Extract of oats as a modulator of fatty acid composition of geese tissues in the conditions of physiological stress

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Feeding natural antioxidant supplements to animals and birds has multiple advantages over traditional synthetic vitamins of the antioxidant group. This study investigated the effect of the *Avena sativa* extract on the antioxidant status and fatty acid composition of liver tissues, the brain, and skeletal muscles of geese, live weight dynamics, and pterylographic parameters during physiological stress of formation of contour and juvenile feathers. It is confirmed that adding oat extract to the geese diet during physiological stress increases tissue antioxidant activity. It was established that during the formation of contour feathers (day 28), the voltage of the antioxidant system is significantly weakened by the action of the extract due to selective inhibition of the synthesis of unsaturated fatty acids, in particular oleic. The synthesis of palmitic and stearic acids is activated. The oat extract caused the most remarkable changes in liver tissues. The subsequent period of formation of juvenile feathers (49 days) is characterized by equalization of the composition of fatty acids in the control and experimental groups. At the end of the experiment, the mass of the geese of the experimental group increased by 17.9% and their pterylographic parameters improved.

Keywords: geese, antioxidant activity, oat extract, fatty acid composition, feathers
INTRODUCTION

The use of antioxidants in feeding birds helps to eliminate the harmful effects of negative factors of different aetiologies. The use of natural antioxidant additives in feeding birds has a number of advantages over traditional synthetic additives. In addition to the known compounds of the phenolic nature of bioflavonoids, more complex phenols – avenantramides, which are characterized by 10–30 times higher antioxidant activity than other natural antioxidants (Nie et al., 2006; Viskupičová et al., 2008; Skoglund, 2008; Deydani, 2009; Antonini et al., 2017; Chen et al., 2018) have been found in the grass of oats. Fatty acids are the main components of cell membranes; they play a key role in energy homeostasis and participate in the antioxidant tissue response (Danchenko et al., 2012). It is also known that fatty acid synthase (FAS) is a multienzymatic complex that catalyses the synthesis of de novo fatty acids. Inhibition of these enzymes, in turn, may be subject to inhibition by the action of natural flavonoids (Brand et al., 2005). The geese of the experimental group were kept on a standard diet balanced on extraneous proteins.

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MATERIALS AND METHODS

The research was conducted on Legarth geese. On the principle of analogues, two groups of 14-day-old geese (control and experimental), 26 birds in each, were formed. Throughout the experiment, the birds of the control group were kept on a standard diet balanced on exchange energy, protein, and vitamins in accordance with the recommendations (Ryabokon, 2005). The geese of the experimental group drank oat extract from day 14 to day 49. For the extraction of bioflavonoids of the Avena sativa, the aboveground part in the earing and flowering phase was used. The removal of flavonoids from the raw material was carried out with the help of water (the ratio of the raw material and extractant was 1:10, the extraction time in the boiling water bath was 60 min) followed by the extract diluted three times.

The slaughter of the geese and the selection of the biological material for biochemical studies were carried out in compliance with the standards of the Convention of the Council of Europe on the protection of animals used in scientific research. Research material was the tissues of the brain, liver, and the muscle tissue of geese. Determination of antioxidant activity and fatty acid composition of these tissues was carried out at physiologically grounded terms: day 14 – completion of postnatal adaptation, day 28 – formation of contour feathers, day 49 – formation of juvenile feathers, and day 56 – presence of the formed feathers and stabilization of the prooxidant-antioxidant equilibrium (Khvostyk, 2013).

Intensity of peroxide oxidation processes was evaluated by the content of their end products (TBARCs) in tissue homogenates and by the initiation of Fe²⁺ (TBARCs) lipid peroxidation (Ionov et al., 2011). As an integral indicator of the state of the antioxidant protection system (AOP), the coefficient of antioxidant activity (CAOA) was used. It was calculated as the ratio of TBARCs to TBARCs, since tissue homogenates contain not only the peroxidation substrate, but also components of the AOP system that can inhibit lipid peroxidation (Danchenko et al., 2012).

