AGRICULTURAL BIOLOGY,
2020, V. 55, № 6, pp. 1159-1170
(SEL'SKOKHOZYAISTVENNAYA BIOLOGIYA)

ISSN 2412-0324 (English ed. Online)
ISSN 0131-6397 (Russian ed. Print)
ISSN 2313-4836 (Russian ed. Online)

## Physiology, pathology

*UDC 636.52/.58.087.3*

doi: 10.15389/agrobiology.2020.6.1159eng
doi: 10.15389/agrobiology.2020.6.1159rus

# THE PHYSIOLOGICAL ASPECTS OF THE SUPPLEMENTATION OF DIETS FOR BROILERS (*Gallus gallus* L.) WITH DIFFERENT VEGETABLE OILS

**V.G. VERTIPRAKHOV** ✉**, I.A. EGOROV, E.N. ANDRIANOVA, A.A. GROZINA**

*Federal Scientific Center All-Russian Research and Technological Poultry Institute RAS,* 10, ul. Ptitsegradskaya, Sergiev Posad, Moscow Province, 141311 Russia, e-mail Vertiprakhov63@mail.ru (✉ corresponding author), olga@vnitip.ru, andrianova@vnitip.ru, Alena_fisinina@mail.ru
ORCID:
Vertiprakhov V.G. orcid.org/0000-0002-3240-7636
Andrianova E.N. orcid.org/0000-0002-6769-6351
Egorov I.A. orcid.org/0000-0001-9122-9553
Grozina A.A. orcid.org/0000-0001-9654-7710
The authors declare no conflict of interests
Acknowledgements:
Supported financially from the Russian Science Foundation for the Project No. 16-16-04089-П "Study of physiological and microbiological aspects of digestion in meat chicken in embryonic and post-embryonic periods to develop diets which fully meet the genetic potential of poultry"
*Received September 24, 2020*

Abstract

The full-diet compound feeds with balanced contents of all limiting macro- and micronutrients are the essential key to the high productive performance in broilers (*Gallus gallus* L.). Fats are indispensable ingredients of animal diets necessary for energy supply and body structure, the source of essential polyunsaturated fatty acids (PUFAs), fat-soluble vitamins, and other bioactive compounds. This multi-functionality determines the physiological role of fats in nutrition. Vegetable oils (unlike animal one) contain a wide range of PUFAs playing an important biological role as a structural component of cell membranes. It is known that fatty acid profiles of individual vegetable oils do not fit the proportion of saturated, monounsaturated, and polyunsaturated fatty acids necessary for full support of the physiological requirements in human and animals. The optimization of the mixtures of different vegetable oils aimed at the improvement of fatty acid nutrition in human is at presented widely discussed; however, this aspect is often missed in the formulation of diets for poultry. In a previous study we presented the pioneer data on the correlation between the activities of the digestive enzymes in the intestine and blood in poultry was obtained. The aim of the study presented was the investigation of the effects of dietary lipid profile on the productive performance, digestibility of dietary nutrients, and biochemical blood indices in broilers. The trial was performed in 2019 in conditions of a vivarium on four treatments of broilers (cross Smena 8, 38 birds per treatment) from 1 to 35 days of age. The basal diets common for all treatments were supplemented with four different vegetable oils: sunflower oil (SFO, control treatment), soybean oil (SBO), flaxseed oil (FSO), and rapeseed oil (RSO) in doses 3.1 % of total diet from 1 to 21 days of age and 6.0 % from 22 to 35 days of age. The indices of the productive performance were recorded (live bodyweight weekly by individual weighing, mortality, average daily weight gains, feed consumption, feed conversion ratio FCR). At 30-35 days of age the balance trial was performed to determine the digestibility and retention rates of dietary nutrients; the biochemical blood indices and the activities of the digestive enzymes in pancreatic tissue were determined. The results evidenced that RSO significantly ($p < 0.05$) increased average live bodyweight at 14, 21, and 28 days of age in compare to control by 1.97; 10.51 and 2.85%, respectively; at 35 days of age this difference was 7.31 % while FCR was lower by 6.49 % in compare to control. RSO improved the digestibility of crude protein by 2.74 % and crude fat by 3.08 %; these improvements resulted in more intense growth in compare to control. It was found that dietary vegetable oils affected lipid profile and the activities of the digestive enzymes and alkaline phosphatase in blood serum thus indicating the modulation of lipid metabolism; the effects were specific and related to the fatty acid profiles of the oils.

Keywords: broiler chicks, sunflower oil, soybean oil, rapeseed oil, flaxseed oil, biochemical blood indices.

