UDC 636.2:577.125

SPECIFICITIES OF ACCUMULATION OF ESSENTIAL POLYUNSATURATED FATTY ACIDS OF Ω-3 AND Ω-6 FAMILIES IN THE TISSUES OF BULLS AFTER SUPPLEMENTING THEIR DIET WITH THE SOURCES OF FATTY ACIDS AND MINERAL ELEMENTS

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Received / Received / Accepted July 19, 2023

Aim. To determine the intensity of growth of fattening bulls and the specificities of the accumulation of essential polyunsaturated fatty acids from the ω-3 and ω-6 families in their tissues after supplementing their diet with the sources of essential fatty acids and copper sulfate to increase their meat productivity and improve the biological value of beef. **Methods.** The study was conducted using the methodological approaches, common for international practice in accordance with the requirements of ISO 17025, and using the conventional methods of peer groups involving clinically healthy animals. The content of polyunsaturated fatty acids of the ω-3 and ω-6 families was determined by gas chromatography using the Chrom-5 device. Copper content was determined by the method of atomic absorption spectrophotometry using the Selmi C-115 M1 device. **Results.** It was found that the introduction of linseed oil (as a source of α-linolenic acid, which is a precursor of polyunsaturated fatty acids of the ω-3 family) and sunflower oil (as a source of linoleic acid, which is a precursor of polyunsaturated fatty acids of the ω-6 family), the synthetic substance doxane (as an inhibitor of biohydrogenation processes in unsaturated fatty acids in the rumen) and pentahydrate copper sulfate (as a source of copper) to the diet of young fattening cattle caused a probable increase in the content of biologically active polyunsaturated fatty acids of the ω-3 and ω-6 family and copper in their liver and skeletal muscles. At the same time, the increase in the content of biologically active polyunsaturated fatty acids of the ω-3 and ω-6 families and copper in the abovementioned tissues due to the stimulation of metabolic processes in the body contributed to a probable increase in the average daily weight gain of young fattening animals. Thus, there was a direct relationship between the content of α-linolenic and linoleic acids and copper in the diet and their content in the tissues of experimental animals, productivity characteristics, and biological value of beef. **Conclusions.** The introduction of a mixture of linseed and sunflower oils into the diet of fattening bulls led to an increase in the content of α-linolenic and linoleic acids and a 1.7-fold decrease in the ratio between essential polyunsaturated fatty acids of the ω-6 family and that of the ω-3 family. The increase in the content of copper and essential polyunsaturated fatty acids of the ω-6 and ω-3 families in the diet of fattening bulls led to their accumulation in the liver and skeletal muscles, which contributed to the enhanced biological value of beef.

Key words: fattening bulls, linseed and sunflower oils, copper, polyunsaturated fatty acids of the ω-3 and ω-6 families, growth intensity, biological value of beef.

DOI:

INTRODUCTION

In our modern world, the leading organizations in charge of addressing the issues of quality and safety of agricultural products and the health of humans and animals are the Food and Agriculture Organization (FAO), the World Organization for Animal Health (OIE), and the World Health Organization (WHO), which have elaborated and have been implementing the One Health strategy and the Global Health Security Agenda. Their main task is to protect human health, including the protection of humans via protecting animal health, i.e. the quality and safety of agricultural products, starting with the producer and ending with the consumer, using the "from the lawn to the table" approach which is an integral part of the food safety and consumer protection policy in our modern world (Hadzalo Ya M, 2017; Willett W et al, 2019; Geiker NRW et al, 2021; Prache S et al, 2021).

The scientific literature demonstrates that the main fodder, used to feed cattle, contains an insufficient amount of essential polyunsaturated fatty acids of the ω-3 and ω-6 families (Wood J D et al, 2004; Doreau M Bauchart D Chilliard Y, 2011; Nassu R T et al, 2011; Mapiye C et al, 2013; Vahmani P et al, 2015; Nogoy KMC et al, 2022; Normand J, Gruffat D, 2023).