The content of the fatty acids was determined by gas-liquid chromatography; lipid extracts for analysis was carried out according to E. G. Bligh and W. J. Dyer (1959) with the recommendations of F. B. Palmer (1971). In addition to the total content of unsaturated fatty acids (UFA) (Σω, %), the total equivalent concentration of fatty acids (FA) was calculated for the multiple bonds (unsaturation, Ŕ2N, mmol/100 g) (Danchenko et al., 2003).

In parallel, the dynamics of the live weight of geese and their pterylographic parameters were monitored. The statistical processing of the results was carried out with Microsoft Office Excel 2013 and SPSS v.13 packages with the Student t-criterion (Landau, Everitt, 2003).

RESULTS AND DISCUSSION

Eggshell hatching of the embryos at the end of the embryonic period causes a transition from hypoxia to hyperoxygenation of atmospheric respiration. This is the genetically-programmed oxidative stress (OS). The ability of the chicks to form an adaptive response to OS at this age is determined by the initial quality of the hatching eggs and the conditions of their incubation. A number of studies have shown that when the diet is balanced and technological conditions are maintained, the postnatal adaptation of the geese is completed by the age of two weeks (Sheremet, Melnik, 2014). Formation of the adaptive response to the conditions of postnatal existence during the first two weeks of the life of the geese is accompanied by an increase in the antioxidant status of their organism (Pushchenko, 2020). The results of the experiment confirmed the sufficient level of oxidative stress in all investigated tissues of 14-day-old geese (Table 1).

From day 14 to day 28, the contour feathers are formed, and in the birds of the control group, the decrease in CAOA was observed in all investigated tissues, namely: in the liver by 48.0%, the brain 57.6%, and in skeletal muscles by 29.4%. At the same time, the influence of the oat extract, the reduction of antioxidant activity significantly decreased in the tissues of 28-day-old geese of the experimental group. Thus, the liver COA of this group decreased by only 37.3% compared with the 14-day limit, the brain COA by 15.8%, and skeletal muscles by 25.0%.

It is known that one of the mechanisms for increasing the antioxidant status of tissues of a functioning organism during physiological stress may be the reduction of the content of the main substrate of peroxide oxidation of lipids of unsaturated fatty acids and, accordingly, of the ability of lipid of biomembranes to oxidative damage. The determination of the changes in the fatty acid composition during the formation of contour and juvenile feathers will allow assessing their role in increasing the adaptive potential of geese at this stage of development.

A comparative analysis of fatty acid composition (FAC) of the investigated tissues of the geese of the control group on day 14 and day 28 suggests the presence of certain changes in the composition of fatty acids. However, these differences are insignificant compared with the differences in FAC of 28-day-old geese of the control and experimental groups. First of all, attention is paid to the sharp drop in the total content of UFA under the influence of the extract. Thus, in the liver tissues of the experimental group, the indicator decreased by

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Table 1. Coefficient of antioxidant activity in tissues and live weight of geese (M ± m, n = 6)

| Tissue | Group | 14 | 28 | 49 | 56 |
|--------|-------|----|----|----|----|
| Brain  | control | 0.57 | 0.42 | 0.40 | 0.42 |
|        | experimental | 0.57 | 0.48 | 0.51 | 0.53 |
| Liver  | control | 0.59 | 0.25 | 0.31 | 0.42 |
|        | experimental | 0.59 | 0.37 | 0.42 | 0.53 |
| Skeletal muscle | control | 0.68 | 0.48 | 0.33 | 0.42 |
|        | experimental | 0.68 | 0.51 | 0.45 | 0.53 |

| Weight of geese, kg | control | 0.61 ± 0.13 | 2.05 ± 0.11 | 2.68 ± 0.14 | 2.95 ± 0.09 |
|                     | experimental | 0.61 ± 0.13 | 2.12 ± 0.08 | 2.91 ± 0.10 | 3.48 ± 0.13 |

Note: difference is probable relative to the control group: * p ≤ 0.05.

