unsaturated fatty acids in goat plasma lipids. Thus, in goats with sympathotonics, which have a predominance of sympathetic nervous system activity, a high percentage of the following lipids in blood plasma was noted: linolenic ($P < 0.01$), cis-4, 7, 10, 13, 16, 19-docosahexaenoic ($P < 0.05$), docosahexapentaenoic ($P < 0.001$), and arachidonic acids ($P < 0.001$) compared to normotonics. These animals also had a lower content of palmitoleic ($P < 0.05$) and oleic acids ($P < 0.01$) in plasma lipids against the background of normotonics. In vagotonic goats, in which the influence of the parasympathetic nervous system predominates, the relative content of cis-4, 7, 10, 13, 16, 19-docosahexaenoic ($P < 0.05$), linoleic ($P < 0.001$) and arachidonic acids ($P < 0.001$) and high cis-11-eicosenoic acid ($P < 0.01$) in blood plasma lipids was found to be low compared to normotonic goats. The established features suggest a substantial influence of the tone of the autonomic nervous system on the quantitative redistribution of unsaturated fatty acids in the composition of goat blood plasma lipids and the need to consider them when analysing the state of the corresponding metabolism in the body, which will substantially improve not only the effectiveness of scientific research, but also its reliability

Keywords: sympathotonia; vagotonia; normotonia; gas-liquid chromatography; plasma

Introduction

Globally, dairy products form an integral part of the diet of most people. In terms of global consumption, cow's milk is the leader, followed by buffalo, and goat's milk, which is rapidly gaining momentum (Monllor *et al.*, 2020). According to A. Maslyuk *et al*. (2020), goat breeding is rapidly beginning to catch up with previous favourites in consumer choice. This can be explained by the fact that people are increasingly faced with the impossibility of consuming cow's milk due to the loss of its full absorption or the development of an allergic reaction. In such situations, goat's milk is a good alternative for consumers. The biological value of goat products is not inferior to that of dairy cattle, and in some respects is even better. According to H. Sedilo *et al*. (2020), this contributes to the intensive development of goat milk production enterprises.

As a result, farm owners are faced with the question of how to improve milk quality at a lower economic cost. The question of the need to enrich milk with essential fatty acids is often raised. Products with a high content of these components, namely omega 3, omega 6, and omega 9 fatty acids, improve the metabolism of mammals, especially lipids. According to J. Djordjevic *et al*. (2019), considering the quality indicators of dairy products, one of the most key factors for evaluation is the study of their fatty acid content, specifically, unsaturated

fatty acids. Today, scientists are actively investigating the issues related to increasing the content of essential fatty acids in dairy products, which creates different avenues for solving them. For this, the introduction of unsaturated fatty acids into the body of goats with the help of various plant-based additives is widely used. Therewith, there were slight changes in the content of fatty acids in the blood against the background of substantial disorders of scarred digestion. Few people pay attention to the fact that not only the diet consumed by the animal will play a role in the concentration of unsaturated fatty acids in the blood and milk. N. Ghavipanje *et al*. (2022) believe that metabolic processes in the body itself and systems that substantially affect homeostasis in general should be considered. This implies the significant role of the autonomic nervous system, which forms an integral part of the centralised system that regulates the synthesis and breakdown of nutrients.

The study of the role of the autonomic nervous system tone in goats, which is a characteristic of the specific individual features of the animal depending on the predominance of the influence of the sympathetic or parasympathetic nervous system, will be a key factor in the analysis of the content of fatty acids in blood plasma lipids. Therefore, depending on the sympatho-vagal balance – normotonia, vagotonia, sympathotonia – the synthesis and breakdown of nutrients in the animal body will differ. Accordingly, the processes of digestion and absorption of nutrients in the gastrointestinal tract will proceed at different rates. Notably, the use of energy-rich substances by the body's cells with the corresponding metabolic rate will also differ. This should be considered when calculating the diet for goats, but generally, the general schemes for highly productive animals should be followed. As a result, different indicators are noted in terms of both milk fat content and productivity of these animals. A.K. Verma *et al*. (2023) argued that it is necessary to increase the dietary intake of essential fatty acids in goats to enrich their dairy products. Consideration of new facts in the investigation of lipid homeostasis in goats depending on the sympathetic-vagal balance will be the basis for ensuring the reliability of scientific results. As a result, I. Erez & U. Serbester (2023) noted that scientists in research on improving the content of unsaturated fatty acids in goat dairy products need to have additional markers for effective statistical analysis of the results.

Therefore, the purpose of this study was to determine the specific features of the quantitative redistribution of unsaturated fatty acids in blood plasma lipids depending on the sympathetic-vagal balance in the body of clinically healthy goats.