Also, due to the fact that cattle has forestomachs, a high amount of polyunsaturated fatty acids is subject to biohydrogenation by the rumen microbial flora and gets transformed into less valuable monounsaturated and saturated fatty acids (Wood J D et al, 2004; Doreau M, Bauchart D, Chilliard Y 2011; Gudla P et al, 2012; Mapiye C et al, 2013; Santos J E P et al, 2013; Saliba L et al, 2014; Vahmani P et al, 2015, 2017; Wolf C et al, 2018). Therefore, the fatty acid composition of beef lipids contains a small number of essential fatty acids of the ω-3 and ω-6 families (Wood J D et al, 2004; Doreau M, Bauchart D, Chilliard Y, 2011; Nassu R T et al, 2011; Mapiye C et al, 2013; Vahmani P. et al, 2015; Vahmani P et al, 2017; Wolf C et al, 2018; Najar-Villarreal F et al, 2019; Nogoy KMC et al, 2022), which decreases its biological value in human nutrition.

There is a global search for ways to increase the productivity of fattening cattle and to enhance the biological value of beef. It involves supplementing the diet of cattle with oils and using various methods of protecting essential polyunsaturated fatty acids from biohydrogenation by the rumen microbial flora via feeding them calcium salts of fatty acids in the form of granules, bricks, and different capsules (Wood J D et al, 2004; Doreau M, Bauchart D, Chilliard Y, 2011; Santos J E P et al, 2013; Garcia M et al, 2014; Scollan N D et al, 2014; Vahmani P et al, 2015; Vahmani P et al, 2017; Wolf C et al, 2018; Park SJ et al, 2018; Reinaldo FC et al, 2023).

At the same time, the global practice is still not unanimous regarding the issue of optimal amounts and the ratio of oils in the diet, which are the source of essential fatty acids of the ω-3 and ω-6 families for ruminants. The insufficient or excessive amount of the abovementioned fatty acids in the diet has a negative effect on the digestion processes in the rumen, their transformation, and accumulation in the tissues of fattening cattle (Nassu R T et al, 2011; Gudla P et al, 2012; Scollan N D et al, 2014; Vahmani P et al, 2015; Wolf C et al, 2018; Lenighan YM et al, 2020).

It was found that essential fatty acids of the ω-3 and ω-6 families in the human organism are predecessors of a series of biologically active substances (prostaglandins, thromboxanes, leukotrienes) and the main constituents of plasma and cell membranes (Kvachov V H, Sokyrko T O, 2003; Santos J E P et al, 2013; Vahmani P et al, 2015; Shahidi F, Ambigaipalan P, 2018). In addition, the essential fatty acids of the ω-3 and ω-6 families can transform atherogenic cholesterol of low-density lipoproteins into its more valuable derivatives: bile acids, 25-OH vitamin D3, sex hormones, and adrenocortical hormones which demonstrates their high biological value for the organisms of animals and humans (Dliaboha Yu Z, Rivis Y F, 2012; Hopanenko O O, Rivis Y F, 2013; Lawrence G D, 2013; Vahmani P et al, 2020).

It is noteworthy that in the tissues of animals, prostaglandins, the predecessors of which are polyunsaturated fatty acids of the ω-6 family, stimulate the synthesis of pro-inflammatory cytokines (IL-1, IL-6, IL-8, TNF-α) (Pereiaslov A A, Chuklin S M, Fedoriv V I, 2000; Simon M C et al, 2013; Scoville E A et al, 2019); in their turn, prostaglandins, formed out of polyunsaturated fatty acids of the ω-3 family, stimulate the synthesis of anti-inflammatory cytokines (IL-4, IL-10) (Kang J X, Weylandt K H, 2008; Simon M C et al, 2013; Darghosian L et al, 2015; Scoville E A et al, 2019). It was proven that a high ratio between fatty acids of ω-6 family and that of the ω-3 family promotes the development of many diseases with high incidence (from cardiovascular diseases and arthritis to cancer), while a lower ratio between ω-6 fatty acids and ω-3 fatty acids prevents the onset of many chronic diseases (Simopoulos A P 2008; Lawrence G D 2013; Vahmani P et al 2015; Hartigh LJ 2019).

