CHAPTER 9

Essential oils in pig diet as a means of improving pork quality

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Abstract

The conducted study of the influence of the feed additive "Activo" on the physico-chemical properties and fatty acid composition of the liver and meat of pigs allowed to detect significant changes in lipid metabolism, which contributes to the improvement of the quality characteristics of the meat. In the meat of pigs of the experimental group, a significantly lower content of peroxide oxidation products was found. Analysis of the fatty acid composition of the liver of pigs proved that the use of the feed additive contributed to a change in the profile of saturated, monounsaturated and polyunsaturated fatty acids. In the meat of pigs of the experimental group, a decrease in the level of stearic and pentadecanoic acids was found, while an increase in the level of monounsaturated fatty acids, in particular oleic acid, was recorded, which contributes to positive changes in the organoleptic characteristics of the meat.

The results obtained allow to conclude that the addition of the feed additive "Activo" affects lipid metabolism in pigs, changing the balance of fatty acids in the liver and muscles, and also contributes to the inhibition of oxidative damage to the lipid component of meat. The detected changes positively affect the quality of meat, in particular its antioxidant status, heat resistance and organoleptic properties.

Keywords

Pork, feed additive, fatty acid composition, essential fatty acids, ω-3 and ω-6 fatty acids, oxidative spoilage, organoleptic properties.

9.1 Introduction

Modern husbandry is in the process of active transformation, aimed at finding safe and effective alternatives to antibiotics. The traditional use of feed antibiotics

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for pigs ensured high productivity, but at the same time it accumulates of excess substances in animal products and increased antibiotic resistance of microorganisms [1]. The development of natural additives that can replace antibiotics without negative consequences for the health of animals and people is becoming one of the priorities for the modern feed industry.

One of the promising alternatives is the use of ethereal oils, which have a wide range of biological effects, including anti-inflammatory, antioxidant and antimicrobial activity [2–4]. Essential oils contain natural terpenoid compounds, which have a positive effect on physiological processes in the human body. They are obtained by steam distillation or extraction by distillers and are used as biologically active components for to improve feed absorption, stimulating digestion and maintaining an optimal balance of intestinal microflora [5, 6]. Recent studies have shown that essential oils can modulate lipid metabolism by influencing the synthesis and oxidation of fatty acids in the liver and muscle. This, in turn, is reflected in the fatty acid profile of meat, improving its quality and sensory characteristics [7]. The influence of essential oils on lipid metabolism is an important aspect for the production of meat products with improved fatty acid composition, which meets the growing consumer demands for healthy and safe nutrition [8].

In addition, essential oils can affect the structural features of muscle tissue, muscle fiber types, and collagen structures that determine the tenderness and texture of meat [9, 10]. Skeletal muscle tissue contains fibers of different types, classified by metabolic activity and contractile properties. It is the ratio of muscle fiber types and their morphological characteristics that affect the final meat quality indicators, including tenderness, juiciness, and water-holding capacity [11]. Research of the mechanisms of the influence of essential oils on muscle morphology is an important direction of modern science, contributing to increasing the efficiency of meat production.

One of such effective feed additives is "Activo", a combination of biologically active compounds obtained from aromatic herbs and spices. It includes essential oils of cinnamon, rosemary, oregano, and chili pepper extract. According to numerous studies, these components have pronounced antioxidant, anti-inflammatory, hepatoprotective properties, stimulate the activity of digestive enzymes, improve feed conversion, and also have a bactericidal effect, inhibiting the development of pathogenic microflora. The positive effect of a feed additive containing biologically active essential oils and extracts on the processes of synthesis of structural lipids, and especially the synthesis of phospholipids in the muscle tissue of pigs has been proven [12]. Studies by S. Huang et al. [13] have proven that the addition of 200 mg/kg of essential oils to the diet of pigs significantly increases the average daily body weight gain and improves nutrient absorption. An increase in antioxidant activity in the muscles and liver was also noted, which was manifested in a decrease in the level of the lipid oxidation marker malondialdehyde. Studies by S. Chen et al. [14] demonstrated that dietary supplementation with oregano essential oil (OEO) and benzoic acid (BA) improved the stability of fatty acids in muscle tissue and reduced moisture loss in meat. A decrease in linoleic acid and an increase in oleic acid were observed, which positively affected the organoleptic properties of meat.