To ensure high productivity of broilers, full-diet compound feeds are required, balanced in all limiting nutrients. In poultry feeding, fats are one of the important irreplaceable nutrients, energy and plastic material, a source of essential polyunsaturated acids, fat-soluble vitamins, and other biologically active compounds [1]. The physiological role of fats in nutrition is due to their diverse functions in the organism [2, 3]. Vegetable oils, unlike animal fats, contain a rich set of polyunsaturated fatty acids (PUFAs), the biological function of which is determined by their role as structural elements of biomembranes of cells. PUFAs are involved in the regulation of cell metabolism, normalization of blood pressure, and platelet aggregation [4]. They affect the metabolism of cholesterol, stimulating its oxidation and excretion from the body; have a normalizing effect on the walls of blood vessels; participate in the exchange of B vitamins; stimulate the defense mechanisms of an organism, increasing resistance to infectious diseases [4]. The cellular hormones prostaglandins are synthesized from PUFAs [4]. The biologically active components of vegetable oils, which ensure normal lipid metabolism, primarily include linoleic (ω-6) and linolenic (ω-3) PUFAs [5]. These fatty acids are not synthesized in the body of animals and humans, that is, they are irreplaceable (or essential) and must be supplied with food [6].

It is known that in vegetable oils, the fatty acid composition does not correspond to the ratio of saturated, unsaturated, and polyunsaturated fatty acids, which makes it possible to fully meet the physiological needs of animals and humans. It was found that rapeseed oil had a beneficial effect on the work of the heart in animals and humans [7]. Rapeseed oil (in comparison with other oils differing in the composition of unsaturated fatty acids) had a beneficial effect on high-density lipoprotein cholesterol, triglycerides, and blood pressure [8]. In sheep, the activity of trypsin and lipase in the biliary-pancreatic secretion increased with the addition of rapeseed and flaxseed oil to the diet, which indicates their positive effect on the digestion processes in ruminants [9]. When studying the effect of various vegetable oils (palm, rapeseed, sunflower, and flaxseed oils) on adult rats, the data were obtained that the composition of fatty acids could affect the rate of feed digestion, and then the lipid profile of serum [10]. This once again confirms that the lipid composition can modulate the state of digestion and absorption in the conditions of the gastrointestinal tract.

The issues regarding optimization of the formulation of vegetable oils (including the use of additives or based on a combination of different types of oil) in order to improve their physiological properties are widely discussed to ensure human nutrition, but when developing rations for feeding poultry, this factor is usually not taken into account. Knowing the mechanism of action of different vegetable oils on the metabolism and productivity of broiler chicks is necessary to improve rations for a more complete realization of the genetic potential of poultry productivity. Earlier, a comparative assessment of compound feed for broilers using unrefined sunflower, soybean, flaxseed, and rapeseed oils was not conducted.

In the study, for the first time, the authors revealed the effect of vegetable oils in the composition of feed for broiler chicks on the lipid profile of the blood, as well as the activity of digestive enzymes and alkaline phosphatase in the blood.

The aim of the work was to assess the impact of different lipid components of the diet on productivity, biochemical parameters of the blood of broiler chicks, and feed digestibility.

*Methods.* The experiments were conducted in the vivarium (Selection and Genetic Centre Zagorskoe, Federal Scientific Center All-Russian Research and Technological Poultry Institute RAS, Moscow Province, 2019) on four groups of broiler chicks (*Gallus gallus* L.) of the Smena 8 cross from 1 to 35 days of age. The groups ($n$ = 38 in each) were formed by the analog method, in each group, the chicks received the main ration (nutritionally balanced compound feed according to the standards of the All-Russian Scientific Research and Technological Poultry Institute — ARRTPI), supplemented with edible unrefined oils. i.e., sunflower, soybean, flaxseed, or rapeseed oil in groups I (control), II, III, and IV, respectively. The nutritional value of broiler rations by rearing periods during the reference period corresponded to the standards of the FSC ARRTPI RAS (Guidelines for optimizing compound feed formulas for agricultural poultry. Sergiev Posad, 2014), with regard to actual nutritional values of raw materials, determined in the Testing Center of FSC ARRTPI RAS in accordance with common methods.

The nutritional value of compound feeds, planting rates, light, temperature and humidity conditions, the feeding and drinking area throughout the entire experiment corresponded to the recommendations of the FSC ARRTPI RAS (Guidelines for optimizing compound feed formulas for agricultural poultry. Sergiev Posad, 2014). The broilers were kept in cages without separation by gender in compliance with the standards for stocking density, feeding and drinking area, duration and intensity of lighting. The poultry was fed ad libitum with dry compound feed, the feed was distributed by hand.