It should also be noted that among the limited microelements of the Carpathian region, there is also copper (Fadieieva A I, Pashchenko Ya V, 2003; Bohdanov H O, 2010; Dzen Ye O et al, 2012; Kulibaba S V, Dolgaya M M, 2018), as its deficiency in the organism of animals promotes the impairment of the metabolism and a decrease in productivity. Copper impacts the activi-ty of more than 30 enzymes, responsible for oxidation and cellular respiration, the processes of hemopoiesis, stimulates the production of female sex hormones and thyroxine, participates in the synthesis of neuromediators (catecholamines), melanin and myeline, enhances the activity of insulin and thyroxine, affects the formation of the typical structure of connective tissue (cartilage, tendons), the biosynthesis of keratine and phospholipids and the lipid composition of blood plasma (Enjalbert F, Lebreton P, Salat O, 2006; Martynova S N, Zovskyi V N, 2010; Soetan K O, Olaiya C O, Oyewole O E 2010; Shapovalov S O, 2011; Prashanth L et al, 2015; Hilal E Y, Elkhairey M A E, Osman A O A 2016).

It is possible to increase the level of essential fatty acids of the ω-3 and ω-6 families in beef, in particular in the liver and skeletal muscles, by supplementing the diet of young fattening cattle with the sources of the abovementioned fatty acids and doxan, a synthetic substance, which inhibits their biohydrogenation and transformation into monounsaturated and saturated fatty acids in the rumen, thus increasing their content in the final products of animal breeding and enhancing the biological value of beef for a human organism. Another way of improving the meat productivity of fattening bulls and ensuring high intensity of metabolic processes, thus increasing the content of essential fatty acids of the ω-3 and ω-6 families in beef, is to feed the cattle with some copper, which plays an important part in metabolic processes in the organism.

Our study was the continuation of the previous cycle of work (Diachenko O, 2019; Diachenko O, Rivis Y, 2020; Diachenko O, 2020), focused on determining the optimal amount and ratio for the mixture of linseed and sunflower oil, which are the sources of essential fatty acids of the ω-3 and ω-6 families in the diet of fattening bulls to obtain beef with higher content of the abovementioned fatty acids. The difference of the suggested approach in this study lies in investigating the impact of the additional administration of different doses of copper in combination with the optimal amounts of oils and doxan, defined by us in the previous studies, on the growth intensity of fattening bulls and the specificities of accumulation of essential polyunsaturated fatty acids of the ω-3 and ω-6 families in their tissues.

MATERIALS AND METHODS

The experiment was conducted in the stall-feeding period at the Bilak farm in Sambir district, Lviv region, using five groups of fattening Polissia meat bulls, aged 15–16 months, 10 animals per group, using the methodological approaches, common for the global practice according to the requirements of ISO 17025, and using the conventional methods of peer groups of clinically healthy animals. The registration period was 60 days.

The bulls in the control group received only the main diet. The animals in experimental groups I–IV had the main diet, supplemented with previously determined by us (Diachenko O, 2020) optimal amount of the mixture of crude linseed and sunflower oils of the second-grade quality (65 and 35 ml/animal/day, respectively) and doxan, the synthetic substance (2 mg/kg of the body weight), which counteracted the biohydrogenation of unsaturated fatty acids in the rumen. The active substances of doxan are sodium dodecyl sulfate and vinylpyrrolidone, a synthetic cation copolymer, which form a polyelectrolyte complex while interacting in the aqueous medium. Due to the specifics of its structure, this polycomplex demonstrates its own superficial biological activity after the introduction into the organism of animals with fodder or drinking water. The content of linoleic and α-linolenic acids in the diet of the bulls under investigation was studied by determining the content of the abovementioned polyunsaturated fatty acids in each type of fodder and investigated oils with the further estimation of their total amount.

