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ORIGINAL ARTICLE

Menadione sodium bisulfite effect on growth performance and fatty acid profiles of geese muscle tissues

O.V. Yakoviichuk[1*], O.O. Danchenko[1,2], S.O. Vovk[3], T.O. Shevchuk[1], O.O. Chromysheva[1], O.S. Maksymov[1], I.O. Kulyk[1], T.M. Haponenko[1], O.V. Yusupova[1], O.G. Bren[1], A.S. Fedorko[1]

[1]Bogdan Khmelnytsky Melitopol State Pedagogical University, Melitopol, Ukraine

[2]Dmytro Motornyi Tavria State Agrotechnological University, Melitopol, Ukraine

[3]Institute of Agriculture of the Carpathian Region NAAS, Obroshyno, Lviv Region, Ukraine

**Corresponding author E-mail: alex.yakov1991@gmail.com*

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The specific effect of menadione sodium *bisulfite* (MSB, vicasol) on the content of specific fatty acids in skeletal muscle and muscular stomach of geese was established. MSB can stimulate the biosynthesis processes and catabolism of fatty acids depending on the period of the geese ontogenesis. Experimental use of MSB in skeletal muscle helps to increase the total content of unsaturated fatty acids (FA) primarily due to n-3 FAs. MSB increases the content of PUFA and SFA on the 35th day of ontogenesis, so the nutritional value of meat improves, and the resistance of myocyte membranes increases to oxidative damage. In the smooth muscle tissue of the goose stomach, the action of MSB revealed a higher content of UFA only on the 21st day of ontogenesis, due to PUFA, in particular, n-6 and MUFA. On the 28th day of ontogenesis, the content of PUFA increases due to n-3, with a decrease in the total content of UFA. At the end of the experiment, the UFA content decreases with increasing SFA. Reducton of the content of essential n-3, n-6, and UFA negatively affects the nutritional value of the product but increases the resistance of tissues to the active forms of oxygen. The use of MSB contributes to the overall increase of the average daily weight gain of geese from the 21st to the 28th day. The average body weight from the 21st to the 35th ontogenesis relative to the control group. We recommend using MSB at a dose of 0.7 mg/kg body weight for gosling feeding to increase the essential FA content in skeletal muscle tissue.

Keywords: Menadione sodium bisulfite, fatty acids, geese, muscle tissues.

Introduction

Poultry Meat's Fatty Acid (FA) profile depends on internal and external factors (Starčević et al., 2014). The selection of the optimal ration thus can be used to change the proportion of polyunsaturated FAs (PUFA) in poultry meat (Givens, 2005). The FA composition of meat determines its technological characteristics and quality: the hardness of adipose tissue, shelf life, and flavor. Due to the significant differences between the melting temperatures of individual FAs, changes in their composition affect the hardness of fat in meat, especially subcutaneous, intermuscular and intramuscular fat (Nieto & Ros, 2012). In terms of organoleptic properties, FAs are the main precursors of compounds that determine the taste of meat. Meat with a high content of polyunsaturated n-3 and n-6 FAs is highly valued. At the same time, FAs with a large number of ethylene units are more easily subjected to peroxide oxidation than saturated ones. In this case, products with a high content of PUFA are usually more valuable for their nutritional quality but have low oxidative resistance. Thus, the shelf life of such products significantly reduces. Oxidation adversely affects the taste and color of meat (Zhou et al., 2012; Trembecká et al., 2016).

The FA composition of animal tissues is associated with many important functional parameters, such as metabolic rate, physical endurance, the recovery period after physical activity. This is because the chemical properties of FAs strongly contribute to cell structure, intercellular signaling, regulation of gene expression, and energy storage (Carter et al., 2019). For example, the fluidity and permeability of membranes, enzymes activity are associated with the cell membrane (Arnold et al., 2015). As well as the biochemical availability of intracellular energy reserves depends on the FA composition of the cell membrane and its organelles (Guglielmo, 2010). Resistance to oxidative damage (Hulbert, 2010; Zdorovtseva et al., 2012; Skrip & McWilliams, 2016) and the implementation of intracellular signaling (Carter et al., 2019) depend on the number and location of double bonds in the FA chain. Thus, the analysis of the FA composition of tissues is a way to predict the functional state of body systems.

Although the FA composition of membranes and reserve lipids plays an important role in physiological functions–it may vary in response to endogenous and exogenous factors. The first ones include fluctuations in the activity of lipogenic enzymes that modify FAs (Shimozuru et al., 2012). The main exogenous factor is the dietary availability of FAs – it depends on the ration (McCue et al.,

2009; Carter et al., 2019). On the other hand, changes in the FA composition of the tissue can be caused by the action of biologically active substances, such as quinones (Hassan, 2013; Wiraswati et al., 2016; Bolton & Dunlap, 2017).

Menadione sodium *bisulfite* (MSB, vicasol) has long been used as an essential component in the standard ration of poultry (Duarte et al., 2014; Guo et al., 2020). It has become widespread in human and veterinary medicine (Committee for veterinary medicinal products, 1998; European Food Safety Authority, 2014; Delaney & Dzanis, 2018). However, the effect on the FA composition of goose tissues has not been sufficiently studied (Yakoviichuk et al., 2019). However, the modulating effect for menadione and its derivatives on the cyclooxygenase system has been established (Kawamura et al., 2010; Kawamura et al., 2006; Ohsaki et al., 2010). It is also known that quinones activate radical processes in the organism and thus stimulate the antioxidant protection (AOP), lead to changes in the FA composition of tissue lipids (Ferland, 2012; Yakoviichuk et al., 2018; Danchenko et al., 2019).

In this case, the study of FA composition of goose muscle tissue by MSB is promising. Properly chosen technology of feeding the MSB can improve the persistence of organisms and food quality for geese farming. The study aimed to determine the effect of MSB on the FA composition of the muscle tissue of the thighs and stomach of geese.