Literature Review

Over the past 50 years, dairy production from goats has increased to 53% and continues to grow. Among the countries most actively developing in this area, Asia ranks first, followed by Africa, Europe, and the Americas (Nudda *et al*., 2021). The most common products made from goat's milk are yoghurts, cottage cheese, and ryazhanka. A. Mavrommatis *et al*. (2020) noted that goat's milk is a good source of fat and protein. The farms that supply these products are committed to improving the quality of their raw materials. A. Lopez *et al*. (2019) noted that the key indicator in this area is the fatty acid content. Comparing milk from cows and goats, the ratio of saturated and unsaturated fatty acids differs. According to S. Mitsiopoulou *et al*. (2021) and X. Tian *et al*. (2022), goat products are healthier because they contain a higher amount of polyunsaturated fatty acids, which ensure the endogenous synthesis of biologically active substances and prevent the accumulation of excess cholesterol in the body.

P. Monllor *et al*. (2020) developed an entire scheme of balanced diets with different composition of plant feeds for goats to improve the intake and synthesis of unsaturated fatty acids. In addition, various mixtures are added to the animals' diet in the form of compound feed, which includes corn, rapeseed, flax, sesame seeds, etc. The results of using this additional supplement changed the fatty acid composition of milk. A. Nudda *et al*. (2021) noted an increase in the content of unsaturated fatty acids, especially polyunsaturated ones, which further increases the oxidative stability of products. However, not all methods involving dietary changes improved the ratio of fatty acids; in most cases, the changes were insubstantial. When using diets enriched with unsaturated fatty acids, the researchers also noted the consequences.

One of the most common problems faced by researchers is the disruption of scar digestion in ruminants. The activity of the microflora in the stomach is highly dependent on the environment. Specifically, excessive intake of unsaturated fatty acids in the stomach can have negative consequences. Thus, rumen microorganisms are activated to provide biohydrogenation of linoleic acid to reduce unsaturated fatty acids and increase saturated fatty acid content. Such processes are explained by the fact that polyunsaturated fatty acids in excess can cause changes in the physical and chemical properties of bacterial cell membranes and provoke their destruction. According to A. Nudda *et al*. (2021), this not only reduces the number of microorganisms in the rumen, but also increases the content of saturated fatty acids.

Notably, the mechanisms of ensuring the homeostasis of lipid metabolism in goats have individual characteristics. As stated by J. Orzuna-Orzuna *et al*. (2023), many factors affect the transformation of lipids in tissues, which provides the necessary conditions for the synthesis and decomposition of the relevant substances. Goats are constantly exposed to a variety of factors that can stimulate or inhibit biochemical processes. A classic example of a mechanism for changing the steady course of any type of metabolism is the development of stress. This is the most common reason that every animal faces in its life, and depending on its individual characteristics, adaptation to it occurs in different ways. B. Paszczyk *et al*. (2020) note that the consequences of this process are differences in the absorption and use of the same lipids that have the highest energy value.

H. Tian *et al*. (2022) pointed out that lipid metabolism and the concentration of these substances in the blood are affected by diet, conditions of detention, the functional state of body systems, especially the digestive system, etc. This study discusses the role of the autonomic nervous system in these processes. As noted by Jr. Myers *et al*. (2022), the sympathetic and parasympathetic parts of the nervous system, through their coordinated influence on the body, correct metabolic processes. The sympathetic nervous system contributes to the body's adaptation to a stressful factor by increasing the activity of the cardiovascular system, enhancing the processes of nutrient breakdown, etc. The parasympathetic system has the opposite function – it slows down the activity of the cardiovascular system, activates digestion, and endogenous synthesis of substances important for the body. These systems work in concert to ensure that the body adapts to endogenous changes and changing environmental conditions. At the same time, each animal has specific individual features in terms of the functioning of adaptation mechanisms. This implies a significant regulatory role for the tone of the autonomic nervous system, which, depending on the predominance of the sympathetic and parasympathetic nervous system, can divide all animals into three groups: normotonics, sympathotonics, and vagotonics. According to

D. Goldstein (2020) and A. Lima *et al*. (2022), the specific features of the influence of the autonomic nervous system tone should be considered when analysing homeostasis indicators.

Materials and Methods

The material for the study was collected from goats of the Zaanenska breed based on a private dairy farm in the village of Kniahynynok, Lutsk district, Volyn region, in 2022-2023. For the study, animals of the same age were pre-selected, and a clinical examination was carried out to confirm the health status of 60 goats. The next stage was the formation of research groups from the selected livestock that met the criteria for the experiment.

Experimental groups of animals were formed by means of a variational pulse oximetry study according to the method of R.M. Baevsky *et al*. (2001). The goats were divided into three experimental groups of five each according to the tone of autonomic nervous regulation: sympathotonics, vagotonics, and normotonics. This division was based on an electrocardiological study considering the following indicators: mode (Mo), mode amplitude (AMo), variation range (Δx), autonomic rhythm index (ARI), autonomic balance index (ABI), and voltage index (VI) (Baevsky *et al*., 2001). According to the results of the variational pulse study, it was found that normotonics have a balanced influence of the sympathetic and parasympathetic nervous systems; vagotonics have a predominant influence of the parasympathetic nervous system; and sympathotonics have a predominant influence of the sympathetic nervous system. As a result, three experimental groups of animals were formed with different tones of the autonomic nervous system, reflecting the individual characteristics of their organism.