During the experiment, the main zootechnical indicators were taken into account: live weight of poultry at the age of 7, 14, 21, 28, and 35 days (individual weighing), livestock preservation, average daily live weight gain, consumption and costs of feed per 1 kg of live weight gain (Methodological guidelines for feeding agricultural poultry. Sergiev Posad, 2015). Physiological experiments to determine the digestibility and use of nutrients from the compound feed were conducted on poultry aged 30-35 days.

Blood samples were taken from the axillary vein prior to feeding. A freshly prepared sodium citrate solution was added to the test tubes, and the blood was centrifuged at 5000 rpm for 3 min. Biochemical blood analysis was performed on a Sinnowa BS-3000P flow-through semi-automatic analyzer (SINNOWA Medical Science & Technology Co., Ltd., China) using biochemical kits (DIAKON-VET, Russia). Blood plasma was tested for lipase activity on a Chem well 2900 (T) device (Awareness Technology, USA) with the required set of reagents (Human GmbH, Germany). Trypsin activity was assessed using a Sinnowa BS-3000P semi-automatic biochemical analyzer [11].

In the homogenate of the pancreas, the activity of amylase was measured by Smith and Roe procedure in the modification to determine the high activity of the enzyme [12], proteases — by hydrolysis of casein purified according to Hammerstein, with photometric control on KFK-3 (Zagorsk Optical-Mechanical plant, Russia) (wavelength 450 nm) [12], and lipases — using a semi-automatic biochemical analyzer SINNOWA BS-3000P with a kit of veterinary diagnostic reagents for determining the activity of lipase in the blood of animals (DIAKON-VET, Russia).

The obtained data were processed by the method of variation statistics. The results in the tables are presented as $M\pm$SEM, where $M$ is the arithmetic mean, ±SEM is the standard error of mean. The significance of the differences was assessed by the Student's $t$-test at $p < 0.05$.

*Results.* The formulas for experimental compound feed for broilers are shown in Table 1.

The fatty acid composition and qualitative indicators of the used unrefined vegetable oils are presented in Table 2. Analysis of the composition of the used vegetable oils showed a relatively low content of saturated fatty acids, in particular, palmitic and stearic acids (see Table 2). The share of these two acids on average ranges from 2.95% in rapeseed oil to 14.84% in soybean oil.

**1. Composition and nutritional value of experimental compound feeds for cross Smena 8 broiler chicks (*Gallus gallus* L.) of different ages** (the vivarium of Selection and Genetic Centre Zagorskoe, Federal Scientific Center All-Russian Research and Technological Poultry Institute RAS, Moscow Province, 2019)