Materials and Methods

The research followed the principles of bioethics, legislation, and requirements following the provisions of the European Convention for the Protection of Vertebrate Animals Used for Experimental and other Scientific Purposes (Strasbourg, 1986), the General Ethical Principles for Animal Experiments (Ukraine, 2001) and Commission on Bioethics of the Khmelnytsky Melitopol State Pedagogical University (№1 dated 15.09.2015). Legart Danish breed geese were used as a model objects. There were 50 geese in the experiment divided into two groups (25 in each) using the analog method (by their weight). The goslings in the experimental group from the 1st day were fed an aqueous solution of MSB daily (0.7 mg/kg body weight) (Yakoviichuk et al., 2017). The dose was defined according to the recommendations (European Food Safety Authority, 2014) and toxic exposure limits at high concentrations (Aoganghua et al., 2011; Marchionatti et al., 2013). Animals in the control group received an appropriate volume of distilled water. Geese were kept in standard sanitary and hygienic conditions. The ration was appropriate according to the recommendations (Ivko, 2009). The birds had free access to water.

The weight and the number of individuals were recorded every seven days during the experiment. Studies of the FA composition of lipids under the action of MSB solution were performed from the 21st to the 35th day of postnatal ontogenesis (physiological stress of contour feather development). During this period, birds were slaughtered. The muscle tissue of the stomach and thighs was sampled for analytical purposes. The samples were stored for no more than 7 days at –18°C.

The FA content was determined by gas-liquid chromatography. Lipids were extracted using Bligh and Dyer method (Sündermann et al., 2016). Preparation of samples, hydrolysis of esters, and methylation of FA were performed by the method (Ichihara & Fukubayashi, 2010). The FA composition of lipids was determined on a Carlo Erba chromatograph. Chromosorb W/DP with the phase of Silar 5CP ("Serva", Germany) was used (concentration: 10%, temperature: 140-250°C, growth rate: 2°C/min, injector temperature: 210°C, detector temperature: 240°C). In addition to the total content of unsaturated FAs (UFA) (ΣC), the total equivalent concentration of UFA relative to multiple bonds (unsaturation, ΣN) mmol*g^{-1} was calculated (Danchenko, 2010).

Statistical processing of the results was performed using analysis of variance. Assessing the reliability of the difference between the compared indicators of the control and experimental groups of geese was determined using the ANOVA test (Christensen, 2018). The difference was considered significant at $p \leq 0.05$, using the software package SPSS v.23 and MS Excel 2019.

Results and Discussion

Fatty acid composition of skeletal muscle tissue of geese under the action of MSB

It was found in the experiment that the use of MSB causes a slight increase of unsaturation and total UFA content in the skeletal muscles of geese (Table 1). These fluctuations of lipid unsaturation are realized due to multidirectional changes in the content of unsaturated FAs in the tissue. In particular, the use of MSB initiates the conversion of linoleic acid in skeletal muscle on the 21st day of ontogenesis. It is confirmed by a decrease of its content by 18.4% ($p \leq 0.05$) and an increase on the 35th by 26.5% ($p \leq 0.05$). The concentration of linolenic acid under the action of MSB increased on the 21st and the 35th day of ontogenesis by 32.2% ($p \leq 0.05$) and 17.2% ($p \leq 0.05$). A decrease was noticed on the 28th day by 49.3% ($p \leq 0.05$) relative to control.

Table 1. Dynamic of fatty acids composition in skeletal muscle tissue of control and experimental geese in ontogenesis (ω-mass part,%; N-unsaturation of FA, mMol / g) (M ± m, n=5).

FA	Control			Experiment		
	21#	28#	35#	21#	28#	35#
(12:0)	0.050 ± 0.003	0.050 ± 0.003	0.063 ± 0.003^{b}	0.062 ± 0.003^{a}	0.038 ± 0.002$^{a\,b}$	0.034 ± 0.002^{a}
(12:1)	0.191 ± 0.010	0.110 ± 0.006^{b}	0.192 ± 0.010^{b}	0.157 ± 0.008^{a}	0.130 ± 0.007$^{a\,b}$	0.138 ± 0.007^{a}
(13:0)	0.062 ± 0.003	0.026 ± 0.001^{b}	0^{b}	0^{a}	0.062 ± 0.003$^{a\,b}$	0.056 ± 0.003$^{a\,b}$
(14:0)	0.208 ± 0.010	0.323 ± 0.016^{b}	0.291 ± 0.015^{b}	0.222 ± 0.011	0.149 ± 0.007$^{a\,b}$	0.397 ± 0.020$^{a\,b}$
(14:1)	0.126 ± 0.006	0.017 ± 0.001^{b}	0^{b}	0^{a}	0.041 ± 0.002$^{a\,b}$	0.092 ± 0.005$^{a\,b}$
(15:0)	0.040 ± 0.002	0^{b}	0	0^{a}	0	0
(15:1)	0.018 ± 0.001	0.067 ± 0.003^{b}	0.030 ± 0.002^{b}	0.028 ± 0.001^{a}	0.646 ± 0.032$^{a\,b}$	0.054 ± 0.003$^{a\,b}$