In addition, the bulls from experimental groups II–IV were additionally fed with 10.0, 20.0, and 30.0 mg of copper, respectively, in the form of pentahydrate copper sulfate ($CuSO_4 \times 5H_2O$) in the amount of 39.0, 78.0, and 117.0 mg, respectively. The scheme of the experiment is presented in **Table 1**.

The method of gas chromatography (Rivis YF et al, 2017) and the Chrom-5 device were used to determine the content of biologically active polyunsaturated fatty acids of the ω-3 and ω-6 families, as well as the fatty acid composition of linseed and sunflower oils, used in the experiment, in the selected samples of fodder. The copper content in the fodder of the diet for the fattening bulls was determined by the atomic absorption spectrophotometry method (Vlizlo V V, Fedoruk R S, Ratych I B et al, 2012) using the Selmi C-115 M1 device.

The body weight of the young fattening cattle was measured at the beginning and at the end of the experiment by weighing. At the end of the experiment, there was a scheduled slaughter of five bulls from each group. For laboratory testing purposes, we selected the samples of the liver and skeletal muscles (longissimus lumborum) to determine the content of essential fatty acids of the ω-3 and ω-6 families using gas chroma-

Table 1. The scheme of the experiment

Group of animals	Number of animals	Specificities of feeding the animals
Control	10	Main diet (MD)
I experimental	10	MD + linseed oil (65 ml/animal/day) + sunflower oil (35 ml/animal/day) + doxan
II experimental	10	MD + linseed oil (65 ml/animal/day) + sunflower oil (35 ml/animal/day) + doxan + pentahydrate copper sulfate (39.0 mg)
III experimental	10	MD + linseed oil (65 ml/animal/day) + sunflower oil (35 ml/animal/day) + doxan + pentahydrate copper sulfate (78.0 mg)
IV experimental	10	MD + linseed oil (65 ml/animal/day) + sunflower oil (35 ml/animal/day) + doxan + pentahydrate copper sulfate (117.0 mg)

tography and to estimate the copper content using the atomic absorption spectrophotometry and the Selmi C-115 M1 device.

The obtained digital material was processed using the variation statistics method with Student's criterion. Arithmetic mean values (M) and deviations from arithmetic mean values (± m) were calculated. The changes were deemed reliable at $P<0.05$, $P<0.01$, and $P<0.001$.

RESULTS

The relative content of fatty acids in the investigated linseed and sunflower oils was determined according to the scheduled testing (**Table 2**).

It is evident in the Table above that the dominant fatty acid in linseed oil is the essential fatty acid – α-linolenic acid (18:3), which, in the organism of animals, is the predecessor of long-chain and unsaturated fatty acids of the ω-3 family – eicosapentaenoic (20:5), docosatrienoic (22:3), docosapentaenoic (22:5) and docosahexaenoic (22:6) acids. At the same time, the dominant fatty acid of sunflower oil is the essential fatty acid – linoleic acid (18:2). In the organism of animals, the latter is the predecessor of more long-chain and unsaturated fatty acids of the ω-6 family – eicosadienoic (20:2), eicosatrienoic (20:3), eicosatetraenoic-arachidonic (20:4), docosadienoic (22:2) and docosatetraenoic (22:4) acids. The ratio between the content of linoleic acid (18:2) and linolenic acid (18:3) in linseed oil was 0.27:1 and that in sunflower oil – 51.00:1.

The content of linoleic, α-linolenic acids, and copper in the fodder of the diet for fattening bulls from the control and experimental groups is presented in **Table 3.**

The diet for fattening bulls, presented above, contains 142.5 of linoleic acid and 30.6 g of α-linolenic acid, which, in the organism of animals, are predecessors of more long-chain and more unsaturated fatty acids of the ω-6 and ω-3 families. It should be noted that there are no consumption norms regarding the mentioned PUFA for these groups of animals. It also contains 96.3 mg of copper, which is below the physiological need (106 mg/day) of young meat cattle with an average daily weight gain of 1,000–1,100 g per 9.7 mg or 9.2 %.