Blood was collected in the morning 4 hours after feeding from the jugular vein using a sterile heparin syringe at the rate of 3 drops of 1% heparin solution per 10 mL of blood. The samples were transported in a thermal container at +4°C. To obtain plasma, blood with anticoagulant was centrifuged at 2,000 rpm for 10 min. Lipid extraction from goat plasma was performed according to the method of J. Folch *et al*. (1957). Blood plasma was introduced into a flask with a lapped lid, then a mixture of methanol and chloroform was added to it in a ratio of 2:1 and to the test material in a ratio of 1:20. Subsequently, the flask was closed and the contents were shaken thoroughly, leaving them overnight for extraction. The next day, the mixture was filtered and 0.74% KCl was added to the filtrate in such a concentration that its content corresponded to one fifth of the total volume. Then it was settled overnight to separate the mixture into two phases. The lower phase was taken off and chloroform was extracted using an extractor, while the lipid residue was used for chromatographic analysis (Folch *et al*., 1957).

The chromatographic study was performed using a Trace GC Ultra chromatograph (USA) with a flame ionisation detector. Chromatography of the samples was performed at the following parameters: detector temperature +260°C, column temperature +140-240°C. A 1 µL sample was injected into the chromatograph using a TriPlus autosampler. The analysis time for one test sample was 65 min. A standard sample of Supelco 37 Component FAME Mix (USA) was used to identify the results of a chromatographic study to determine the fatty acid composition of plasma lipids in goats. The study was conducted in three parallel groups. The analysis of the chromatographic display of the components of the material under study was determined considering the following characteristics: peak retention time, peak base, peak area, peak height, peak width, and peak half-width. The chromatograph software automatically processes the results in the following steps: noise filtering, peak marking, qualitative

analysis with peak identification, and quantitative analysis of the area or height of the peaks. The results obtained during the distribution of the extracted lipids in the chromatograph column were compared with the standard for the identification of fatty acids in the sample.

Procedures for sampling biological material from goats for subsequent fatty acid analysis of plasma lipids were carried out following ARRIVE recommendations without violating the main provisions of EUs Directive 2010/63/EU "On the Protection of Animals Used for Scientific Purposes" (2010).

The statistical processing of the study results involved the use of Microsoft Excel with an assessment of the significance of the difference in assessment indicators according to Student's t-test and $P < 0.05$, $P < 0.01$, $P < 0.001$.

Results and Discussion

The statistical analysis of the chromatographic results revealed differences in the content of unsaturated fatty acids depending on the tone of autonomic nervous regulation (Table 1). The relative content of omega-3, omega-6, and omega-9 acids in goat plasma lipids was determined among the essential fatty acids. Animals with different tone of the autonomic nervous system – normotonics, vagotonics, and sympathotonics – differed in the relative content of unsaturated fatty acids compared to that of the experimental group (normotonics).

Table 1. Content of unsaturated fatty acids in plasma lipids in goats depending on the tone of autonomic nervous regulation (M ± m; n = 5, %)

Unsaturated fatty acid	Normotonics	Sympathotonics	Vagotonics
Myristoleic C14:1	0.18 ± 0.01	0.15 ± 0.01	0.23 ± 0.01**
Palmitoleic C16:1ω9	0.44 ± 0.03	0.34 ± 0.02*	0.51 ± 0.04
Oleic C18:1ω9	18.89 ± 0.14	18.02 ± 0.20**	18.46 ± 0.10*
Linoleic C18:2ω6	24.54 ± 0.51	24.65 ± 0.43	20.69 ± 0.19***
Linolenic C18:3ω3	1.04 ± 0.06	1.33 ± 0.05**	1.03 ± 0.05
Cis-11-eicosenoic, C20:1ω9	0.47 ± 0.01	0.51 ± 0.01*	0.53 ± 0.01**
Cis-8,11,14-eicosatrienoic C20:3ω6	0.07 ± 0.01	0.11 ± 0.01*	0.15 ± 0.01***
Arachidonic C20:4ω6	6.75 ± 0.14	7.75 ± 0.15***	5.58 ± 0.11***
Docosapentaenoic C22:5ω3	0.22 ± 0.01	0.34 ± 0.01***	0.24 ± 0.01
Cis-4,7,10,13,16,19-docosahexaenoic C22:6ω3	0.76 ± 0.05	0.94 ± 0.04*	0.64 ± 0.01*

Notes: **P < 0.05, **P < 0.01, ***P < 0.001 – relative to the data in the experimental group (normotonic)*
Source*: developed by the author of this study*

Analysing the relative content of unsaturated fatty acids in goat plasma lipids, it was found that the most significant total volume is made up of such acids as oleic, linoleic, linolenic, arachidonic, and cis-4, 7, 10, 13, 16, 19-docosahexaenoic. The highest content of omega-3 fatty acids was recorded in sympathotonics. Thus, in sympathotonics, the level of linolenic acid in the blood plasma is 1.3 times higher than in normotonic goats, which is 1.33 ± 0.05% ($P < 0.01$). Furthermore, the highest percentage of sympathotonics was observed for docosapentaenoic acid (1.6 times), which was 0.34 ± 0.01% ($P < 0.001$). The content of cis-4, 7, 10, 13, 16, 19-docosahexaenoic acid was 1.2 times higher in goats with sympathotonia 0.94 ± 0.04% ($P < 0.05$) compared to normotonics and 1.5 times higher in vagotonics 0.64 ± 0.01% ($P < 0.05$). Thus, animals with a predominance of sympathetic nervous system processes had the highest levels of unsaturated fatty acids belonging to the omega-3 fatty acid family (Fig. 1).