(16:0)	19.416 ± 0.970	21.158 ± 1.060	21.073 ± 1.050	18.943 ± 0.950	15.074 ± 0.750$^{a\,b}$	19.289 ± 0.970^{b}
(16:1)	1.132 ± 0.060	2.135 ± 0.110^{b}	1.619 ± 0.081^{b}	1.072 ± 0.054	0.970 ± 0.049^{a}	3.772 ± 0.189$^{a\,b}$
(17:0)	0.111 ± 0.010	0.089 ± 0.010^{b}	0.155 ± 0.008^{b}	0.188 ± 0.009^{a}	0.102 ± 0.005^{b}	0.130 ± 0.007$^{a\,b}$
(17:1)	0.055 ± 0.003	0.610 ± 0.031^{b}	0.084 ± 0.004^{b}	0.067 ± 0.003^{a}	0.128 ± 0.006$^{a\,b}$	0.087 ± 0.004^{b}
(18:0)	21.473 ± 1.070	14.356 ± 0.720^{b}	17.814 ± 0.890^{b}	19.363 ± 0.970	19.354 ± 0.970^{a}	17.211 ± 0.860^{b}
(18:1), n-9	26.017 ± 1.300	27.703 ± 1.390	32.342 ± 1.620^{b}	27.667 ± 1.380	29.054 ± 1.450	25.490 ± 1.280$^{a\,b}$
(18:2), n-6	17.305 ± 0.870	14.928 ± 0.750^{b}	12.315 ± 0.620^{b}	14.120 ± 0.710^{a}	13.711 ± 0.690	15.577 ± 0.780^{a}
(18:3), n-3	0.368 ± 0.018	0.807 ± 0.040^{b}	0.537 ± 0.027^{b}	0.490 ± 0.025^{a}	0.409 ± 0.020^{a}	0.857 ± 0.043$^{a\,b}$
(20:0)	0.527 ± 0.026	0.431 ± 0.022^{b}	0472 ± 0.024	0.547 ± 0.027	0.534 ± 0.027^{a}	0.523 ± 0.026
(20:1), n-9	0.529 ± 0.026	0.437 ± 0.022^{b}	0.588 ± 0.029^{b}	0.547 ± 0.027	0.569 ± 0.028^{a}	0.981 ± 0.049$^{a\,b}$
(20:2), n-6	0.729 ± 0.036	0.579 ± 0.029^{b}	0.472 ± 0.024^{b}	0.787 ± 0.039	0.788 ± 0.039^{a}	0.731 ± 0.037^{a}
(20:3), n-6	0.408 ± 0.020	1.426 ± 0.071^{b}	0.186 ± 0.009^{b}	0.372 ± 0.019	0^{a}	0.359 ± 0.018$^{a\,b}$
(20:4), n-6	6.978 ± 0.350	11.460 ± 0.570^{b}	7.748 ± 0.390^{b}	9.811 ± 0.490^{a}	13.867 ± 0.690$^{a\,b}$	8.568 ± 0.430 ^{b}
(22:0)	0.966 ± 0.048	0.694 ± 0.035^{b}	0.895 ± 0.045^{b}	1.429 ± 0.071^{a}	0.983 ± 0.049$^{a\,b}$	0.622 ± 0.031$^{a\,b}$
(22:1), n-9	0.143 ± 0.007	0.150 ± 0.008	0.099 ± 0.005^{b}	0.274 ± 0.014^{a}	0.167 ± 0.008^{b}	0.136 ± 0.007$^{a\,b}$
(24:0)	0.625 ± 0.031	0.411 ± 0.021^{b}	0.723 ± 0.036^{b}	0.520 ± 0.026^{a}	0.598 ± 0.030$^{a\,b}$	1.191 ± 0.060$^{a\,b}$
(22:3)	0.245 ± 0.012	0.245 ± 0.012	0.308 ± 0.015^{b}	0.304 ± 0.015^{a}	0.366 ± 0.018$^{a\,b}$	0.269 ± 0.014 ^{b}
(22:4), n-6	0.108 ± 0.005	0^{b}	0.153 ± 0.008^{b}	0^{a}	0.158 ± 0.008$^{a\,b}$	0.221 ± 0.011$^{a\,b}$
(22:5), n-3	0.515 ± 0.026	0.306 ± 0.015^{b}	0.405 ± 0.020^{b}	0.662 ± 0.033^{a}	0.316 ± 0.016 ^{b}	0.645 ± 0.032$^{a\,b}$
(22:6), n-3	0.457 ± 0.023	0.302 ± 0.015^{b}	0.314 ± 0.016	0.465 ± 0.023	0.480 ± 0.024^{a}	0.432 ± 0.022^{a}
(24:1)	0.332 ± 0.017	0.143 ± 0.007^{b}	0.142 ± 0.007	0.937 ± 0.047^{a}	0.351 ± 0.018$^{a\,b}$	0.213 ± 0.011$^{a\,b}$
∑ n-3, %	1.340	1.415	1.256	1.617	1.205	1.934
∑ n-6, %	25.528	28.393	20.874	25.090	28.524	25.456
∑MUFA, %	28.543	31.372	35.096	30.749	32.056	30.963
∑PUFA, %	27.113	30.053	22.438	27.011	30.095	27.659
∑SFA, %	43.478	37.538	23.672	41.274	36.894	39.453
∑C, %	55.656	61.425	57.534	57.760	62.151	58.622
∑N	348.788	407.652	341.586	373.292	422.159	374.713

Note: The difference is reliable where: $a - p \leq 0.05$ in comparison with the control group, $b - p \leq 0.05$ in comparison with previous value inside group; # - 21, 28, 35 – ontogenesis periods (days).

MSB, or its metabolites, are likely to activate the corresponding enzymes of lipid metabolism. According to Cherian G., the FA composition of tissues is regulated by activating the corresponding elongases, desaturases and accelerating microsomal and β-oxidation (Cherian, 2015).

Also, the use of MSB showed an increase of the arachidonic acid (AA) content relative to control on the 21st, 28th, and 35th days of ontogenesis. Such a fact may be a consequence of blocking its conversion in the cyclooxygenase pathway. According to (Kawamura et al., 2006; Kawamura et al., 2010), MSB dose-dependently inhibits the conversion of arachidonic acid to leukotrienes by disrupting the translocation of 5-lipoxygenase from the cytoplasm to the nuclear membrane and reducing the supply of extracellular Ca^{2+}.