| Ingredient, %, indicator | Chicks aged 1-21 days | | | | Chicks aged 22-35 days | | | |
|---|---|---|---|---|---|---|---|---|
| | group | | | | group | | | |
| | I (c) | II | III | IV | I (c) | II | III | IV |
| **Composition** | | | | | | | | |
| Wheat | 20.85 | 20.85 | 20.85 | 20.85 | 19.97 | 19.97 | 19.97 | 19.97 |
| Corn | 35.50 | 35.50 | 35.50 | 35.50 | 36.20 | 36.20 | 36.20 | 36.20 |
| Soybean meal | 26.00 | 26.00 | 26.00 | 26.00 | 25.00 | 25.00 | 25.00 | 25.00 |
| Sunflower meal | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| Fish flour | 6.50 | 6.50 | 6.50 | 6.50 | 4.00 | 4.00 | 4.00 | 4.00 |
| Sunflower oil | 3.10 | 0 | 0 | 0 | 6.00 | 0 | 0 | 0 |
| Soybean oil | 0 | 3.10 | 0 | 0 | 0 | 6.00 | 0 | 0 |
| Flaxseed oil | 0 | 0 | 3.10 | 0 | 0 | 0 | 6.00 | 0 |
| Rapeseed oil | 0 | 0 | 0 | 3.10 | 0 | 0 | 0 | 6.00 |
| Lysine monochlorohydrate | 0.18 | 0.18 | 0.18 | 0.18 | 0.22 | 0.22 | 0.22 | 0.22 |
| DL-methionine | 0.24 | 0.24 | 0.24 | 0.24 | 0.23 | 0.23 | 0.23 | 0.23 |
| Table salt | 0.22 | 0.22 | 0.22 | 0.22 | 0.27 | 0.27 | 0.27 | 0.27 |
| Monocalcium phosphate | 0.30 | 0.30 | 0.30 | 0.30 | 0.60 | 0.60 | 0.60 | 0.60 |
| Limestone flour | 0.90 | 0.90 | 0.90 | 0.9 | 1.30 | 1.30 | 1.30 | 1.30 |
| Premix | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| **Nutritional value** | | | | | | | | |
| Exchange energy: | | | | | | | | |
| kcal/100 g of feed | 304 | 305 | 304 | 304 | 320 | 320 | 319 | 319 |
| MJ/kg | 12.74 | 12.78 | 12.74 | 12.74 | 13.41 | 13.41 | 13.37 | 13.37 |
| Crude protein | 22.65 | 22.65 | 22.65 | 22.65 | 20.74 | 20.74 | 20.74 | 20.74 |
| Crude fat | 5.80 | 5.81 | 5.80 | 5.80 | 8.49 | 8.50 | 8.49 | 8.48 |
| Linoleic acid | 2.91 | 2.62 | 0.59 | 0.93 | 4.60 | 4.05 | 0.91 | 1.38 |
| Crude fiber | 4.30 | 4.30 | 4.30 | 4.30 | 4.21 | 4.21 | 4.21 | 4.21 |
| Lysine (total) | 1.36 | 1.36 | 1.36 | 1.36 | 1.25 | 1.25 | 1.25 | 1.25 |
| Lysine (assimilable) | 1.19 | 1.19 | 1.19 | 1.19 | 1.09 | 1.09 | 1.09 | 1.09 |
| Methionine (total) | 0.64 | 0.64 | 0.64 | 0.64 | 0.58 | 0.58 | 0.58 | 0.58 |
| Methionine (assimilable) | 0.58 | 0.58 | 0.58 | 0.58 | 0.53 | 0.53 | 0.53 | 0.53 |
| Methionine + cystine (total) | 0.98 | 0.98 | 0.98 | 0.98 | 0.90 | 0.90 | 0.90 | 0.90 |
| Methionine + cystine (assimilable) | 0.95 | 0.95 | 0.95 | 0.95 | 0.84 | 0.84 | 0.84 | 0.84 |
| Threonine (total) | 0.83 | 0.83 | 0.83 | 0.83 | 0.76 | 0.76 | 0.76 | 0.76 |
| Threonine (assimilable) | 0.70 | 0.70 | 0.70 | 0.70 | 0.64 | 0.64 | 0.64 | 0.64 |
| Tryptophan (total) | 0.27 | 0.27 | 0.27 | 0.27 | 0.25 | 0.25 | 0.25 | 0.25 |
| Tryptophan (assimilable) | 0.23 | 0.23 | 0.23 | 0.23 | 0.21 | 0.21 | 0.21 | 0.21 |
| Calcium | 0.82 | 0.82 | 0.82 | 0.82 | 0.90 | 0.90 | 0.90 | 0.90 |
| Phosphorus (total) | 0.64 | 0.64 | 0.64 | 0.64 | 0.63 | 0.63 | 0.63 | 0.63 |
| Phosphorus (assimilable) | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 |
| Sodium | 0.18 | 0.18 | 0.18 | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 |
| Chlorine | 0.25 | 0.25 | 0.25 | 0.25 | 0.27 | 0.27 | 0.27 | 0.27 |

Note. Group I — control (c), sunflower oil, II — soybean oil, III — flaxseed oil, IV — rapeseed oil in the ration.

**2. Basic fatty acids and qualitative indicators of vegetable oils used in experimental compound feeds for cross Smena 8 broiler chicks (*Gallus gallus* L.)** (the vivarium of Selection and Genetic Centre Zagorskoe, Federal Scientific Center All-Russian Research and Technological Poultry Institute RAS, Moscow Province, 2019)

| Fatty acid, %, indicator | Oil | | | |
|---|---|---|---|---|
| | sunflower | soybean | flaxseed | rapeseed |
| Saturated acids | 13.25 | 15.50 | 12.28 | 4.58 |
| including: | | | | |
| myristic | 0.08 | 0.14 | – | 0.17 |
| pentadecanoic | 0.31 | 0.40 | 0.27 | 0.34 |
| palmitic | 8.62 | 10.80 | 5.81 | 2.04 |
| stearic | 4.14 | 4.04 | 6.10 | 0.91 |
| arachidic | 0.10 | 0.12 | 0.10 | 1.12 |
| Monounsaturated acids | 26.69 | 26.56 | 21.40 | 66.32 |
| including: | | | | |
| myristoleic | – | – | – | 0.20 |
| palmitoleic | – | – | – | 0.40 |
| oleic | 26.69 | 26.56 | 21.40 | 65.72 |
| erucic | – | – | – | 0.23 |