According to the results of the studies by K. Czyż et al. [15], essential oils are able to change the fatty acid profile in the skeletal muscles of pigs, reduce the proportion of saturated fatty acids (SFA) and increase the content of polyunsaturated fatty acids, in particular omega-3. This aspect is of great importance for consumers, since meat with an increased content of omega-3 fatty acids has improved nutritional properties and contributes to human health. Studies by A. B. Smith et al. [16] also confirm that the use of essential oils in pig feeding promotes the activation of genes responsible for lipid metabolism, such as LPL (lipoprotein lipase), CD36 (fatty acid transporter) and CPT-1 (carnitine palmitoyltransferase-1), which indicates the stimulation of the processes of β-oxidation of fatty acids.

However, the published results of the research by M. V. Valero et al. [17] reported that the addition of essential oils does not have a significant effect on the overall composition of fatty acids in meat. Thus, when propolis and essential oils were added to the diet of fattening bulls, no significant changes in the composition of fatty acids in the long chest muscle were recorded. At the same time, according to V. Vasta and R. Bessa [18], some essential oils can modulate the processes of rumen biohydrogenation and affect the composition of fatty acids in the muscles, although the mechanism of this effect requires further research.

Under the influence of the feed additive "Activo", there was a significant decrease in the content of unesterified cholesterol in the latissimus dorsi muscle ($p \leq 0.001$) and an increase in the content of phospholipids ($p \leq 0.001$) [18]. The effect of the feed additive "Activo" on the content of lipid peroxidation products and the activity of antioxidant enzymes in sows and piglets obtained from them was also studied. It was found that the use of the feed additive "Activo" for sows and piglets obtained from them helps to reduce the negative impact of oxidative stress, which negatively affects both sows and their offspring. This led to an improvement in slaughter yield by 6.59% in the experimental group [12]. Feeding rearing pigs of "Activo" has no probable effect on the change of physico-chemical indicators of meat quality. However, the actual figures have some differences in individual indicators within the statistical deviations. Laboratory studies of the Longissimus dorsi muscle showed that there was no significant difference between trial and control groups in water holding capacity of muscle tissue. Also, there is no significant difference in terms of meat marbling and color intensity.

Thus, the previously published results confirm the effectiveness of the feed additive "Activo" for improving the general condition of animals, increasing the digestibility of nutrients and improving the quality characteristics of meat. The effect of essential oils on antioxidant status and lipid metabolism is an important factor in reducing the level of oxidative processes, which contributes to extending the shelf life of meat products. However, further studies are needed to more fully determine the mechanisms of action of essential oils, including the analysis of their effects on morphological changes in muscle tissue and the dynamics of biochemical processes in the liver and skeletal muscles of pigs [19].

The aim of this work was to determine the effect of the phytogenic feed additive "Activo" on the fatty acid composition of the liver and muscle tissue of pigs. The results obtained will allow to draw a conclusion about the feasibility of using essential oils as a functional component of feed to increase animal productivity and improve the quality characteristics of meat.

9.2 Schemes and methods of research

The study was conducted at a pig farm located in the Odesa region. The experiment used piglets of the same age with an average body weight of 70 kg, which were divided into two groups according to the principle of analogues: control and experimental, 43 animals in each group. The pigs were kept in standard conditions within the same premises with the same microclimate parameters and technological regime. Feeding was carried out with standard compound feed (CF), balanced in terms of essential nutrients, vitamins and trace elements. The composition of the compound feed included: wheat, barley, corn, soybean meal, full-fat soybean, sunflower meal, NutriMix 70–115 kg premix (3.0%), recipe: 380673222001-C5 Nutrimin Finish 70–115 kg.

After a preparatory period lasting one month, the phytogenic feed additive "Activo" was introduced into the diet of the pigs of the experimental group in the amount of 0.1 kg/t of compound feed. The duration of the experiment was 40 days.