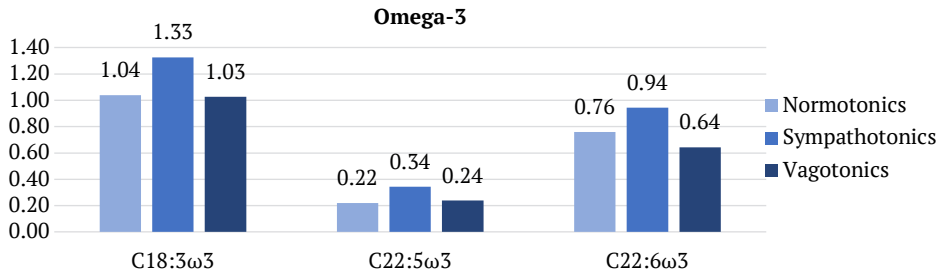

Figure 1. The content of omega-3 fatty acids (%) in blood plasma lipids in goats of experimental groups

***Sourse**: developed by the author of this study*

The high content of omega-3 fatty acids in sympathotonic goats with a predominance of sympathetic nervous system activity indicated a more pronounced intensity of metabolic processes in the body. This is explained by the functional characteristics of this part of the autonomic nervous system. The sympathetic nervous system stimulates the breakdown of nutrients to provide the body with the necessary energy, which is important for maintaining homeostasis. This was reflected in the increase in the content of omega-3 fatty acids in the blood plasma, which indicated an increase in the intensity of metabolism in the body of these animals. Furthermore, goats with a predominance of sympathetic nervous system activity have a more excitable nervous system. In confirmation of this, sympathotonic goats had a higher content of docosahexaenoic acid compared to animals in other experimental groups, which plays an essential role in ensuring the transmission of nerve impulses.

Considering the percentage of omega-6 fatty acids, it was found that the content of linoleic acid in the blood plasma of vagotonic goats was the lowest among all experimental groups ($P < 0.001$) and amounted to $20.69 \pm 0.19\%$. The level of arachidonic acid in the blood plasma of goats compared to animals of the normotonic group was 1.2 times higher in sympathotonics (7.75 ± 0.15, $P < 0.001$) and 1.2 times lower in vagotonics (5.58 ± 0.11, $P < 0.001$). Cis-8,11,14-eicosatrienoic acid had the highest percentage in goats with vagotonia by 2.1 times ($0.15 \pm 0.01\%$, $P < 0.001$) compared to normotonics. Indicators of unsaturated fatty acids in animals with a predominance of the parasympathetic nervous system, primarily omega-6 fatty acids in plasma lipids, were the lowest among other experimental groups (Fig. 2).

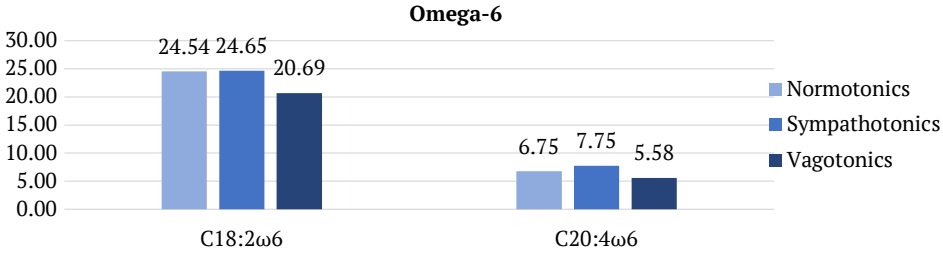

Figure 2. The content of linoleic and arachidonic acid in plasma lipids of goats of experimental groups, %

***Sourse**: developed by the author of this study*

Analysing the results on the content of omega-6 fatty acids, it was found that animals with a more pronounced activity of the parasympathetic nervous system had the lowest content of these acids in the blood plasma. Considering that this part of the autonomic nervous system is responsible for processes that are opposite to the sympathetic nervous system, the predominance of vagotonia has been found to play a significant role in shaping the level of essential fatty acids in the blood plasma. Furthermore, the relative content of linoleic acid in the blood plasma of animals with the predominance of the influence of the parasympathetic nervous system on the studied processes substantially decreased compared to that of goats in other experimental groups. This omega-6 fatty acid plays a significant role in the correction of cholesterol levels – the higher its concentration, the more actively this essential fatty acid is consumed. Since the parasympathetic nervous system affects digestion and endogenous synthesis of substances, a corresponding decrease in the content of linoleic acid, which is actively involved in them, was observed.