*Continued Table 2*

| | | | | |
|---|---|---|---|---|
| Polyunsaturated acids | 59.60 | 57.94 | 66.32 | 24.84 |
| including: | | | | |
| linoleic | 57.58 | 51.53 | 11.69 | 17.60 |
| linolenic | 0.28 | 4.54 | 54.32 | 6.60 |
| eicosadienoic | 0.40 | 0.25 | 0.20 | 0.10 |
| arachidonic | 1.34 | 1.62 | 0.11 | 0.54 |
| Unsaturated to saturated acids | 6.51 | 5.45 | 7.14 | 19.90 |
| The ratio of palmitic and oleic acids | 0.32 | 0.41 | 0.27 | 0.03 |
| Acid value, mg KOH/g | 12.44 | 17.25 | 6.07 | 5.31 |
| Peroxide value J, % | 0.17 | 0.22 | 0.15 | 0.14 |
| Tocopherols, μg/g | 750 | 627 | 620 | 1200 |

Note. The tests were performed in accordance with GOST 30418 (Vegetable oils. Method for determining fatty acid composition) at the Test Laboratory Center of All-Russian Scientific Research Institute of Poultry Processing Industry (Rzhavki, Moscow Province). Acid peak magnitude is indicated as a percentage of the total peak area of all fatty acids. Dashes indicate the absence of the corresponding fatty acid.

It should be noted that there are large differences in the content of polyunsaturated linoleic, linolenic acids, and monounsaturated oleic acid. Soybean and sunflower oils were 51.53 and 57.58% linoleic acid, respectively, while flaxseed and rapeseed oils were 11.69 and 17.60% linoleic acid. A high content of linolenic acid was characteristic of flaxseed oil, oleic acid — for rapeseed oil. By the amount of polyunsaturated essential linolenic acid, flaxseed oil exceeded soybean, sunflower, and rapeseed oils, respectively, by 49.78, 54.04, and 47.72%. In terms of linoleic acid content, rapeseed oil was inferior to soybean and sunflower oil (the levels were 33.93% and 39.98% lower), but exceeded flaxseed oil (the content was 5.91% higher). The tested batch of rapeseed oil practically did not contain erucic acid (0.23%).

The greatest excess of the amount of unsaturated fatty acids over the saturated ones was noted in rapeseed oil, the 19.90:1 vs. ratios below 8:1 in soybean, sunflower, and flaxseed oils (see Table 2). In rapeseed oil, the proportion between palmitic and oleic acids was the smallest, 0.03:1. In addition, in rapeseed oil, the acid and peroxide values were the smallest. In terms of the total number of tocopherols, rapeseed oil also exceeded soybean, sunflower, and flaxseed oils (by 91.4%, 60.0%, and 93.5%).

**3. Productivity of cross Smena 8 broiler chicks (*Gallus gallus* L.) fed experimental compound feeds with different vegetable oils** (*M*±SEM, (the vivarium of Selection and Genetic Centre Zagorskoe, Federal Scientific Center All-Russian Research and Technological Poultry Institute RAS, Moscow Province, 2019)

| Indicator | Group (*n* = 35 in each) | | | |
|---|---|---|---|---|
| | I (c) | II | III | IV |
| Mortality rate, % | 0 | 0 | 0 | 2,86 |
| Live weight at different ages, g | | | | |
| 1 day | 42.0±2.44 | 42.0±1.77 | 42.0±2.01 | 42.0±1.99 |
| 5 days | 110.5±0.80 | 110.7±0.80 | 111.1±0.70 | 111.0±0.80 |
| 7 days | 167.9±1.63 | 166.2±2.27 | 169.5±1.42 | 169.5±1.54 |
| 14 days | 443.2±5.070 | 434.4±5.37 | 444.9±4.82 | 451.9±4.62 |
| 21 days | 813.7±24.94 | 842.5±10.70 | 854.9±12.23 | 899.2±10.68* |
| 28 days | 1467.8±20.26 | 1453.5±17.52 | 1458.8±19.63 | 1509.6±22.44 |
| 35 days | 2106.9±34.02 | 2169.6±32.48 | 2191.4±34.08 | 2235.5±38.78* |
| Average live weight on day 35 | 2110.79 | 2180.33 | 2222.56 | 2265.06 |
| (difference with the control) | | (+3.29 %) | (+5.3 %) | (+7.31 %) |
| including | | | | |
| for male chickens | 2247.47±36.40 | 2305.19±37.10* | 2378.50±31.66 | 2432.36±46.67* |
| for female chickens | 1974.11±34.48 | 2055.47±33.50 | 2066.67±30.18 | 2097.75±31.18* |
| Feed consumption: | | | | |
| per chick, kg | 3.663 | 3.669 | 3.623 | 3.636 |
| per 1 kg weight gainkg, кг | 1.773 | 1.724 | 1.686 | 1.658 |
| difference with the control | | –2.76 % | –4.91 % | –6.49 % |
| Daily weight gain, g | 60.85 | 62.89 | 64.13 | 65.38 |

Note. Group I — control (c), sunflower oil, II — soybean oil, III — flaxseed oil, IV — rapeseed oil in the ration. The description of the rations is given in Table 1.
* Differences with the control are statistically significant at $p < 0.05$.