Phytogenic supplement "Activo" contains a combination of biologically active substances of plant origin that affect the metabolic processes of the pig's body. The components of the supplement include: cinnamon essential oil, which stimulates taste and olfactory receptors, has anti-inflammatory properties, reduces stress levels and exhibits antioxidant activity; rosemary essential oil, which acts as a natural antioxidant and anti-inflammatory agent, regulates the body's thermoregulation, reduces oxidative stress and pain during inflammatory processes; chili pepper extract, which helps increase appetite, stimulates salivation, activates the secretion of gastric juices and enzymatic activity, which has a positive effect on the absorption of nutrients and increases feed conversion; oregano essential oil, which has a pronounced bactericidal activity, inhibits the development of gram-positive and gram-negative bacteria, as well as viruses and fungal microorganisms. This component has a positive effect on the functioning of the digestive system and the antioxidant status of the body.

At the end of the study animals of both groups were control-slaughtered and samples of liver, longissimus dorsi and latissimus dorsi muscles were taken for laboratory studies. The study is fully complied with the ethical requirements for the use of animals in experimental research (Strasbourg, 1986; Kyiv, 2002), and the research methodology was approved by the Bioethics Committee of the Institute of Animal Biology of the National Academy of Agricultural Sciences of Ukraine (Protocol No. 93-01 from 03.06.2021).

The determination of the fatty acid composition of lipids was performed by gas chromatography [20] on an Agilent Technologies 7890A gas chromatograph using a ZB-FAME capillary column (length 60 m, internal diameter 0.25 mm, phase thickness 0.20 μm; carrier gas: helium; carrier gas flow rate: 1.2 ml/min; detector temperature (DTC): 280°C; injector temperature: 250°C). The Student's *t*-test and Microsoft Excel software was used for the statistical calculation of digital data.

9.3 Results and discussion

9.3.1 Analysis of the fatty acid composition of the liver of pigs

Analysis of the fatty acid composition of the liver of pigs fed the feed additive "Activo" demonstrates significant changes in the profile of saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids compared to the control group (**Table 9.1**).

In the experimental group receiving the feed additive, a decrease in the concentration of some SFA was recorded. In particular, the content of lauric acid in the liver of pigs in the experimental group decreased by 1.60 times ($p < 0.05$) compared to this indicator in animals in the control group, and the content of pentadecanoic acid decreased by 1.45 times ($p < 0.001$), respectively. At the same time, there was an increase in the level of palmitic acid, its share increased by 17.9% ($p < 0.01$), which indicates a possible effect of the additive on the processes of lipogenesis in the liver.

Table 9.1 Fatty acid composition of the liver fed with the additive "Activo" ($M \pm m$, $n = 5$)

Fatty acid	Code	Groups	
		Control	Experiment
Lauric	12:0	0.08 ± 0.009	0.05 ± 0.003*
Myristic	14:0	0.22 ± 0.017	0.292 ± 0.023*
Pentadecanoic	15:0	0.24 ± 0.005	0.166 ± 0.009***
Palmitic	16:0	13.34 ± 0.226	15.728 ± 0.611**
Palmitoleic	16:1	0.30 ± 0.004	0.596 ± 0.049***
Margarine	17:0	2.160 ± 0.027	1.382 ± 0.103***
Heptadecenoic	17:1	0.244 ± 0.022	0.270 ± 0.031
Stearic	18:0	30.188 ± 0.289	27.002 ± 1.223*
Oleic	t 18:1	0.512 ± 0.009	0.374 ± 0.036**
	c9 18:1	8.190 ± 0.118	13.124 ± 0.525***
	c11 18:1	1.238 ± 0.014	1.328 ± 0.039
Linoleic	c, t 18:2	0.220 ± 0.004	0.186 ± 0.014
	18:2 ωn6	15.798 ± 0.091	16.640 ± 2.269
	c9 t11 18:2	–	0.065 ± 0.015
Linolenic	18:3 ω 6	0.102 ± 0.002	0.03 ± 0.015**
	18:3 ω 3	0.47 ± 0.005	0.32 ± 0.018***
Arachidic	20:0	0.227 ± 0.007	0.118 ± 0.018**
Eicosenoic	c11 20:1	0.180 ± 0.010	0.212 ± 0.008*
	c9 20:1	–	0.044 ± 0.005***
Eicosadienoic	c11 20:2	0.546 ± 0.015	0.424 ± 0.026**
Eicosatrienoic	20:3 ω 6	0.956 ± 0.012	1.040 ± 0.089
Arachidonic	20:4 ω 6	18.524 ± 0.434	16.046 ± 0.726*
Behenic	22:0	0.310 ± 0.008	–
Erucose	c9 22:1	0.147 ± 0.014	–
	c11 22:1	–	0.063 ± 0.017*
Eicosapentaenoic	20:5 ω 3	0.830 ± 0.021	0.634 ± 0.072*
Lignoceric	24:0	0.602 ± 0.035	0.175 ± 0.006***
Nervonic	24:1 ω 9	0.380 ± 0.019	0.165 ± 0.018***
Docosapentaenoic	22:5 ω 3	3.164 ± 0.117	2.942 ± 0.189
Docosahexaenoic	22:6 ω 3	1.144 ± 0.074	0.70 ± 0.077**
Saturated (SFA)		47.062 ± 0.500	44.878 ± 1.594
Monounsaturated (MUFA)		11.162 ± 0.129	16.524 ± 0.426***
Polyunsaturated (PUFA)		41.776 ± 0.607	38.598 ± 1.446