It was also found that the release of arachidonic acid from phospholipids requires phospholipase-A_2, which is also a calcium-dependent enzyme. Therefore, the violation of extracellular Ca^{2+} decreases enzyme activity, which may cause the accumulation of arachidonic acid in phospholipids. The accumulation of arachidonic acid during the development of contour feathers can increase the body's resistance because it is part of the phospholipids of cell membranes. This FA interacts with protein complexes and affects the functioning of receptors in cells, transport, and signaling systems. In addition, this acid is involved in the synthesis of hormones of local action (Cherian, 2015). Moreover, redistribution of calcium in tissues is important for feather development. Ca^{2+} ions are required to activate the SHH-signaling pathway that provides feather growth and hair follicle formation (Chen et al., 2020).

Additionally, there is information in papers that using 2-methyl-1,4-naphthoquinone derivatives reduces the activation of nuclear factor NF-κB and inhibits IKKα phosphorylation. Thus, the inflammatory response suppresses (Ohsaki et al., 2010). This may reduce physiological stress and increase the productivity of poultry.

The use of MSB contributed to the increase in DPA content in our experiment on the 21st (by 28.5%; $p \leq 0.05$) and 35th day (by 59.3%; $p \leq 0.05$) comparing with the control variant. At the same time, the DHA content in the experimental group on the 28th and the 35th day increased by 58.9% ($p \leq 0.05$) and 37.6% ($p \leq 0.05$) relative to control. Accumulation of DHA can inhibit cyclooxygenase pathways. Thereby AA conversion is reducing and anti-inflammatory activity is exhibiting (Norris & Dennis, 2012). DHA also provides mechanisms for modifying the composition of cell membrane phospholipids. This affects ion channels and transporters (Hamano et al., 1996; Wang et al., 2011; Billman, 2013; Sato et al., 2014). Accumulation of DHA stabilizes cell membranes because n-3 FAs and their metabolites contribute to it (Khyzhnyak et al., 2016).

The use of MSB caused the accumulation of long-chain tetracosanoic acid during the experiment by 182.2% ($p \leq 0.05$), 145.5% ($p \leq 0.05$), and 50.0% ($p \leq 0.05$) relative to control for 21st, 28th, and 35th days, respectively. At the end of the experiment, an increase of the content of palmitoleic acid under the action of MSB by 133.0%. This acid and oleic constitute the main pool of FAs. Under the action of MSB on the 35th day of ontogenesis, the oleic acid content decreased by 21.2% ($p \leq 0.05$). This FA has a cytoprotective effect–it increases the cell's resistance to the damaging effects of reactive oxygen species (ROS) and lipophilic xenobiotics. It may be a mechanism for increasing tissue resistance to peroxidation. On the other hand, these rearrangements may result from a response to MSB-induced production of ROS. It is realized by activating lipid catabolism end products of the transcription factor Nrf2 (Ma, 2013), which regulates lipogenesis and β-oxidation of FAs (Hayes & Dinkova-Kostova, 2014). This mechanism is plausible because, according to the results of previous work (Yakoviichuk et al., 2017), the content of the lipid peroxidation end products increases a week before the registered changes. In general, the use of MSB in the selected dose causes an increase in the total content of UFA in the skeletal muscle tissue of the geese thighs. In particular, the content of n-3 FAs in skeletal muscle tissue relative to the control group on the 21st and 35th days of ontogenesis. The content of n-6 FAs increases by 22.0% on the 35th day of ontogenesis using MSB. Also, the 35th day of ontogenesis due to MSB increases PUFA and saturated FAs (SFA). The accumulation of essential n-3 and n-6 FA improves the nutritional value of poultry meat, and SFA increases the resistance of cell membranes to the active forms of oxygen.

Fatty acid composition of the muscular tissue of the stomach of geese under the action of MSB

In contrast to skeletal muscle in smooth muscle tissue, there is a tendency to reduce lipids' content and total unsaturation using the MSB (Table 2).

Table 2. Dynamic of fatty acids composition in stomach muscle tissue of control and experimental geese in ontogenesis (ω–mass part, %; N–unsaturation of FA, mMol/g) (M ± m, n=5).