Thus, rapeseed oil differed from other vegetable oils used in the experiment by a low content of polyunsaturated and saturated acids and a high content of monounsaturated acids. It was found that the positive effect of the use of rapeseed oil in the diet is manifested in an increase in the content of unsaturated fatty acids in broiler meat [13]. This fatty acid composition of rapeseed oil, apparently, influenced the productivity of broiler chicks (Table 3).

The results of studying the effectiveness of the use of sunflower, soybean, flaxseed, and rapeseed oils in the rations of broilers (see Table 3) confirmed that the quality of experimental compound feeds with different sources of edible vegetable oils provided a favorable zootechnical background and, as a consequence, high productivity and safety of chicks during the entire accounting period. The average daily gain in live weight of 35-day-old broilers was in the range of 60.85-65.38 g with feed consumption per 1 kg of live weight gain 1.658-1.773 kg.

As is known, sunflower oil is mainly used in manufacturing compound feed [14, 15]. A compound feed with sunflower oil in our studies was fed to the chicks of the control group. In feed production, the practice of using soybean oil is widespread. Soybean oil surpasses sunflower oil in terms of metabolic energy content, serves as a good source of vitamin E, carotenoids, but contains less linoleic acid. Comparing the productivity of chicks from groups I (control) and II, it should be noted that in the initial period of rearing, chicks from group II were slightly inferior in terms of live weight to the control ones (by 2.6 and 0.97%, respectively, at 14 and 28 days of age) (the differences are insignificant). By the end of rearing, the average live weight of chicks in group II was 3.39% higher than the control, and the male chickens in terms of live weight significantly exceeded their counterparts from the control group (by 2.57%, $p < 0.05$). It was found that feed costs per 1 kg of live weight gain in chicks from group II decreased by 2.76% in comparison with the control. The obtained result confirms the justification of the widespread use of soybean oil in feed production, since it allows ensuring high productivity of poultry.

Unlike soybean and sunflower oil, the use of flaxseed and rapeseed oil in feed production is limited. This is due not only to the smaller volume of their industrial production but also to the possible presence of anti-nutritional factors. In the study, the authors explain the high growth rate of chicks that received flaxseed and rapeseed oil as part of compound feeds by the fact that freshly made high-quality edible oils were used in the experiments.

As it is seen from Table 3, 3.1% flaxseed oil in the composition of compound feeds for chicks from group III provided an increase in the live weight of individuals by 0.37 and 5.07% at 14 and 21 days of age as compared to the control. An increase in the dosage of flaxseed oil to 6.0% from 22 days of age did not negatively affect the growth rate of chicks: up to 28 days of age, their live weight gain did not differ from the control, and by the end of fattening it was 5.3% with a decrease in feed costs by 4.91% per 1 kg of live weight gain.

Rapeseed oil (group IV) contributed to a significant ($p < 0.05$) increase in this indicator at 14, 21, and 28 days of age by 1.97, 10.51, and 2.85%. By the end of rearing, a noticeable advantage of broilers from group IV in terms of average live weight in comparison with the control (a 7.31% excess) was manifested with an improvement in feed conversion (by 6.49%).

The data on the digestibility of nutrients by the groups are presented in Table 4. The obtained results indicate that the addition of soybean oil to feed increases the fat digestibility by 1.58% ($p < 0.05$), but the availability of methionine decreases by 2.8% ($p < 0.05$) when compared with sunflower oil. The use of flaxseed oil instead of sunflower oil increased the digestibility of feed protein by 2.4%

($p < 0.05$) and fat by 2.7% ($p < 0.05$). Replacing sunflower oil with rapeseed oil increased the digestibility of protein by 2.7% ($p < 0.05$), fat by 3.1% ($p < 0.05$), and the availability of lysine in the feed increased by 2.4% ($p < 0.05$).