*Note: here and below, the difference is significant relative to the control group: * – $p \leq 0.05$; ** – $p \leq 0.01$; *** – $p \leq 0.001$*

At the same time, a decrease in the level of stearic acid in the experimental group compared to the control group by 10.6% ($p < 0.05$) was detected, which may indicate an intensification of β-oxidation or a change in the metabolic pathways of the transformation of saturated fatty acids in the liver under the influence of essential oils contained in the studied feed additive.

In the experimental group, a significant increase in the content of monounsaturated fatty acids was observed. Thus, the level of palmitoleic acid increased almost twice ($p < 0.001$), which may indicate the active involvement of this fatty acid in energy metabolism and the formation of the lipid profile of the liver. In the liver of the experimental group, a significant increase (by 60.2%, $p < 0.001$) in the content of oleic acid was also recorded. This confirms previously obtained data on the effect of phytogenic supplements on increasing the level of MUFA, which can positively affect the quality of meat, in particular its tenderness and taste.

The presence of eicosenoic acid was found only in the liver of pigs in the experimental group, in the control group this acid was absent altogether. Such an increase in MUFA may indicate an increase in the mobilization processes of long-chain MUFA in the liver under the influence of essential oils.

The total proportion of MUFA in the liver of animals in the experimental group was 48.0% ($p < 0.001$) higher compared to the corresponding indicator in the control, which indicates a significant effect of the feed additive on lipid metabolism.

In the experimental group, a decrease in the level of some polyunsaturated fatty acids was observed, which may be due to their active use in metabolic processes or increased oxidation. For example, the level of linolenic acid (18:3 ω3) decreased by 31.9% ($p < 0.001$), and docosahexaenoic acid – by 1.63 times ($p < 0.01$).

The decrease in the proportion of ω-3 PUFAs can be explained by their increased incorporation into biological membranes and use in antioxidant protection processes, since the essential oils included in the feed additive have pronounced antioxidant properties. The level of arachidonic acid in the experimental group also decreased by 13.4% ($p < 0.05$), which may probably indicate a decrease in inflammatory processes, since this acid is a precursor of pro-inflammatory eicosanoids.

However, changes in the total content of PUFA in animals of the experimental group did not acquire a statistically significant difference ($p > 0.05$) compared to the control. The obtained data indicate a significant effect of the phytogenic feed additive "Activo" on the fatty acid composition of the liver of pigs.

Therefore, the most significant changes occurred in the content of MUFA, in particular, the level of oleic and palmitoleic acids increased, which may be a positive factor for the quality of meat. At the same time, a decrease in the concentration of individual PUFAs, such as docosahexaenoic and linolenic acids, may be a consequence of their active involvement in oxidation.

The results obtained are consistent with the data of previous studies [13, 14], where it was also shown that essential oils can modulate the fatty acid composition of the liver and improve its antioxidant status.

9.3.2 Analysis of the fatty acid composition of pig tenderloin

Analysis of the fatty acid composition of pig tenderloin fed with the feed additive "Activo" showed significant changes in the content of saturated, monounsaturated and polyunsaturated fatty acids compared to the control group (**Table 9.2**).