As for omega-9 fatty acids, cis-11-eicosenoic acid had 1.1 times higher percentage in sympathotonics (0.51 ± 0.01%) ($P < 0.05$) and 1.1 times higher percentage in vagotonics (0.53 ± 0.01%) ($P < 0.01$) compared to the experimental group of normotonics. Palmitoleic acid was the lowest in goats with a predominance of the sympathetic nervous system of 0.34 ± 0.02% ($P < 0.05$) (Fig. 3). Oleic acid, as the representative with the highest percentage concentration in the body of goats among omega-9 fatty acids, had 1.1 times lower relative content in sympathotonics (18.02 ± 0.20%, $P < 0.01$) and 0.46% lower in vagotonics (18.46 ± 0.10%, $P < 0.05$) compared to normotonics (Fig. 4).

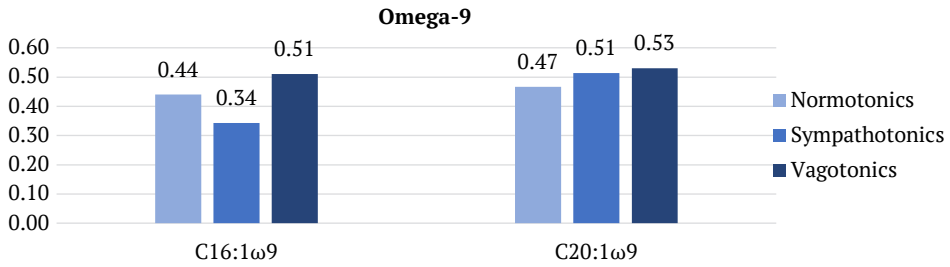

Figure 3. Content of palmitoleic and cis-9 eicosenoic acid in plasma lipids of goats of experimental groups, %

***Sourse**: developed by the author of this study*

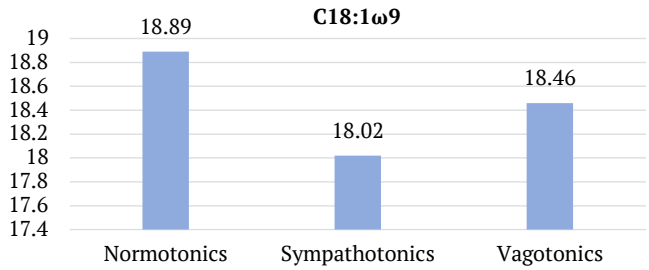

Figure 4. Oleic acid content in blood plasma lipids of goats of experimental groups, %

***Sourse**: developed by the author of this study*

The content of omega-9 fatty acids in the blood plasma of sympathotonic goats was the lowest. The obtained values reflect the specific feature of the intensity of metabolic processes in these animals. Considering the impact of omega-9 fatty acids, especially oleic acid, on immunity, regeneration, and inflammation, their metabolic activity should also be accommodated. Therefore, animals with a predominance of sympathetic nervous system activity showed a more pronounced intensity of metabolism. As a result, omega-9 fatty acids are used more efficiently by the goat's body, as indicated by the findings of this study.

It is important to note the significant role of omega-3, omega-6, and omega-9 fatty acids in the body. All products obtained from the farm are used in human nutrition, both in primary and secondary form. It is an integral component of every consumer's diet, which can be implemented in various variations. Emphasis is placed on the consumption of essential fatty acids. The reason is that they cannot be endogenously synthesised in mammals. This is because they are not synthesised in the mammalian body, but come from food, mainly plant foods. The concentration of unsaturated fatty acids in the mammalian body within certain limits is crucial. These acids play a leading role in stabilising lipid metabolism. Comparing the same saturated and unsaturated fatty acids, their ratio should always be in favour of essential fatty acids. One of the first reasons is their effect on blood cholesterol levels. Due to a sufficient concentration of unsaturated fatty acids in blood plasma lipids, they are quite effective in improving the process of removing excess fat from the body. Essential fatty acids stimulate the formation of high-density lipoprotein, which transports excess cholesterol from the tissues into the bloodstream to the liver, where it is converted to bile acids and excreted in bile into the duodenum. It is also important to highlight certain groups of unsaturated fatty acids that can substantially affect the homeostasis of lipid metabolism in mammals. These include such fatty acids as omega-3, omega-6, and omega-9 fatty acids (Czyż *et al.*, 2020; Giger-Reverdin *et al.*, 2020; Coniglio *et al.*, 2022).