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18.3 times (Table 2), in the brain by 2.46 times (Table 3), and in the skeletal muscle by 3.62 times (Table 4) compared with the control group.

The largest decrease of unsaturation of the FA was in the liver (10.5 times) and the smallest in the brain (1.85 times). Consequently, an increase in antioxidant activity occurs both at the expense of the reduction of the total content of UFA and selective metabolism of UFA aimed at reducing the content of polyunsaturated fatty acids (PUFAs). Among all the differences in the UFA in tissues of 28-day-old geese, attention is drawn to the sharp drop in the content of oleic acid under the influence of the extract: in the liver of the experimental group of geese, this figure is 161.4, in the brain 43.6, and in the skeletal muscle – 86.5 times smaller than the corresponding control group.

Table 2. The content (μg, %) and total unsaturation (ΣN, m mol/100 g) of fatty acids in the liver of the geese of the control (C) and experimental (E) groups (M ± m, n = 5)

| Acid          | 14       | 28       | 49       | 56       | 14       | 28       | 49       | 56       |
|--------------|---------|---------|---------|---------|---------|---------|---------|---------|
|              | C   | E   | C   | E   | C   | E   | C   | E   | C   | E   | C   | E   | C   | E   |
| (16:0)       | 28.76 ± 1.23 | 27.29 ± 0.93 | 50.83 ± 2.14** | 27.11 ± 1.09 | 25.80 ± 1.17 | 24.21 ± 1.07 | 19.07 ± 0.67* |
| (18:0)       | 19.87 ± 0.94 | 25.02 ± 0.74 | 42.27 ± 1.32** | 25.51 ± 1.73 | 23.21 ± 0.95 | 22.93 ± 0.99 | 25.64 ± 1.12 |
| (18:1)       | 34.45 ± 1.25 | 29.05 ± 0.82 | 0.18 ± 0.01** | 27.00 ± 0.98 | 25.73 ± 1.03 | 23.02 ± 1.14 | 22.96 ± 0.98 |
| (18:2)       | 5.44 ± 0.37 | 7.70 ± 0.21 | 0.08 ± 0.00** | 8.69 ± 0.27 | 7.91 ± 0.24 | 8.88 ± 0.31 | 8.48 ± 0.39 |
| (18:3)       | 0.04 ± 0.00 | 0.04 ± 0.00 | 0.00 ± 0.00** | 0.08 ± 0.00 | 0.07 ± 0.00 | 0.02 ± 0.09 | 0.01 ± 0.00** |
| (20:2)       | 4.19 ± 0.28 | 5.43 ± 0.20 | 1.42 ± 0.03** | 7.66 ± 0.28 | 9.77 ± 0.29* | 12.45 ± 0.42 | 16.66 ± 0.58** |
| (20:3)       | 0.15 ± 0.00 | 0.32 ± 0.01 | – | 0.55 ± 0.02 | 0.86 ± 0.03** | 0.55 ± 0.02 | 0.71 ± 0.03** |
| (20:4)       | 0.26 ± 0.01 | 0.13 ± 0.00 | – | 0.51 ± 0.03 | 1.04 ± 0.04** | 1.12 ± 0.03 | 1.48 ± 0.06* |
| Σω UFA    | 47.8 ± 2.05 | 45.88 ± 2.31 | 47.47 ± 1.87 | 49.70 ± 2.52 |
| Σω N      | 239.03 ± 90.59 | 238.80 ± 90.59 | 290.96 ± 90.59 | 321.94 ± 90.59 |

Note: difference is probable relative to the control group: * – p ≤ 0.05,** – p ≤ 0.01.