In the experimental group, compared to the control group, a tendency to a decrease in the total level of saturated fatty acids was recorded. Using the example of individual SFA, a common dynamic is observed, characterized by a decrease in the content of these acids in the muscles of the experimental group. In particular, the level of pentadecanoic acid decreased by 1.87 times ($p < 0.001$) compared to the control group, margarine acid – by 1.82 times ($p < 0.001$), and stearic acid – by 14.4% ($p < 0.01$).

The decrease in the level of these fatty acids may be associated with the activation of β-oxidation processes in the skeletal muscles of animals receiving the phytogenic feed additive. At the same time, no significant changes in the content of the main SFA – palmitic acid – were recorded. Its level remained practically did not differ in the control and experimental groups, which indicates the stability of lipogenesis processes in muscle tissues regardless of the studied feeding factors.

The increase in the level of monounsaturated fatty acids in the muscles of pigs of the experimental group by 14.7% ($p > 0.05$) compared to the control group indicates an intensification of metabolic processes associated with the formation of MUFA. In particular, the level of palmitoleic acid increased by 23.5% ($p < 0.05$), which indicates an increase in its synthesis in response to feeding the feed additive. A significant increase was also found for oleic acid, the content of which increased by 16.3% ($p < 0.05$) compared to the control group, which is an indicator of an improvement in the fatty acid profile of muscle tissue, since oleic acid is associated with improved taste characteristics of meat. At the same time, an increase in the level of oleic acid isomers was also recorded: by 15.8% ($p < 0.01$) in animals of the experimental group compared to the control group. In addition, the level of eicosenoic acid in the experimental group decreased to 0% ($p < 0.001$), which may indicate its more intensive involvement in metabolic processes in the presence of phytogenic components.

Table 9.2 Fatty acid composition of tenderloin of pigs fed with the additive "Activo" ($M \pm m$, $n = 5$)

Fatty acid	Code	Groups	
		Control	Experiment
Capric	10:0	0.094 ± 0.011	0.116 ± 0.008
Lauric	12:0	0.142 ± 0.016	0.118 ± 0.013
Myristic	14:0	1.212 ± 0.024	1.306 ± 0.050
Pentadecanoic	15:0	0.142 ± 0.015	0.076 ± 0.009***
Palmitic	16:0	24.664 ± 0.262	24.836 ± 0.614
Palmitoleic	16:1	2.268 ± 0.080	2.800 ± 0.173*
Margarine	17:0	0.604 ± 0.037	0.332 ± 0.050**
Heptadecenoic	17:1	0.368 ± 0.026	0.202 ± 0.029***
Stearic	18:0	16.572 ± 0.309	14.182 ± 0.574**
Oleic	t 18:1	0.420 ± 0.018	0.222 ± 0.015***
	c9 18:1	29.236 ± 0.411	34.00 ± 0.508*
	c11 18:1	2.880 ± 0.086	3.334 ± 0.077**
	c12 18:1	0.102 ± 0.006	0.110 ± 0.008
Linoleic	c, t 18:2	0.100 ± 0.005	0.056 ± 0.014*
	18:2 ω 6	13.960 ± 0.271	13.634 ± 2.794
Linolenic	18:3 ω 3	0.634 ± 0.070	0.540 ± 0.063
Arachidic	20:0	0.162 ± 0.004	0.170 ± 0.003
Eicosenoic	c11 20:1	0.493 ± 0.023	0.562 ± 0.051
	c11 20:1	0.526 ± 0.040	0.0 ± 0.00***
Eicosadienoic	c11 20:2	0.366 ± 0.021	0.326 ± 0.020
Eicosatrienoic	20:3 ω 6	0.366 ± 0.022	0.308 ± 0.056
Arachidonic	20:4 ω 6	3.846 ± 0.285	2.226 ± 0.483*
	c11 22:1	0.0 ± 0.00	0.020 ± 0.006**
Eicosapentaenoic	20:5 ω 3	0.158 ± 0.015	0.080 ± 0.008**
	22:2	0.150 ± 0.036	0.0 ± 0.00**
Docosapentaenoic	22:5 ω 3	0.584 ± 0.049	0.312 ± 0.043**
Docosahexaenoic	22:6 ω 3	0.160 ± 0.013	0.158 ± 0.006
Saturated (SFA)		43.614 ± 0.298	41.136 ± 1.103
Monounsaturated (MUFA)		36.076 ± 0.495	41.378 ± 2.747
Polyunsaturated (PUFA)		20.310 ± 0.511	17.489 ± 3.207