According to A. Moustafa (2021), among the omega-6 fatty acids with the highest concentration is linoleic acid, which is involved in the regulation of many processes. Normal intake of this fatty acid improves the structural integrity of the skin, which also ensures its barrier function. These features are explained by the fact that this omega-6 fatty acid is part of the composition of ceramics. Linoleic acid is involved in the correction of cholesterol content in the body. It enhances the transcription of the hepatic receptor X alpha, which promotes the activation of the peroxisome proliferator. As a result, the expression of the cholesterol 7α-hydroxylase gene, which is responsible for encoding enzymes whose main role is its conversion into bile acids, increases. As a result of the process of lipid conversion in the liver, the synthesis of high-density lipoprotein increases. This also engages proteins involved in the binding of sterol regulatory elements, which are transcription factors and play a major role in the regulation of cholesterol levels. The elements responsible for sterols activate the transcription of genes that encode the synthesis of high-density lipoprotein, cholesterol, fatty acids, and triacylglycerols. This ensures the process of lipid metabolism in the body. According to R.D. Taylor & E.H. Clayton *et al.* (2021), arachidonic acid plays a significant role in the inflammatory process. This omega-6 fatty acid makes up 25% of the fatty acids that make up the phospholipids of skeletal muscle, brain, liver, platelets, and immune cells. The deacylation and reactivation process maintains low levels of free arachidonic acid in the cell membranes, which helps prevent oxidation. The interaction

of this fatty acid with oxygen through cyclooxygenase, lipoxygenase, and cytochrome P450 pathways gives rise to the formation of mediators, commonly called eicosanoids (prostaglandins, thromboxanes, and leukotrienes). Considering this, arachidonic acid plays a major role in inflammation processes as their mediator and regulator. When omega-6 fatty acids are used as feed additives, researchers have noted their stimulating effect on metabolic processes, the functioning of the antioxidant system, and the reproductive function of the body. According to the findings of this study, goats with lower levels of omega-6 fatty acids in their blood plasma showed fewer functional features compared to animals in other groups.

J. Shunthwal *et al*. (2023) note that omega-3 fatty acids correct the course of important processes that ensure the full functioning of the animal body. Docosahexaenoic acid performs many functions, such as regulation of active transport of amino acids (choline, glycine, taurine) across cell membranes; regulation of sodium channel function and implementation of the rhodopsin response to visual stimuli. This fatty acid is the most abundant component in the central nervous system and retina. This is explained by the fact that docosahexaenoic acid supports such processes as neurotransmission, neuroplasticity, and nerve impulse transmission. This fatty acid also increases the concentration of serotonin and acetylcholine in nervous tissue and is a precursor of neuroprotectin D1. Docosahexaenoic acid has anti-inflammatory effect. It primarily affects the formation of eicosanoids. This feature is provided by the effect on the release of arachidonic acid from cell membranes, inhibition of enzymes and competition with omega-6 fatty acids for participation in enzyme-dependent metabolic processes. The feed additives described by the authors were effective in improving the balance of fatty acids. However, changes in their concentration were not considered in the analysis of the overall course of lipid metabolism. Therewith, the findings obtained suggest that to clarify the specific features of metabolic processes, the factor of influence of the autonomic nervous system should be considered, especially in relation to the use of feed additives.

A.K. Verma *et al*. (2023) indicate that omega-9 fatty acids, specifically oleic acid, are involved in the regulation of immunity, inflammation, and tissue regeneration. For instance, when there is an injury to the skin structure, the processes of inflammation are activated. For the normal course of these stages, a large number of mediators, such as nitric oxide, is required, which is essential for rapid wound healing. This is explained by the fact that it ensures the functioning of fibroblasts, macrophages, and keratonocytes during the regenerative process. A sufficient concentration of oleic acid provides an effective anti-inflammatory effect, which occurs as a result of an increase in the supply of neutrophils to the affected tissue area, and the mediator neutrophilamine is also produced, which accelerates wound healing. The authors noted the pronounced effectiveness of using oil blends enriched with essential fatty acids. Nevertheless, slight differences in the findings obtained are noteworthy, which may be primarily due to the individual characteristics of the animals. It is quite difficult to successfully classify animals according to the criteria of the respective groups. Therefore, such studies should consider the factor of autonomic nervous system tone, which causes substantial differences in the content of omega-9 fatty acids in the blood plasma of goats.

Considering the enormous benefits of essential fatty acids, which are classified as unsaturated fatty acids, it is important to ensure that dairy products are better supplied with these substances. Such useful compounds will enrich the raw materials obtained from goat

breeding. Every day, many scientists provide increasingly more evidence of the value of these fatty acids. Due to this, people are beginning to enrich their diets with unsaturated fatty acids to prevent problems with the cardiovascular system, improve lipid metabolism in the body, etc. As a result, consumers are becoming more focused in their choice of dairy products and are forcing farmers to adjust the composition of milk and secondary raw materials. As a result of this rapid pace of development and growing demand, scientists are increasingly interested in investigating the issues that arise on goat farms. J.F. Orzuna-Orzuna *et al*. (2023) point out that one of the main challenges facing scientists is to improve animal productivity and the quality of raw materials obtained in production, while reducing the costs of solving this problem. In their research, they provide examples of the successful use of feed additives in this regard. However, according to the findings of the presented study, in conducting such studies, when forming experimental groups of animals, it is necessary to consider the individual properties of the autonomic nervous system tone, which will substantially improve the analysis and calculation of the results obtained.