FA	Control			Experiment		
	21#	28#	35#	21#	28#	35#
(12:0)	0.069 ± 0.003	0.040 ± 0.002^{b}	0.057 ± 0.003^{b}	0.037 ± 0.002^{a}	0.032 ± 0.002^{a}	0.053 ± 0.003^{b}
(12:1)	0.175 ± 0.009	0.151 ± 0.008^{b}	0.160 ± 0.008^{b}	0.104 ± 0.005^{a}	0.097 ± 0.005^{a}	0.153 ± 0.008^{b}
(13:0)	0.048 ± 0.002	0.052 ± 0.003^{b}	0^{b}	0^{a}	0.158 ± 0.008$^{a\,b}$	0.023 ± 0.001$^{a\,b}$
(14:0)	0.218 ± 0.011	0.292 ± 0.015^{b}	0.211 ± 0.011^{b}	0.255 ± 0.013	0.218 ± 0.011$^{a\,b}$	0.245 ± 0.012
(14:1)	0	0.076 ± 0.004^{b}	0^{b}	0	0^{a}	0
(15:0)	0	0	0	0	0	0
(15:1)	0.467 ± 0.023	0.046 ± 0.002	0.032 ± 0.002^{b}	0.050 ± 0.003^{a}	0.036 ± 0.002$^{a\,b}$	0.031 ± 0.002^{b}
(16:0)	23.277 ± 1.160	24.093 ± 1.210	22.133 ± 1.110	20.838 ± 1.040	21.395 ± 1.070	23.640 ± 1.180
(16:1)	0.744 ± 0.037	1.590 ± 0.080^{b}	1.155 ± 0.058^{b}	0.861 ± 0.043	0.836 ± 0.042^{a}	1.030 ± 0.052^{b}
(17:0)	0.118 ± 0.006	0.133 ± 0.007^{b}	0.177 ± 0.009^{b}	0.128 ± 0.006	0.113 ± 0.006	0.122 ± 0.006^{a}
(17:1)	0.046 ± 0.002	0.045 ± 0.002	0.047 ± 0.002	0.033 ± 0.002^{a}	0.031 ± 0.002^{a}	0.033 ± 0.002^{a}
(18:0)	21.626 ± 1.080	18.200 ± 0.910^{b}	18.232 ± 0.910	20.787 ± 1.040	21.420 ± 1.070^{a}	20.124 ± 1.010
(18:1), n-9	17.564 ± 0.880	25.500 ± 1.28^{b}	23.617 ± 1.180	20.125 ± 1.010	21.852 ± 1.093	22.801 ± 1.140
(18:2), n-6	10.304 ± 0.515	10.610 ± 0.531	10.518 ± 0.526	13.483 ± 0.674^{a}	9.736 ± 0.487^{b}	7.892 ± 0.395$^{a\,b}$
(18:3), n-3	0.324 ± 0.016	0.298 ± 0.013^{b}	0.364 ± 0.018^{b}	0.159 ± 0.008^{a}	0.128 ± 0.006$^{a\,b}$	0.100 ± 0.005$^{a\,b}$
(20:0)	0.316 ± 0.016	0.258 ± 0.013^{b}	0.291 ± 0.015^{b}	0.381 ± 0.019^{a}	0.358 ± 0.018$^{a\,b}$	0.284 ± 0.014^{b}
(20:1), n-9	0.360 ± 0.018	0.377 ± 0.019^{b}	0.359 ± 0.018^{b}	0.476 ± 0.024^{a}	0.511 ± 0.026$^{a\,b}$	0.390 ± 0.020^{b}
(20:2), n-6	0.935 ± 0.047	0.802 ± 0.040^{b}	0.732 ± 0.037^{b}	0.997 ± 0.050	0.925 ± 0.046^{b}	0.639 ± 0.032^{b}
(20:3), n-6	0	0.500 ± 0.025^{b}	0.469 ± 0.023^{b}	0.766 ± 0.038^{a}	0$^{a\,b}$	0.462 ± 0.023^{b}
(20:4), n-6	13.605 ± 0.680	8.202 ± 0.410^{b}	11.530 ± 0.580^{b}	9.664 ± 0.480^{a}	9.924 ± 0.490^{a}	11.045 ± 0.550^{b}
(22:0)	1.926 ± 0.100	1.561 ± 0.080^{b}	1.679 ± 0.084^{b}	1.920 ± 0.100	2.137 ± 0.107$^{a\,b}$	1.968 ± 0.100^{b}
(22:1), n-9	0.172 ± 0.009	0.198 ± 0.010^{b}	0.115 ± 0.006^{b}	0.100 ± 0.005^{a}	0.264 ± 0.013$^{a\,b}$	0.209 ± 0.010$^{a\,b}$
(24:0)	1.014 ± 0.051	1.234 ± 0.062^{b}	1.618 ± 0.080^{b}	1.482 ± 0.074^{a}	1.417 ± 0.071	1.855 ± 0.093^{b}
(22:3)	0.437 ± 0.022	0.283 ± 0.014^{b}	0.391 ± 0.020^{b}	0.416 ± 0.021	0.417 ± 0.021^{a}	0.358 ± 0.018^{b}
(22:4), n-6	0	0	0	0	0	0
(22:5), n-3	0	0	0	0	0	0
(22:6), n-3	3.206 ± 0.160	2.956 ± 0.148^{b}	3.405 ± 0.170^{b}	4.010 ± 0.201^{a}	4.167 ± 0.208^{a}	3.654 ± 0.183^{b}
(24:1)	2.095 ± 0.105	1.635 ± 0.082^{b}	1.782 ± 0.089^{b}	2.183 ± 0.109	2.356 ± 0.118^{a}	2.350 ± 0.118^{a}
∑ n-3, %	3.530	3.254	3.769	4.169	4.295	3.754
∑ n-6, %	24.844	20.114	23.249	24.910	20.585	20.038
∑MUFA, %	21.623	29.618	27.267	23.932	25.983	26.997
∑PUFA, %	28.811	23.651	27.409	29.495	25.297	24.150
∑SFA, %	48.612	45.863	44.398	45.828	47.248	48.314
∑C, %	50.434	53.269	54.676	53.427	51.280	51.147
∑N	399.719	357.481	401.049	399.014	377.271	375.14

Note: The difference is reliable where: a–$p \leq 0.05$ in comparison with the control group, b–$p \leq 0.05$ in comparison with previous value inside group; #-21, 28, 35–ontogenesis periods (days).

Changes in unsaturation and UFA content have a significant place in implementing mechanisms of AOP of tissue (Danchenko, 2010). As previously was found, with a background of lower average enzyme activity of AOP comparing to other studied tissues (Yakoviichuk et al., 2019), and high activity of the Krebs cycle dehydrogenases in this period, the tissue involves alternative mechanisms of antioxidant protection, one of which is the reduction of lipid unsaturation.

Using MSB, the linolenic acid content was lower than the control on the 21st, 28th and 35th days of ontogenesis. Probable changes in the content of linoleic acid were found in the experimental group at the beginning of the studied time interval (it was 30.9% ($p \leq 0.05$) higher than the control and on the 35th day, it was lower by 25.0% ($p \leq 0.05$)). It is also probably a consequence of its conversion to AA, to ensure an adaptive response of the body to the induction of MSB.