The ratio between the content of essential linoleic acid (18:2, ω-6) and essential α-linolenic acid (18:3, ω-3) in the main diet of the control group of bulls was 4.66:1 (**Table 4**).

The introduction of a mixture of linseed and sunflower oils into the diet of fattening bulls from ex-

Table 2. The fatty acid composition of sunflower and linseed oils, %

Fatty acids and their code	Linseed oil	Sunflower oil
Lauric, 12:0	0.1	0.3
Myristic, 14:0	0.2	0.4
Pentadecanoic, 15:0	0.5	0.6
Palmitic, 16:0	5.8	5.8
Palmitoleic, 16:1	0.1	0.2
Stearic, 18:0	4.2	3.9
Oleic, 18:1	18.9	25.6
Linoleic, 18:2	14.7	61.2
α-linolenic, 18:3	54.9	1.2
Arachidic, 20:0	0.4	0.7
Eicosenoic, 20:1	0.1	0.3
ω-6/ω-3	0.27:1	51.00:1

perimental groups I, II, III, and IV led to an increase in the content of α-linolenic acid by 31.8 g (103.9 %) and that of linoleic acid – by 27.2 g (19.1 %) and a 1.7-fold decrease in the ratio between essential polyunsaturated fatty acids of the ω-6 family and that for the ω-3 family (4.66:1 against 2.72:1). It is noteworthy that the optimal ω-6/ω-3 ratio for the course of physiological processes and prevention of chronic disease development was 2–2.5:1 (Simopoulos AP, 2002, 2008).

The additional introduction of different doses of pentahydrate copper sulfate to the diet of the animals from experimental groups II, III, and IV increased the copper content in their diet by 10.4, 20.8, and 31.2 %, respectively, as compared to the control group.

The increase in the content of linoleic and α-linolenic acids and copper in the diet of fattening bulls in the final period of their breeding led to higher intensity of their growth (**Table 5**).

The data in the Table demonstrates that during the experimental period, the weight gains of the animals in experimental groups I, II, III, and IV were higher by 70.0, 73.3, 76.6, and 70.0 g, respectively, as compared to the control peers.

The additional feeding of fattening bulls with different doses of pentahydrate copper sulfate promoted the increase in copper content in their liver and skeletal muscles (**Table 6**).

For instance, in the liver of the animals from experimental groups II, III, and IV, as compared to the control group, the copper content increased by 8.0, 21.3, and 35.7 %, respectively, and that in the skeletal muscles – by 6.0, 14.5, and 26.5 %.

Table 3. The content of linoleic (ω-6) and α-linolenic (ω-3) acids and copper in some fodder of the diet for fattening bulls

Diet fodders, kg	Linoleic, acid (ω-6), g	α-linolenic acid (ω-3), g	Copper, mg
Grain-legume hay (4.0)	18.8	5.2	4.4
Grain-legume haylage (10.0)	45.7	17.8	16.0
Combined fodder (4.0)	69.2	5.6	12.4
Wheat juice (20.0)	8.8	2.0	63.4
Water 50.0	0	0	0.1

Table 4. The content of linoleic and α-linolenic acids and copper in the fodders of the diet for the bulls under experiment

Group of animals	Linoleic, acid, g	α-linolenic acid, g	Copper, mg	ω-6/ω-3
Control	142.5	30.6	96.3	4.66:1
I experimental	169.7	62.4	96.3	2.72:1
II experimental	169.7	62.4	106.3	2.72:1
III experimental	169.7	62.4	116.3	2.72:1
IV experimental	169.7	62.4	126.3	2.72:1