A tendency to decrease the total proportion of PUFA in the tenderloin of animals of the experimental group compared to the control was established, which indicates a possible decrease in the need for these fatty acids due to the improvement of the antioxidant status of the animals. The level of arachidonic acid in the experimental group decreased by 1.73 times ($p < 0.05$) compared to the control, which may be in favor of reducing the level of inflammatory processes in muscle tissue under the influence of phytogenic supplements. A twofold decrease ($p < 0.01$) in the level of eicosapentaenoic acid was also established.

Similar changes were recorded for docosapentaenoic acid, the level of which in the muscles of animals in the experimental group decreased by 1.87 times ($p < 0.01$). The decrease in the content of ω-3 PUFA may be associated with their more active involvement in the antioxidant protection of muscle tissues in animals receiving the feed additive "Activo".

The results obtained indicate a significant effect of the feed additive "Activo" on the fatty acid composition of pork tenderloin. The main changes concerned an increase in the level of MUFA, in particular oleic acid, which may have a positive effect on the quality of meat, making it more tender and juicier. A decrease in the content of some PUFA was also noted, which may be associated with their active use in the processes of regulating inflammatory reactions and antioxidant protection. The results confirm previous scientific results [13, 14], according to which the use of essential oils in animal nutrition contributes to the improvement of the fatty acid profile of muscle tissue and enhances the antioxidant potential of the body.

9.3.3 Fatty acid composition of back muscles

Analysis of the fatty acid composition of the longest back muscle of pigs fed the feed additive "Activo" revealed significant changes in the balance of saturated, monounsaturated and polyunsaturated fatty acids, which may also indicate the effect of the phytogenic additive on lipid metabolism in muscle tissues (**Table 9.3**).

The results of the study showed that in the experimental group the total content of saturated fatty acids tended to increase, which may indicate an increase in the synthesis of saturated fatty acids or a decrease in their catabolism under the conditions of using the feed additive. Significant changes were observed in the concentration of individual SFA. Thus, the level of lauric acid under the influence of the additive decreased by 1.7 times ($p < 0.001$), which may be a consequence of its more active use as an energy source. At the same time, the content of palmitic acid, which is the main component of SFA, tended to increase, which may be associated with an increase in the synthesis of this acid under the influence of biologically active substances of the feed additive. A similar trend was also found in the study of the content of stearic acid in the muscles of animals of the experimental group, which may indicate a change in the fatty acid profile of muscle tissue aimed at improving the stability of fat reserves.

The tendency to decrease the total content of MUFA in the longissimus dorsi muscle of the experimental group of animals compared to the control group may indicate the possible use of these fatty acids as energy substrates in metabolic processes. The same dynamics was established for oleic acid and its isomer in these muscles, which may be the result of more active β-oxidation or certain changes in the mechanisms of regulation of lipid metabolism.

The total proportion of PUFA in the longissimus dorsi muscle of the experimental group compared to the control group had a tendency to decrease, which may be associated with changes in the processes of lipid metabolism and antioxidant protection. A tendency to decrease in the content in these tissues was established for linoleic acid. The reasons for this decrease may be both its more active use in the synthesis of oxylipin derivatives and a change in the activity of enzymes responsible for its metabolism. In contrast, the level of arachidonic acid, despite changes in the overall balance of PUFA in the experimental group, remained practically unchanged compared to the control, which indicates the stability of its synthesis. A tendency to increase in content was also observed for docosapentanoic acid, which is a representative of omega-3 PUFA. This may indicate an increase in the metabolic activity of this class of fatty acids in response to feeding the feed additive.

The results of the study indicate that the addition of the feed additive "Activo" significantly affects the fatty acid composition of the muscle tissue of pigs, in particular the balance between saturated, monounsaturated and polyunsaturated fatty acids. The increase in the content of SFA, especially palmitic and stearic acids, may be associated with increased lipid synthesis under the influence of biologically active substances contained in the supplement. The decrease in MUFA levels is likely due to their increased metabolic utilization, particularly in β-oxidation. This is consistent with other studies [13, 14], which found that essential oils added to pig diets modulate the expression of genes involved in lipid metabolism, such as CPT-1 (carnitine palmitoyltransferase-1) and LPL (lipoprotein lipase).