There was a significant increase of PUFA content compared to the control: linoleic, DHA by 25.1% ($p \leq 0.05$), and eicosatriene on the 21st day of ontogenesis in the stomach muscles of the experimental group of animals. At the same time, DPA is absent in the experimental tissue.

During the experiment, the content of oleic acid (which forms the main pool of FAs, under the action of the MSB) probably did not change. It indicates the maintenance of balance between prooxidant-antioxidant processes. According to the literature, oleic acid is the main endogenous acceptor of ROS. Only after the oxidation of oleic acid, the residual ROS react with other UFAs (Khyzhnyak et al., 2016).

On the 28th day of ontogenesis, under the action of MSB, linolenic acid undergoes biotransformation. A decrease of concentration by 57.1% ($p \leq 0.05$) and fully used eicosatrienoic acid result, likely to cause complete the depletion of DPA, as this FA may be synthesized through its intermediate formation. As in the skeletal muscle tissue, such changes may be due to the production of ROS in the tissue by MSB use. Realization of it goes through the activation of Nrf2 by the end products of lipid catabolism (Ma, 2013). According to the results of previous work (Yakoviichuk et al, 2019), the content of the end products of lipid peroxidation increased in the studied tissues a week before the registered changes.

There are significant fluctuations of the content of other FAs relative to the control group on the 28th day of ontogenesis. In particular, increase 20:4 by 21.0% ($p \leq 0.05$), 22:6 by 41.0% ($p \leq 0.05$) and 24:1 to 44.1% ($p \leq 0.05$).

The use of MSB initiates the conversion of linoleic and linolenic acids to more unsaturated derivatives on the 35th day of ontogenesis. It is confirmed by a decrease in their content relative to control by 25.0 and 72.5% ($p \leq 0.05$), respectively. Additionally, there is an accumulation of long-chain unsaturated 24:1 by 31.9% ($p \leq 0.05$).

The use of MSB in the smooth muscle tissue of the goose stomach increases the total content of SFA on the 35th day of ontogenesis while reducing the total content of UFA and each of their classes. However, the action of MSB on the 21st and the 28th days of ontogenesis showed an increase in the concentration of PUFA, in particular, due to n-3 on the 28th day and n-3 and monounsaturated FAs (MUFA) on the 21st day of ontogenesis. Reducing the content of essential n-6 and UFA negatively affects the product's nutritional value but increases the resistance of tissues to the active forms of oxygen.

Growth rates of geese under the action of MSB

Analysis of morphometric parameters of geese using MSB shows the anabolic effect on the average weight and average daily gain of geese compared to the control (Table 3). MSB helps increase the average weight of geese–experimental animals had more weight relative to control on the 21st and 28th days by 21.0% and 20.4%, respectively ($p \leq 0.05$). On the 35th day, this difference was only 8,0% ($p \leq 0.05$). Also, on the 21st and 28th days, the average daily gain was increased relative to the control group of animals.

Table 3. Grows indicators of control and experimental geese group (M–Average weight, g; ΔM–Average daily weight gain, g) (M ± m, n=5).

Age, days	Control		Experiment	
	M	**ΔM**	**M**	**ΔM**
21	964.3 ± 34.3	68.3	1166.7 ± 13.8^{a}	89.5
28	1237.7 ± 44.3^{b}	39.1	1490.7 ± 26.2$^{a\,b}$	46.3
35	1713.0±25.5^{b}	67.9	1850.3±40.8$^{a\,b}$	51.4

Note: The difference is reliable where: a–$p \leq 0.05$ in comparison with the control group, b–$p \leq 0.05$ in comparison with previous value inside the group; #-21, 28, 35–ontogenesis periods (days).

No information has been found in the scientific literature about the anabolic effects of MSB and its analogs for geese. However, broiler chickens were found to increase average weight –3.9% with the addition of MSB and 8.2% with nicotinamide form of menadione sulfate at a dose of 2.5 g/t of feed (Saparova, 1999) (without specifying the ontogenesis periods in the paper). At the same time, Ivanova reports that the use of MSB at a dose of 5 g/t of feed increases the average weight of broiler chickens in ontogenesis, respectively by 11.0; 9.5; 8.9, and 6.6% for 10-, 20-, 30- and 40-day-old chickens (Ivanova, 2003). This data correlates with our experimental results for geese. The average daily gains for broilers also increased – the peak of productivity was

set from the 21st to the 30th day of ontogenesis. This data corresponds with the results obtained for geese. This period is characterized by increased heat production, rapid plumage, and increasing demand for feed. Such period is associated primarily with the end of the contour feathers' growth, with the consolidation of conditioned reflexes for feeding and adaptation to environmental conditions (Ivanova, 2003).

Conclusion

According to the experiment results, a specific effect of MSB on the content of certain FAs in skeletal muscle and muscular stomach of geese was established. In particular, depending on the period of geese ontogenesis, MSB can stimulate the biosynthesis processes and catabolism of FAs. The use of MSB helps increase the total content of UFAs in skeletal muscle, primarily due to n-3 FAs. On the 35th day of ontogenesis, MSB increases the content of PUFA and SFA–these compounds improve the nutritional value of meat and the resistance of myocyte membranes to oxidative damage. MSB increases the content of UFA on the 21st day of ontogenesis due to PUFA, in particular, n-3 in the smooth muscle tissue of the goose stomach. On the 28th day of ontogenesis, the content of PUFA increases, in particular, due to n-3 FAs, while the total content of UFA is reducing. Reducing the content of essential n-6 and UFA negatively affects the product's nutritional value but increases the resistance of tissues to the active forms of oxygen. The use of MSB contributes to the overall increase in the average daily weight gain of geese from 21st to 28th days. The average body weight increases due to the MSB action from the 21st to 35th days of ontogenesis relative to the control group of birds. In addition, the overall increase of essential FAs in skeletal muscle tissue was noted during the experiment. These facts give a reason to recommend using MSB at a dose of 0.7 mg/kg body weight for feeding goslings.