R. Zhang *et al*. (2022) note that the most popular opinion among the majority is the issue of dietary adjustment. The researchers pointed out a wide range of different food additives in the form of mixed fodder from different cereals, even the addition of seaweed to the goats' diet. When analysing the researchers' recommendations on the use of feed additives to maintain the required level of essential fatty acids in animals, attention should be drawn to the significance of considering the individual characteristics of lipid metabolism depending on the tone of the autonomic nervous system.

Analysing the results of introducing an excess of essential fatty acids into the diet of goats, in most cases there was an increase in their concentration in the body and subsequently in milk. Most often, polyunsaturated fatty acids are added to the diet of these animals. There are two schemes for enriching goats with unsaturated fatty acids. According to the findings of E. Amr *et al*. (2023), the first is to increase their content in the feed, while the second is to control biohydrogenation processes in the rumen with the subsequent accumulation of polyunsaturated fatty acids. Each of the areas has an interesting foundation for achieving the desired result. It should also be borne in mind that, despite all the positive aspects of unsaturated fatty acids, there are many undesirable consequences. The simplest problem cited by M. Afshar *et al*. (2022) lies in the deterioration of the productive state of microorganisms in the rumen. This can cause further dysfunction of the digestive system. Therefore, the use of different feed additives is not always an effective solution. The data obtained by N. Ghavipanje *et al*. (2022), R. Zhang *et al*. (2022) suggested a slight increase in unsaturated fatty acids or even no clear change. This was mainly explained by the inclusion of a small number of fatty acids in the diet to prevent their negative effects.

Considering the studies of researchers aimed at implementing the idea of increasing the content of unsaturated fatty acids in feed, the question arises as to why the body's reaction to the consumption of excess of these substances is not observed. Insufficient attention is paid to the mechanism of maintaining lipid homeostasis in the body of goats, its provision and correction. The autonomic nervous system is a good example of this, and its role as a component of a well-coordinated homeostasis regulation system reflects metabolic processes quite well. J. Imai & H. Katagiri (2022) described in detail the mechanisms of metabolic homeostasis adjustment involving the sympathetic and parasympathetic nervous systems,

especially in the correction of lipid metabolism. They gave an example of the coordinated work of these parts of the autonomic nervous system. Thus, the sympathetic nervous system not only accelerates the breakdown of nutrients in the body, but also constantly adjusts the stability of the necessary energy compounds, including glucose and lipids, to ensure the nutrition of the brain, muscles, and other tissues. In turn, the parasympathetic nervous system ensures the processes of glycogen synthesis and accumulation and the formation of adipose tissue. There was an increase in oxidative processes in animals with a predominance of the activity of the sympathetic nervous system, which contributed to an increase in the content of fatty acids in the blood due to lipid breakdown in the muscles. J. Zhang *et al*. (2023) conducted a study to determine the effect of the autonomic nervous system on the fatty acid composition of muscles in sheep. Specifically, an increase in the content of unsaturated fatty acids, especially linoleic and oleic acids, was found in animals with a predominance of sympathetic nervous system activity. This difference was explained by the fact that due to the greater activity of sympathotonia, oxidation processes in the body are accelerated, and as a result, a large number of free radicals accumulate in the blood.

According to the findings described in this study, there is a considerable difference in the content of unsaturated fatty acids in goat plasma lipids depending on the tone of the autonomic nervous system. Omega-3 fatty acids in sympathotonics have the highest concentration compared to other experimental groups of animals. Omega-6 fatty acids were characterised by low levels in vagotonics and elevated levels in goats with a predominance of sympathetic nervous system activity. Omega-9 fatty acids differed in their percentage content, but sympathotonics showed a lower concentration in plasma lipids compared to vagotonics and normotonics. Comparing the findings obtained with the data of other researchers, J. Zhang *et al*. (2023) noted a comparable trend towards an increase in the concentration of unsaturated fatty acids in animals with a predominance of sympathetic nervous system activity. With this in mind, it is worth noting that in goats with a predominance of sympathetic nervous system activity, a considerable increase in the content of unsaturated fatty acids is observed. This feature is characterised by the increased activity of metabolic processes in the body of these animals. The sympathetic nervous system mainly regulates the breakdown of nutrients, which leads to an increase in the content of unsaturated fatty acids in blood plasma lipids. Accordingly, high levels of omega-3 and omega-6 fatty acids were noted compared to other experimental groups of animals. Goat vagotonics, which have the advantage of the influence of the parasympathetic nervous system, were characterised by lower levels of unsaturated fatty acids in plasma lipids. Animals with active vagotonia processes have an advantage in the reactions of increasing the synthesis of nutrients and their subsequent storage in reserve.

Considering the above, adjusting the fatty acid content is the key to understanding lipid metabolism, which makes it possible to counteract the growth of excess fat and maximise its positive role. When investigating a topical issue, one should consider the key mechanisms that affect the course of the synthesis and breakdown of nutrients to obtain reliable results. Such a factor as the autonomic nervous system demonstrates the distribution of animals according to the criterion of metabolic processes. This suggests the need to consider it when assessing lipid metabolism in goats. Since a clear division of animals depending on the tone of the autonomic nervous system has been established in the analysis of the content of

unsaturated fatty acids in blood plasma lipids, gradations of indicators are observed between vagotonics, sympathotonics, and normotonics.