The decrease in PUFA content, particularly linoleic acid, may be associated with a decrease in inflammation in muscle tissue, as derivatives of these acids are involved in the synthesis of pro-inflammatory prostaglandins [12]. The results obtained confirm the effectiveness of using phytogenic feed additives to improve the lipid profile of muscle tissue, which may positively affect the quality of meat products. Further research is needed to determine the mechanisms of action of the active components of the "Activo" supplement at the level of cellular metabolism and their impact on the long-term quality of the product.

Table 9.3 Fatty acid composition of back muscles of pigs fed with the additive "Activo" ($M \pm m$, $n = 5$)

Fatty acid	Code	Groups	
		Control	Experiment
Capric	10:0	0.134 ± 0.011	0.118 ± 0.014
Lauric	12:0	0.160 ± 0.008	0.092 ± 0.008***
Myristic	14:0	1.292 ± 0.081	1.148 ± 0.064
Pentadecanoic	15:0	0.086 ± 0.004	0.084 ± 0.021
Palmitic	16:0	23.68 ± 1.179	26.494 ± 1.972
Palmitoleic	16:1	3.036 ± 0.318	2.702 ± 0.225
Margarine	17:0	0.240 ± 0.017	0.298 ± 0.031
Heptadecenoic	17:01	0.180 ± 0.026	0.136 ± 0.027
Stearic	18:0	12.97 ± 0.670	16.83 ± 2.583*
Oleic	t 18:1	0.226 ± 0.021	0.216 ± 0.015
	c9 18:1	34.732 ± 0.969	32.034 ± 2.216
	c11 18:1	3.606 ± 0.294	3.284 ± 0.255
Linoleic	c, t 18:2	0.050 ± 0.006	0.064 ± 0.013
	18:2 ω 6	15.05 ± 3.602	11.452 ± 2.759
Arachidic	20:0	0.162 ± 0.013	0.194 ± 0.28
Linolenic	18:3 ω 6	0.033 ± 0.007	0.037 ± 0.0025
	18:3 ω 3	0.332 ± 0.022	0.378 ± 0.051
Eicosenoic	c11 20:1	0.446 ± 0.034	0.478 ± 0.332
	c9 20:1	0.063 ± 0.029	0.067 ± 0.021
Eicosadienoic	c11 20:2	0.232 ± 0.027	0.282 ± 0.034
Eicosatrienoic	20:3 ω 6	0.298 ± 0.046	0.366 ± 0.084
Arachidonic	20:4 ω 6	2.534 ± 0.394	2.654 ± 0.673
Eicosapentaenoic	20:5 ω 3	0.128 ± 0.029	0.125 ± 0.032
Docosapentaenoic	22:5 ω 3	0.407 ± 0.052	0.512 ± 0.053
Saturated (SFA)		38.724 ± 1.924	45.258 ± 4.483
Monounsaturated (MUFA)		42.264 ± 1.520	38.904 ± 2.622
Polyunsaturated (PUFA)		19.010 ± 3.136	15.838 ± 3.635

The proportion of ω-3 and ω-6 PUFAs plays an important role in human health, in regulating inflammation and maintaining cardiovascular, neurological and metabolic health. For optimal ratios of ω-3 to ω-6 PUFAs, the ratio is 1:4, or even lower. These recommendations are explained by the fact that these acids compete for the same enzymes in metabolic pathways and produce lasting physiological effects: ω-6 fatty acids (especially linoleic and arachidonic acids) There is a tendency to reduce inflammation, throat blood and cell proliferation, and ω-3 (linoleic, docosapentaenoic, docosahexaenoic), however, exhibit anti-inflammatory, antithrombotic and neuroprotective effects.

Daily diets, therefore, have a very high ratio of ω-3:ω-6 fatty acids, around 1:15–1:20. This is due, in principle, to the significant production of vegetable oils (such as corn, soybean and sunflower) and the low production of fatty fish. This imbalance is associated with an increased risk of chronic diseases, such as cardiovascular diseases, obesity, type 2 diabetes, autoimmune diseases.