Table 5. The growth intensity of the bulls in the experiment

Group of animals	Bodyweight of bulls, kg		Average daily weight gain of bulls, g
	at the beginning of the experiment	at the end of the experiment	
Control	465.0 ± 2.35	496.4 ± 2.59	1046.7 ± 12.4
I experimental	465.2 ± 2.16	498.7 ± 2.32	1116.7 ± 11.4 ***
II experimental	464.9 ± 2.30	498.5 ± 2.46	1120.0 ± 8.9 ***
III experimental	465.1 ± 2.21	498.8 ± 2.29	1123.3 ± 13.2 ***
IV experimental	465.0 ± 2.44	498.5 ± 2.75	1116.7 ± 15.1 **

Note. Hereinafter * – $P < 0.05$; ** – $P < 0.00$; *** – $P < 0.001$.

Table 6. The copper content in the liver and skeletal muscles of fattening bulls

Group of animals	Copper content, mg/kg	
	in the liver	in the skeletal muscles
Control	2.49 ± 0.14	0.83 ± 0.04
I experimental	2.52 ± 0.13	0.84 ± 0.04
II experimental	2.69 ± 0.11	0.88 ± 0.05
III experimental	3.02 ± 0.14 *	0.95 ± 0.03 *
IV experimental	3.38 ± 0.16 **	1.05 ± 0.07 *

Table 7. The content of polyunsaturated fatty acids ω-6 and ω-3 in the liver of fattening bulls, g/100 g of raw weight (M ± m, n = 5)

Group of animals	Essential polyunsaturated fatty acids		ω-6/ω-3
	ω-6 family	ω-3 family	
Control	0.47 ± 0.017	0.23 ± 0.013	2.0:1
I experimental	0.54 ± 0.016 *	0.32 ± 0.012 ***	1.7:1
II experimental	0.55 ± 0.018 *	0.32 ± 0.011 ***	1.7:1
III experimental	0.55 ± 0.016 **	0.34 ± 0.015 ***	1.6:1
IV experimental	0.54 ± 0.019 *	0.34 ± 0.019 **	1.6:1

Table 8. The content of polyunsaturated fatty acids of the ω-6 and ω-3 families in the skeletal muscles of fattening bulls, g/100 g of raw weight (M ± m, n = 5)

Group of animals	Essential polyunsaturated fatty acids		ω-6/ω-3
	ω-6 family	ω-3 family	
Control	0.25 ± 0.012	0.12 ± 0.009	2.1:1
I experimental	0.30 ± 0.014 *	0.19 ± 0.010 ***	1.6:1
II experimental	0.30 ± 0.013 *	0.21 ± 0.008 ***	1.4:1
III experimental	0.30 ± 0.012 *	0.22 ± 0.011 ***	1.4:1
IV experimental	0.31 ± 0.015 *	0.20 ± 0.012 ***	1.6:1

The introduction of sunflower oil, linseed oil, and doxan to the main diet of the animals from experimental groups I–IV led to some changes in the content and ratio of the abovementioned fatty acids in their tissues (**Table 7** and **8**).

In particular, as compared to the animals from the control group, the content of essential polyunsaturated fatty acids of the ω-6 family in the liver of bulls from experimental groups I, II, III, and IV increased by 14.9, 17.0, 17.0, and 14.9 %, and that of fatty acids of the ω-3 family – by 39.1, 39.1, 47.8, and 47.8 %, respectively. Here, the ratio between the content of essential polyunsaturated fatty acids of the ω-3 family to that of the ω-6 family in the liver of bulls from experimental groups I–IV decreased 1.2–1.3 times (Table 7).

As compared to the animals from the control group, the concentration of essential polyunsaturated fatty acids of the ω-6 family animals in the skeletal muscles of bulls from experimental groups I, II, III, and IV increased by 20.0, 20.0, 20.0, and 24.0 %, and that of fatty acids of the ω-3 family – by 58.3, 75.0, 83.3, and 66.7 %, respectively (Table 8). The ratio between the content of essential polyunsaturated fatty acids of the ω-3 family and that of the ω-6 family in the skeletal muscles of bulls decreased 1.3–1.5 times.