Conclusions

It was found that the tone of the autonomic nervous system has a substantial effect on the content of unsaturated fatty acids in goat plasma lipids. This is evidenced by the high relative content of linolenic acid, cis-11-eicosanoic acid, cis-8, 11, 14-eicosatrienoic acid, arachidonic acid, docosapentaenoic acid, cis-4, 7, 10, 13, 16, 19-docosahexaenoic acid and low concentration of palmitoleic acid, oleic acid in animals with predominance of sympathetic nervous system activity compared to normotonics and vagotonics. Therewith, animals characterised by the predominance of the parasympathetic nervous system influence had a higher content of myristoleic acid, cis-11-eicosenoic acid, cis-8, 11, 14-eicosatrienoic acid and lower values of linoleic, arachidonic and cis-4, 7, 10, 13, 16, 19-docosahexaenoic acids in blood plasma lipids compared to other experimental groups of animals.

The autonomic nervous system plays a major role in regulating homeostasis in mammals. Considering this feature, it is possible to predict the course of lipid metabolism with their additional introduction into the body of goats. For instance, if an animal has a predominance of the sympathetic nervous system over the parasympathetic nervous system, this will result in a more active breakdown of nutrients. And if one takes goats with a predominance of the parasympathetic nervous system over the sympathetic nervous system, an increase will be observed in the synthesis of metabolic products and their storage in the body's reserves. Analysing the findings of this study, a number of features of lipid metabolism in goats depending on the tone of the autonomic nervous system should be noted, which is vital to consider when adjusting the fatty acid composition of blood plasma lipids, specifically, the content of unsaturated fatty acids, in this species of animals. Consideration of individual animal characteristics should also be used in the study of homeostasis, which is crucial when assessing the nutritional and biological value of feeds in the diet for dairy goats. It is promising to investigate the effect of fatty acid supplements on the body of goats with different tone of the autonomic nervous system.

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Conflict of Interest

None.

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Вплив тонусу автономної нервової системи на вміст ненасичених жирних кислот у складі ліпідів крові в кіз

Божена Кролічевська

Кандидат технічних наук, доцент
Вроцлавський університет природничих наук
50375, вул. Ц.К. Норвіда, 31, м. Вроцлав, Польща
https://orcid.org/0000-0002-0291-3562

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

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

Андрій Грищук

Кандидат ветеринарних наук, доцент
Луганський національний університет імені Тараса Шевченка
36003, вул. Коваля, 3, м. Полтава, Україна
https://orcid.org/0000-0002-4608-337X

Анотація. Актуальність дослідження полягає у необхідності визначення ролі автономної нервової системи в обміні ненасичених жирних кислот, насамперед, незамінних, в

організмі кіз, що поліпшить розуміння індивідуальних особливостей метаболізму в цих тварин. Використання встановлених маркерних показників крові надасть можливість здійснювати аналіз стану обміну ліпідів в організмі кіз та забезпечить підвищення ефективності методів його корекції. Метою роботи було визначення особливостей впливу автономної нервової системи на відносний вміст ненасичених жирних кислот у ліпідах плазми крові кіз. В експеримент залучали кіз породи Заненська, з яких завдяки використанню електрокардіографічного аналізу за методикою Баєвського та залежно від тонусу автономної нервової системи формували три дослідні групи: нормотоніки, симпатотоніки, ваготоніки. Для визначення відсоткового вмісту ненасичених жирних кислот у ліпідах плазми крові кіз використовували метод газорідинної хроматографії. Так, у кіз симпатикотоніків, які мають перевагу активності симпатичної нервової системи, відмічали високий відсотковий вміст у ліпідах плазми крові: ліноленової ($P < 0,01$), цис-4, 7, 10, 13, 16, 19-докозагексаєнової ($P < 0,05$), докозапентаєнової ($P < 0,001$) і арахідонової кислот ($P < 0,001$) порівняно з нормотоніками. У цих тварин також зафіксовано менший вміст у складі ліпідів плазми крові пальмітоолеїнової ($P < 0,05$) і олеїнової кислот ($P < 0,01$) на тлі нормотоніків. У кіз ваготоніків, в яких переважає вплив парасимпатичної нервової системи, у ліпідах плазми крові встановлено низький відносний вміст: цис-4, 7, 10, 13, 16, 19-докозагексаєнової ($P < 0,05$), лінолевої ($P < 0,001$) і арахідонової кислот ($P < 0,001$) та високий – цис-11-ейкозенової кислоти ($P < 0,01$) порівняно з нормотоніками. Встановлені особливості свідчать про істотний вплив тонусу автономної нервової системи на кількісний перерозподіл ненасичених жирних кислот у складі ліпідів плазми крові кіз та необхідність їх врахування при аналізі стану відповідного обміну в організмі, що істотно покращить не лише результативність наукових досліджень, а й їх достовірність

Ключові слова: симпатотонія; ваготонія; нормотонія; газорідинна хроматографія; плазма