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Conflict of Interest

The authors declared that they have no conflict of interest in this study.

References

Aoganghua, A., Nishiumi, S., Kobayashi, K., Nishida, M., Kuramochi, K., Tsubaki, K., Yoshida, M. (2011). Inhibitory effects of vitamin K3 derivatives on DNA polymerase and inflammatory activity. International Journal of Molecular Medicine, 28:937-945.

Arnold, W., Giroud, S., Valencak, T. G., Ruf, T. (2015). Ecophysiology of omega fatty acids: a lid for every jar. Physiology, 30:232-240.

Billman, G.E. (2013). The effects of omega-3 polyunsaturated fatty acids on cardiac rhythm: a critical reassessment. Pharmacology & Therapeutics, 140:53-80.

Bolton, J.L., Dunlap, T. (2017). Formation and biological targets of quinones: cytotoxic versus cytoprotective effects. Chemical Research in Toxicology, 30:13-37.

Carter, W.A., Whiteman, J.P., Cooper-Mullin, C., Newsome, S.D., McWilliams, S.R. (2019). Dynamics of individual fatty acids in muscle fat stores and membranes of a songbird and its functional and ecological importance. Physiological and Biochemical Zoology, 92:239-251.

Chen, M.J., Xie, W.Y., Jiang, S.G., Wang, X.Q., Yan, H.C., Gao, C.Q. (2020). Molecular Signaling and Nutritional Regulation in the Context of Poultry Feather Growth and Regeneration. Frontiers in Physiology, 10:1609.

Cherian, G. (2015). Nutrition and metabolism in poultry: role of lipids in early diet. Journal of Animal Science and Biotechnology, 6:1-9.

Committee for veterinary medicinal products. (1998). Phytomenadione (vitamin K1) and menadione (vitamin K3) summary report. The European Agency for the Evaluation of Medicinal ProductsVeterinary Medicines Evaluation Unit.

Danchenko, M., Ruban, H., Danchenko, O., Yakoviichuk, O., Klimashevskyi, V., Konovalenko, T., Haponenko, T. (2019). The effect of vitamin E on the quality of geese meat.

Danchenko, O.O. (2010). Antioxidant status of domestic geese under different anthropogenic load.

Delaney, S.J., Dzanis, D.A. (2018). Safety of vitamin K, and its use in pet foods. Journal of the American Veterinary Medical Association, 252:537-542.

Duarte, C.R.A., Bratti, F.C., Murakami, A.E., Fernandes, J.I.M., Ospina-Rojas, I.C., Furlan, A.C. (2014). Effects of vitamin K3 supplementation on growth performance and bone quality of broiler chickens. Archivos de Medicina Veterinaria, 46:305-313.

EFSA Panel on Additives and Products or Substances used in Animal Feed (FEEDAP). (2014). Scientific Opinion on the safety and efficacy of vitamin K3 (menadione sodium bisulphite and menadione nicotinamide bisulphite) as a feed additive for all animal species. EFSA Journal, 12:3532.

Ferland, G. (2012). The discovery of vitamin K and its clinical applications. Annals of Nutrition and Metabolism, 61:213-218.

Guglielmo, C.G. (2010). Move that fatty acid: fuel selection and transport in migratory birds and bats. Integrative and Comparative Biology, 50:336-345.

Guo, S., Xv, J., Li, Y., Bi, Y., Hou, Y., Ding, B. (2020). Interactive effects of dietary vitamin K 3 and Bacillus subtilis PB6 on the growth performance and tibia quality of broiler chickens with sex separate rearing. Animal, 14:1610-1618.