Table 3. The content (μg, %) and total unsaturation (ΣN, m mol/100 g) of fatty acids in the brain of the geese of the control (C) and experimental (E) groups (M ± m, n = 5)

| Acid          | 14       | 28       | 49       | 56       | 14       | 28       | 49       | 56       |
|--------------|---------|---------|---------|---------|---------|---------|---------|---------|
|              | C   | E   | C   | E   | C   | E   | C   | E   | C   | E   | C   | E   | C   | E   |
| (16:0)       | 29.39 ± 1.35 | 32.67 ± 1.17 | 44.04 ± 1.57** | 25.86 ± 1.17 | 25.24 ± 1.03 | 25.66 ± 1.12 | 21.95 ± 0.96 |
| (18:0)       | 20.17 ± 1.08 | 25.24 ± 1.04 | 38.17 ± 1.05** | 22.06 ± 0.93 | 21.82 ± 0.97 | 22.51 ± 0.93 | 21.21 ± 0.98 |
| (18:1)       | 22.02 ± 0.89 | 22.72 ± 0.72 | 0.42 ± 0.01** | 21.95 ± 1.02 | 21.73 ± 0.83 | 21.85 ± 1.05 | 21.23 ± 0.83 |
| (18:2)       | 0.67 ± 0.02 | 0.95 ± 0.03 | 1.48 ± 0.03** | 1.46 ± 0.04 | 1.15 ± 0.04* | 0.70 ± 0.02 | 1.04 ± 0.03* |
| (18:3)       | 0.08 ± 0.00 | 0.37 ± 0.02** | – | – | – | – | – |
| (20:2)       | 6.87 ± 0.31 | 6.85 ± 0.16 | 8.66 ± 0.27* | 7.43 ± 0.27 | 6.30 ± 0.19* | 6.98 ± 0.24 | 9.26 ± 0.27* |
| (20:3)       | 0.75 ± 0.26 | 0.66 ± 0.02 | 0.06 ± 0.00** | 0.93 ± 0.03 | 1.05 ± 0.06 | 0.88 ± 0.03 | 1.07 ± 0.03 |
| (22:2)       | 1.66 ± 0.00 | 2.11 ± 0.08 | 0.17 ± 0.01** | 3.31 ± 0.13 | 3.11 ± 0.05 | 364 ± 0.11 | 5.63 ± 0.18** |
| (22:3)       | 3.99 ± 0.09 | 3.68 ± 0.12 | – | 6.56 ± 0.22 | 7.11 ± 0.26 | 7.65 ± 0.29 | 7.15 ± 0.2 |
| Σω UFA    | 39.68 ± 2.05 | 36.66 ± 2.05 | 45.77 ± 2.05 | 47.45 ± 2.05 |
| Σω N      | 287.45 ± 90.59 | 275.77 ± 90.59 | 368.10 ± 90.59 | 364.39 ± 90.59 |

Note: difference is probable relative to the control group: * – p ≤ 0.05,** – p ≤ 0.01.
The completion of feathering processes of 56-day-old geese is accompanied by the stabilization of the prooxidant-antioxidant equilibrium in the tissues. The transition to this state is characterized by a gradual increase in the total content of UFA and unsaturation of FA. In the liver, the increase of unsaturation occurs mainly due to AA and docosahexaenoic acid. In the brain, it occurs due to LA, AA, and docosatetraenoic acid.

In the skeletal muscle, a certain tendency of an increase in the total content of UFA was observed at the expense of OA and linoleic acid against the background of reduction of the content of other PUFA, and this was accompanied by a decrease in the unsaturation of FA.

Thus, the antioxidant activity of the oat extract at the earlier stages of the development of the bird organism is manifested by selective modulation of the synthesis of fatty acids.