DISCUSSION

It can be asserted that the increase in the content of copper and essential polyunsaturated fatty acids of the ω-6 and ω-3 families in the diet of fattening bulls led to their accumulation in the liver and skeletal muscles, which contributed to the enhanced biological value of beef.

It was found that in the winter stall-feeding period of keeping, the best results of the average daily weight gain and the content of copper and essential polyunsaturated fatty acids of the ω-3 and ω-6 families in the liver and the skeletal muscles of fattening bulls were obtained after additional introduction of 78.0 mg of pentahydrate copper sulfate and linseed and sunflower oils in the amount of 65 and 35 ml/animal/day into the diet of the fattening bulls.

Our study results are in agreement with the publications, demonstrating that the amount and composition of polyunsaturated fatty acids of the ω-3 and ω-6 families in beef depend on their amount in the diet and the related factors, affecting the degree of PUFA biohydrogenation (Doreau M, Bauchart D, Chilliard Y, 2011; Nassu RT et al, 2011; Mapiye C et al, 2013; Scollan ND et al, 2014; Vahmani P et al, 2015, 2017). In particular, our findings confirm the conclusion that one of the efficient strategies for increasing the amount of unsaturated fatty acids in beef is supplementing the diet of the animals with oils rich in PUFA (Noci F et al, 2007; Gonzalez L et al, 2014; Vahmani P et al, 2015), and elaborating the ways of protecting them from biohydrogenation in the rumen (Lee M R et al, 2009; Brogna D et al, 2011; Park SJ et al, 2018).

The high efficiency of microbial biohydrogenation of polyunsaturated fatty acids in the rumen and the impact of different fodder in the diet on its course should also be noted. For instance, a slight accumulation of PUFA in beef was found after the introduction of 4.5 % sunflower, linseed, or soybean oil to the diet using concentrates (Gonzalez L et al, 2014). Therefore, different methods are used to protect essential polyunsaturated fatty acids from biohydrogenation by the microbial flora in the rumen, namely, feeding them in the form of calcium salts of fatty acids, granules, bricks and different capsules (Wood J D et al, 2004; Doreau M, Bauchart D, Chilliard Y, 2011; Santos J E P et al, 2013; Garcia M et al, 2014; Scollan N D et al, 2014; Vahmani P. et al, 2015; Vahmani P et al, 2017; Wolf C et al, 2018; Park SJ et al, 2018; Reinaldo FC et al, 2023) or using different substances and preparations, inhibiting the biohydrogenation processes (Lee M R et al, 2009; Brogna D et al, 2011; Park SJ et al, 2018). In the future, there might also be possibilities to affect the biohydrogenation in the rumen during direct feeding, as several species of bacteria with biohydrogenation activity were identified (Lourenço M, Ramos-Morales E, Wallace, RJ, 2010).

At the same time, the introduction of the sources of fatty acids, protected from biohydrogenation, into the diet of bulls not only triggers their accumulation in the longissimus lumborum but also increases the weight gain of the young fattening cattle (Reinaldo FC et al, 2023).

It should be noted that polyunsaturated fatty acids of the ω-3 family, as compared to fatty acids of the ω-6 family, regulate the functional activity of the organism on a much higher level, thus stimulating the metabolic processes in the organism of animals on a higher level. In the long run, it leads to improved productivity features of animals and the biological value of beef.

CONCLUSIONS

The introduction of a mixture of linseed and sunflower oils into the diet of fattening bulls from experimental groups I, II, III, and IV led to an increase in the content of α-linolenic acid by 31.8 g (103.9 %) and that of linoleic acid – by 27.2 g (19.1 %) and a 1.7-fold decrease in the ratio between essential polyunsaturated fatty acids of the ω-6 family and that for the ω-3 family.

It was found that the diet of the animals of the control group contained 96.3 mg of copper, which was lower than the physiological need of young meat cattle with an average daily weight gain of 1,000–1,100 g by 9.2 %.