Hamano, H., Nabekura, J., Nishikawa, M., Ogawa, T. (1996). Docosahexaenoic acid reduces GABA response in substantia nigra neuron of rat. Journal of Neurophysiology, 75:1264-1270.
Hassan, G.S. (2013). Menadione. Profiles of drug substances, excipients and related methodology, 38:227-313.
Hayes, J.D., Dinkova-Kostova, A.T. (2014). The Nrf2 regulatory network provides an interface between redox and intermediary metabolism. Trends in Biochemical Sciences, 39:199-218.
Hulbert, A.J. (2010). Metabolism and longevity: is there a role for membrane fatty acids?. Integrative and Comparative Biology, 50:808-817.
Ichihara, K.I., Fukubayashi, Y. (2010). Preparation of fatty acid methyl esters for gas-liquid chromatography [S]. Journal of Lipid Research, 51:635-640.
Ivanova, O.V. (2003). The effect of vicasol and probiotics on the productivity of broiler chickens.
Ivko, I.I., Mykytyuk, D.M., Melnyk, V.O., Ryabinina, O.V., Bratyshko, N.I. (2009). Recommendations for targeted breeding, keeping and fattening of waterfowl. Birky.
Kawamura, F., Hirashima, N., Furuno, T., Nakanishi, M. (2006). Effects of 2-methyl-1, 4-naphtoquinone (menadione) on cellular signaling in RBL-2H3 cells. Biological and Pharmaceutical Bulletin, 29:605-607.
Kawamura, F., Nakanishi, M., Hirashima, N. (2010). Effects of menadione, a reactive oxygen generator, on leukotriene secretion from RBL-2H3 cells. Biological and Pharmaceutical Bulletin, 33:881-885.
Khyzhnyak, S.V., Midyk, S.V., Sysoliatin, S.V., Voitsitsky, V.M. (2016). Fatty acids composition of inner mitochondrial membrane of rat cardiomyocytes and hepatocytes during hypoxia-hypercapnia. Ukrainian Biochemical Journal, 88:92-98.
Wang, X. (2001). The expanding role of mitochondria in apoptosis. Genes & Development, 15:2922-2933.
Marchionatti, A.M., Pacciaroni, A., de Talamoni, N.G.T. (2013). Effects of quercetin and menadione on intestinal calcium absorption and the underlying mechanisms. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 164:215-220.
McCue, M.D., Amitai, O., Khozin-Goldberg, I., McWilliams, S.R., Pinshow, B. (2009). Effect of dietary fatty acid composition on fatty acid profiles of polar and neutral lipid tissue fractions in zebra finches, Taeniopygia guttata. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 154:165-172.
Nieto, G., Ros, G. (2012). Modification of fatty acid composition in meat through diet: effect on lipid peroxidation and relationship to nutritional quality—a review. Lipid Peroxidation, 12:239-258.
Norris, P.C., Dennis, E.A. (2012). Omega-3 fatty acids cause dramatic changes in TLR4 and purinergic eicosanoid signaling. Proceedings of the National Academy of Sciences, 109:8517-8522.
Ohsaki, Y., Shirakawa, H., Miura, A., Giriwono, P. E., Sato, S., Ohashi, A., Komai, M. (2010). Vitamin K suppresses the lipopolysaccharide-induced expression of inflammatory cytokines in cultured macrophage-like cells via the inhibition of the activation of nuclear factor κB through the repression of IKKα/β phosphorylation. The Journal of Nutritional Biochemistry, 21:1120-1126.
Rymer, C., Givens, D.I. (2005). n−3 fatty acid enrichment of edible tissue of poultry: A review. Lipids, 40:121-130.
Saparova, E.I. (1999). The effectiveness of using different dosages of nicotinamide form of vicasol in the diet of broiler chickens.
Sato, K., Chino, D., Nishioka, N., Kanai, K., Aoki, M., Obara, K., Tanaka, Y. (2014). Pharmacological Evidence Showing Significant Roles for Potassium Channels and Cytochrome P450 Epoxygenase Metabolites in the Relaxant Effects of Docosahexaenoic Acid on the Rat Aorta Contracted with U46619. Biological and Pharmaceutical Bulletin, 37:394-403.
Shimozuru, M., Kamine, A., Tsubota, T. (2012). Changes in expression of hepatic genes involved in energy metabolism during hibernation in captive, adult, female Japanese black bears (Ursus thibetanus japonicus). Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology, 163:254-261.
Skrip, M.M., McWilliams, S.R. (2016). Oxidative balance in birds: An atoms-to-organisms-to-ecology primer for ornithologists. Journal of Field Ornithology, 87:1-20.
Starčević, K., Mašek, T., Brozić, D., Filipović, N., Stojević, Z. (2014). Growth performance, serum lipids and fatty acid profile of different tissues in chicken broilers fed a diet supplemented with linseed oil during a prolonged fattening period. Veterinarski arhiv, 84:75-84.
Sündermann, A., Eggers, L.F., Schwudke, D. (2016). Liquid extraction: bligh and dyer. Encyclopedia of Lipidomics. Edited by Wenk MR. Springer Netherlands, pp:1-4.
Trembecka, L., Haščík, P., Čuboň, J., Bobko, M., Pavelkova, A. (2016). Fatty acids profile of breast and thigh muscles of broiler chickens fed diets with propolis and probiotics. Journal of Central European Agriculture.
Wang, R.X., Li, K.L., Zhang, C.Y., Zheng, J., Guo, S.X., Wu, Y., Lee, H.C. (2011). Mechanism related to docosahexaenoic acid induced large conductance calcium-activated potassium channel currents increase in coronary smooth muscle cells. Zhonghua Xin Xue Guan Bing Za Zhi, 39:348-352.
Wiraswati, H.L., Hangen, E., Sanz, A.B., Lam, N.V., Reinhardt, C., Sauvat, A., Modjtahedi, N. (2016). Apoptosis inducing factor (AIF) mediates lethal redox stress induced by menadione. Oncotarget, 7:76496.
Yakoviichuk, O.V., Danchenko, O.O., Kurtyak, B., Nikolaeva, Y., Fedorko, A.S., Halko, T. (2018). Ontogenetic features of redox reactions in the myocardium of geese. Biologija, 64:259-266.
Yakoviichuk, O.V., Danchenko, O.O., Danchenko, M.M., Fedorko, A.S., Gaponenko, T.M. (2019). The effect of vikasol on the activity of Krebs cycle dehydrogenases and the state of the antioxidant defense system of the stomach muscles of geese. Bioresources and Nature Management, 11:15–24.

Yakoviichuk, O.V., Danchenko, O.O., Danchenko, M.M., Fedorko, A.S., Kulyk, I.O. (2019). Fatty acid composition of goose myocardium affected by vicasol. Scientific Issue Ternopil Volodymyr Hnatiuk National Pedagogical University. Series: Biology, 77:32-38.

Yakoviichuk, O.V., Ruban, H.V., Danchenko, O.O. (2017). Influence of vicasol on the activity of Krebs cycle enzymes, antioxidant system and peroxide oxidation in the muscles of geese. Animal Husbandry Products Production and Processing, 134:105-112.

Zdorovtseva L.M., Khromishev V.O., Danchenko O.O. (2012). Geese fatty acid composition of brain and heart lipids in hypo- and hyperoxia. Biological Bulletin of Bogdan Chmelnitskiy Melitopol State Pedagogical University, 2:9-18.

Zhou, L.J., Wu, H., Li, J.T., Wang, Z.Y., Zhang, L.Y. (2012). Determination of fatty acids in broiler breast meat by near-infrared reflectance spectroscopy. Meat Science, 90:658-664.

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