**4. Digestibility of experimental compound feeds and utilization of basic nutrients by the cross Smena 8 broiler chicks (*Gallus gallus* L.)** (*M*±SEM, the vivarium of Selection and Genetic Centre Zagorskoe, Federal Scientific Center All-Russian Research and Technological Poultry Institute RAS, Moscow Province, 2019)

| Indicator, % | Group (*n* = 35 in each) | | | |
|---|---|---|---|---|
| | I (c) | II | III | IV |
| Digestibility of | | | | |
| dry matter | 71.4±0.34 | 71.5±0.30 | 72.6±0.32 | 72.6±0.34 |
| protein | 90.4±0.42 | 90.6±0.40 | 92.7±0.37* | 93.1±0.30* |
| fat | 80.8±0.37 | 82.4±0.30* | 83.5±0.32* | 83.9±0.34* |
| fiber | 28.5±0.27 | 29.4±0.22 | 28.6±0.25 | 28.8±0.27 |
| Use of | | | | |
| nitrogen | 60.8±0.44 | 61.3±0.42 | 61.6±0.47 | 62.6±0.41 |
| calcium | 48.7±0.39 | 49.1±0.35 | 48.8±0.37 | 49.6±0.31 |
| phosphorus | 33.5±0.22 | 33.3±0.24 | 33.6±0.20 | 33.8±0.22 |
| Availability of | | | | |
| lysine | 91.8±0.28 | 91.5±0.47 | 92.1±0.70 | 94.2±0.45* |
| methionine | 93.9±0.20 | 91.1±0.49* | 92.8±0.65 | 94.8±0.41 |

N o t e. Group I — control (c), sunflower oil, II — soybean oil, III — flaxseed oil, IV — rapeseed oil in the ration. The description of the rations is given in Table 1.
* Differences with the control are statistically significant at $p < 0.05$.

**5. Blood biochemical parameters in 35-day-old cross Smena 8 broiler chicks (*Gallus gallus* L.) fed experimental compound feeds with different vegetable oils** (*n* = 5, *M*±SEM, the vivarium of Selection and Genetic Centre Zagorskoe, Federal Scientific Center All-Russian Research and Technological Poultry Institute RAS, Moscow Province, 2019)

| Parameter | Group | | | |
|---|---|---|---|---|
| | I (c) | II | III | IV |
| Trypsin activity, U/l | 99±6.0 | 76±5.9* | 72±4.1* | 98±4.7 |
| Lipase activity, U/l | 7.4±0.13 | 8.5±0.31* | 10.1±0.72* | 8.7±0.23* |
| Triglycerides, mmol/l | 1.1±0.01 | 0.9±0.02* | 1.0±0.01* | 0.8±0.02* |
| Cholesterol, mmol/l | 2.6±0.11 | 2.6±0.18 | 2.3±0.09* | 2.7±0.03 |
| Total protein, g/l | 30.0±0.9 | 32±0.5 | 31±0.9 | 33±0.2* |
| Alkaline phosphatase, u/l | 2448±163.0 | 3265±502.0 | 2541±135.1 | 3309±248.1* |
| Phosphatase-protease index | 24 | 43 | 35 | 34 |

N o t e. Group I — control (c), sunflower oil, II — soybean oil, III — flaxseed oil, IV — rapeseed oil in the ration. The description of the rations is given in Table 1.
* Differences with the control are statistically significant at $p < 0.05$.

Biochemical analysis (Table 5) revealed the unequal effect of the studied vegetable oils, differing in chemical composition, on the blood parameters of chicks. In terms of trypsin activity, broilers that received the addition of soybean and flaxseed oil lagged behind the control ones by 23.2 and 27.3%, respectively ($p < 0.05$), the increase in lipase activity upon replacing sunflower oil in groups II-IV was 14.9, 17.6, and 36.5% ($p < 0.05$), respectively, while the blood level of triglycerides decreased by 18.2% ($p < 0.05$) for soybean oil, by 27.3% ($p < 0.05$) for flaxseed oil, and by 9.1% ($p < 0.05$) for rapeseed oil. Flaxseed oil reduced blood cholesterol levels by 11.5% compared to the control ($p < 0.05$), rapeseed oil increased the activity of alkaline phosphatase by 35.2% ($p < 0.05$) and the amount of total protein by 10.0% ($p < 0.05$). The phosphatase-protease index (the ratio of the activity of alkaline phosphatase and trypsin) was optimal when sunflower oil was added to the feed and consistently increased for rapeseed, flaxseed, and soybean oil, which indicates intense metabolism in the liver.

The study of enzyme activity in the pancreatic tissue (Table 6) did not confirm the significance of differences between the groups due to the small sample size, but revealed a persistent tendency to an increase in lipase activity in broilers, that received flaxseed and rapeseed oil in the rations. In group II, there was a decrease in enzymatic activity compared with control broilers, which may be associated with pancreatic hypertrophy when using soybean oil containing trypsin inhibitors. This is indicated by the mass of the pancreas (6.4% higher than the control value, $p > 0.05$).