Analysis of the effect of the feed additive "Activo" on the ratio of ω3:ω6 PUFA in the studied tissues of pigs indicates its tissue specificity (**Fig. 9.1**).

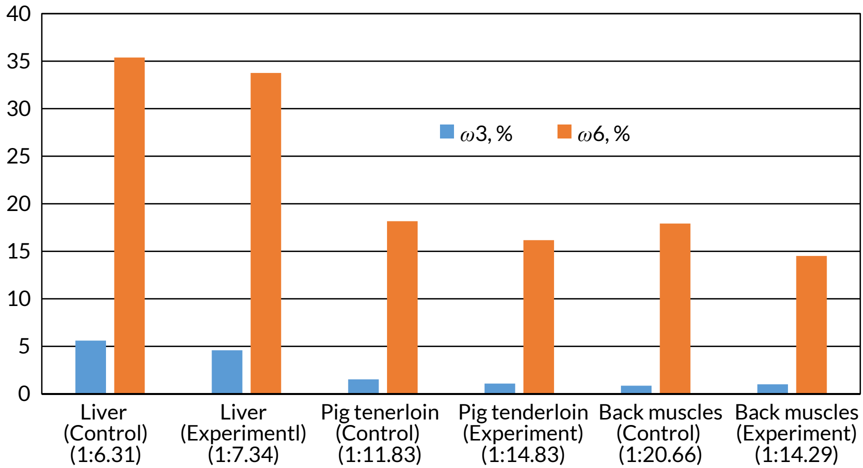

Fig. 9.1 The content of ω3 and ω6 fatty acids in the tissues of pigs fed with the feed additive "Activo" ($M \pm m$, $n = 5$)

The best ratio of these acids, which most closely meets the recommendations, was found in the liver of pigs in the control group. In the liver of animals in the experimental group, a synchronous tendency to decrease both ω-3 and ω-6 PUFA was observed, but the deterioration of the ratio of these acids in the experimental group compared to the control group was insignificant and remained within the recommendations [21, 22]. In the muscle tissues of the tenderloin of pigs in the control group, the level of this ratio is inferior to the liver, but remains within the limits of a satisfactory assessment. Under the influence of the additive, a tendency to decrease the level of this indicator was also found in the tenderloin of animals in the experimental group.

However, in the back muscles, which among all the tissues studied were characterized by the lowest ratio of $\omega3$:$\omega6$ PUFA, under the action of the additive "Activo" there were significant positive changes in this indicator.

9.4 Conclusions

The results obtained indicate that the addition of the feed additive "Activo" to the diet of pigs affects the metabolism of fatty acids in various tissues. The most significant changes were recorded in the reduction of the level of polyunsaturated fatty acids in the liver by 4.6% ($p > 0.05$), in the tenderloin tissues by 5.7% ($p > 0.05$), and an increase in the proportion of monounsaturated compounds by 48.0% ($p < 0.001$), 14.7% ($p > 0.05$), respectively. In the long back muscle, there was an increase in polyunsaturated fatty acids by 16.9% ($p > 0.05$), and a decrease in monounsaturated compounds by 7.9% ($p > 0.05$). These changes may positively affect the quality of meat products. Changes in the composition of fatty acids in muscle tissues and liver may indicate an increase in the resistance of lipids to oxidation and an improvement in the organoleptic characteristics of meat. In the dorsal muscles of pigs under the influence of the supplement "Activo", in contrast to the decrease in the total content of unsaturated fatty acids, an increase in the proportion of ω-3 PUFA was observed, which contributed to an increase in the biological value of the lipid component of these muscles.

The results obtained confirm the effectiveness of using the phytogenic feed additive "Activo" to improve the lipid profile of muscle tissue, which may positively affect the quality of meat products. Further studies are needed to study the mechanisms of influence of biologically active substances of this feed additive on the regulation of lipid metabolism and its potential to increase pig productivity.

Thus, the use of feed additives based on essential oils is a promising direction for increasing animal productivity and improving the quality of the final meat product. Further studies should be aimed at studying the mechanisms of the influence of essential oils on lipid metabolism and determining the optimal doses of their use in pig diets.

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