The highest average daily weight gains were registered in the fattening bulls of the experimental group III, which were higher than those for the animals from the control group by 76.6 g (7.3 %).

As compared to the control group, the additional feeding of fattening bulls from experimental groups II, III, and IV with pentahydrate copper sulfate promoted the increase in the copper content in their liver by 8.0, 21.3, and 35.7 %, respectively, and that in the skeletal muscles – by 6.0, 14.5, and 26.5 %.

The increase in the content of copper and essential polyunsaturated fatty acids of the ω-6 and ω-3 families in the diet of fattening bulls led to their accumulation in the liver and skeletal muscles, which contributed to the enhanced biological value of beef.

Adherence to ethical principles. The information about compliance with standards of working with animals: we used the methodological approaches of the global practice in accordance with the requirements of ISO 17025.

Conflict of interests. The authors deny any conflict of interests.

Financing. The source of financing for our study was the state budget.

Особливості накопичення есенціальних поліненасичених жирних кислот родин w-3 і w-6 в тканинах бугайців за введення у їх раціон джерел жирних кислот і мінеральних елементів

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Мета. Встановити інтенсивність росту відгодівельних бугайців та особливості накопичення у їхніх тканинах незамінних поліненасичених жирних кислот родин w-3 і w-6 за введення у їхній раціон джерел есенціальних жирних кислот і сульфату міді для підвищення їхньої м'ясної продуктивності та покращення біологічної цінності яловичини. **Методи.** Дослідження проводилися з використанням методичних підходів, які застосовуються в міжнародній практиці відповідно до вимог ISO 17025, а також згідно з загальноприйнятими методиками груп-аналогів на клінічно здорових тваринах. Вміст поліненасичених жирних кислот родин w-3 і w-6 визначався методом газової хроматографії за допомогою приладу "Chrom-5". Вміст купруму було визначено методом атомно-абсорбційної спектрофотометрії за допомогою приладу Selmi C-115 M1. **Результати.** Встановлено, що введення лляної олії (як джерела α-ліноленової кислоти, яка є попередником поліненасичених жирних кислот родини w-3) і соняшникової олії (як джерела лінолевої кислоти, яка є попередником поліненасичених жирних кислот родини w-6), синтетичної речовини доксан (як інгібітора процесів біогідрогенізації ненасичених жирних кислот у рубці) та сульфату міді п'ятиводневої (як джерела купруму) до раціону відгодівельного молодняку великої рогатої худоби викликає вірогідне зростання вмісту біологічно активних поліненасичених жирних кислот родини w-3 і w-6 та купруму в їхній печінці й скелетних м'язах. Водночас зростання вмісту біологічно активних поліненасичених жирних кислот родин w-3 і w-6 та купруму у вказаних вище тканинах за рахунок стимулювання обмінних процесів в організмі сприяє вірогідному збільшенню середньодобових приростів маси тіла відгодівельного молодняку. Тобто спостерігається прямий зв'язок між вмістом α-ліноленової й лінолевої кислот і купруму у раціоні та їхнім вмістом у тканинах дослідних тварин, продуктивними ознаками і біологічною цінністю яловичини. **Висновки**. Введення суміші лляної і соняшникової олій до раціону відгодівельних бугайців привело до збільшення в ньому вмісту α-ліноленової і лінолевої кислот та зниження співвідношення есенціальних поліненасичених жирних кислот родини ω-6 до родини ω-3 у 1,7 рази. Збільшення у раціонах відгодівельних бугайців вмісту купруму та незамінних поліненасичених жирних кислот родин w-6 і w-3 приводить до їхнього накопичення в печінці та скелетних м'язах, що сприяє підвищенню біологічної цінності яловичини.

Ключові слова: відгодівельні бугайці, лляна і соняшникова олії, купрум, поліненасичені жирні кислоти родин w-3 і w-6, інтенсивність росту, біологічна цінність яловичини.

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