The control of the weight dynamics of the geese during the experiment indicates a certain tendency of weight increase in the geese of the experimental group compared with the control one (Table 1). However, a significant weight increase in the geese of the experimental group compared to the control group (17.9%) was observed only at the end of the experiment, at 56 days of age, and this was an additional confirmation of the activation of the AOP of geese under the influence of the oat extract.

During the comparative analysis of the plumage stage in the geese of the control and experimental groups at the end of the experiment (Figure), it was found that in the control group the birds’ feathers – especially the fly feathers that were in the process of formation – looked sloppy. The development of feathers was somewhat delayed (Figure), especially the primary and secondary flywheel and steering feathers compared to the control; in addition, the growth of feathers on the hips and the sides of the trunk was delayed.

In the experimental group, the plummage, overall, and on all individual parts, looked healthy and fresh. The flywheel and steering feathers on the back continued to grow. On other parts, the growth and development of feathers was complete, including feathers and feather-brush on the fifth point.

Consequently, the addition of oats to the diet of geese during the formation of feathers increased the antioxidant activity of geese tissues. Increasing the antioxidant activity in geese tissues contributes not only to a significant increase in the weight of the geese at the end of the experiment, but also to the improvement of the pterylographic parameters.

CONCLUSIONS

Inclusion of the oat extract in the diet of geese stabilizes the prooxidant-antioxidant balance in their tissues, and provides an increase in the antioxidant activity of these tissues during physiological stress the formation of feathers. Under the influence of the oat extract, the physiological tension associated with the formation of contour feathers is significantly weakened in the geese organism by the inclusion of regulatory mechanisms that selectively inhibit the synthesis of NLCs and thus weaken the ability of peroxidation. Forming juvenile feathers is characterized by a lack of significant difference in FSW 49-day-old geese control and experimental groups. Increasing the antioxidant activity in geese tissues contributes not only to a significant increase in their mass at the end of the experiment, but also to the improvement of the pterylographic parameters.

The condition of feathers of the wings of the geese of the control (a) and experimental (b) groups at 56 days of age

Figure. The condition of feathers of the wings of the geese of the control (a) and experimental (b) groups at 56 days of age

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AVIŲ EKSTRAKTAS KAIP ŽASŲ AUDINIŲ RIEBALŲ RŪGŠČIŲ SUDĖTIES MODULIATORIUS FIZIOLOGINIO STRESO SĄLYGOMIS

Santrauka
Augintinių maitinimas natūraliais antioksidantų papildais yra kur kas pranašesnis, palyginti su tradiciniais antioksidantų grupės vitaminais. Šiame tyrime buvo tiriamas avižų ekstrakto „Avena sativa“ poveikis žąsų kepenų, smegenų ir griauciuų raumenų audinių antioksidantų būkle bei riebalų rūgščių sudėčiai, gyvojo svorio dinamikai, taip pat pterilografiniams parametrams formuojantį kontūrinėms ir jauniklio plunksnoms. Tyrimas patvirtino, kad į žąsų mitybą įtrauktas avižų ekstraktas padidina audinių antioksidantinį aktyvumą fiziologinio streso metu. Nustatyta, kad formuojantį kontūrinėms plunksnoms (28-oji diena) minėtas ekstraktas, selektiui slopindamas nesočiųjų riebalų rūgščių, ypač oleino, sintezę, gerokai sumažina antioksidantų sistemų įtampą. Aktyvuoja palmitino ir stearino rūgščių sintezė. Ryškiausius pokyčius avižų ekstraktas sukėlė kepenų audiniuose. Vėlesnis jauniklių plunksnų susidarymo laikotarpis (49 dienos) pasižymi panašaus riebalų rūgščių sudėtimi kontroliuojame ir eksperimentinėje grupėse. Eksperimento pabaigoje bandomosios grupės žąsų masė buvo 17,9 % didesnė, pagerėjo pterilografiniai parametrai.

Raktažodžiai: žąsys, antioksidantinis aktyvumas, avižų ekstraktas, riebalų rūgščių sudėtis, plunksnos