**6. Activity of pancreatic enzymes in the pancreas homogenates of cross Smena 8 broiler chicks (*Gallus gallus* L.) fed experimental compound feeds with different vegetable oils** ($n = 3$, $M\pm$SEM, the vivarium of Selection and Genetic Centre Zagorskoe, Federal Scientific Center All-Russian Research and Technological Poultry Institute RAS, Moscow Province, 2019)

| Parameter | Group | | | |
|---|---|---|---|---|
| | I (c) | II | III | IV |
| Pancreas weight, g | 4.7±0.17 | 5.0±0.15 | 4.7±0.14 | 4.8±0.16 |
| Amylase, mg/(g · min) | 17600±150.0 | 16667±311.1* | 17467±366.5 | 17533±283.4 |
| Lipase, μmol/(l · min) | 107940±4305.0 | 97116±7341.1 | 122740±5675.3 | 117584±8614.1 |
| Proteases, mg/(g · min) | 669±23.1 | 628±36.5 | 616±18.3 | 628±40.2 |

N o t e. Group I — control (c), sunflower oil, II — soybean oil, III — flaxseed oil, IV — rapeseed oil in the ration. The description of the rations is given in Table 1.
* Differences with the control are statistically significant at $p < 0.05$.

Thus, the biochemical parameters of the blood of broiler chicks reflect the state of metabolism when various vegetable oils are added to the feed. The most critical values are when using flaxseed and soybean oil. In this case, the phosphatase-protease index increases in broiler chicks. The reason for the low efficiency of fatty acid metabolism when using flaxseed oil, according to available reports [16], is an excess of linoleic acid, which distinguishes this oil from other oils in the experiment. There are data that flaxseed oil practically does not cause changes in adipose tissue, but promotes the accumulation of α-linolenic acid in the liver and blood of broilers [17]. It is known [18] that linoleic acid, coming mainly from plant sources, is used by various types of intestinal microbes to obtain conjugated linoleic acid, which has anti-inflammatory, antiadipogenic, antidiabetic, and anticarcinogenic properties. There is no consensus in the scientific literature on the ratio of ω-6:ω-3 fatty acids in oils. Thus, it is believed that for a healthy person the optimal ratio of ω-6 to ω-3 fatty acids in oils is 10:1 or 11:1 [19]. According to the results of the authors' experiment on poultry, the ratio of ω-6 and ω-3 fatty acids is 193:1 in sunflower oil, 11:1 in soybean oil, 5:1 in flaxseed oil, and 3:1 in rapeseed oil. The proportions in which these unsaturated acids enter the body with food significantly affect the further synthesized long-chain and more unsaturated fatty acid metabolites, which, under certain conditions, can cause an undesirable disruption of metabolic processes [20]. It is known that the addition of a mixture of soybean and flaxseed oils to broilers' diet has a positive effect on the content of ω-6 and ω-3 fatty acids in muscle fibers, improving the nutritional value of meat and having a beneficial effect on human health [21]. A mixture of palm and sunflower oil increases broiler carcass yield and reduces the content of muscle and abdominal fat [22]. The positive influence of the combination of vegetable oils on the quality of livestock products was noted. Thus, when a 3% mixture of vegetable oils (corn, palm, flaxseed, peanut and soybean) was added to the broilers' ration, an increase in the content of glucose, albumin, ω-6 and ω-3 fatty acids in the blood serum was noted, and also an increase in the color of muscle tissue in comparison with the option when only soybean oil was used [23]. At the same time, the age of poultry did not affect the absorption of fatty acids from the diet [24].

Rapeseed oil is rich in oleic acid, the content of which exceeds 50% [25]. There is evidence that the addition of peanut flour with a high content of oleic acid (10-12%) to the feed has a positive effect on the palatability of broiler meat and reduces the cost of feed [26].

Our data are consistent with the studies of the effect of vegetable oils on the productivity and biochemical parameters of the blood of broiler chicks. In particular, various correlations were revealed between the composition of fatty acids in the feed and lipid profiles of blood serum (Pearson's *r* values are provided by the authors) [22]. It was established [27] that bile preparations can affect the lipid profile of the blood. This suggests that the composition of fatty acids can first affect the rate of food digestion and then the lipid profiles of blood serum. Therefore, the lipid composition of the diet can modulate digestion and absorption in the gastrointestinal tract. The data obtained by other authors give an idea of the presence of links between the lipid composition of vegetable oils and their functional differences [10, 23, 28, 29]. However, in our studies, it was first established that the activity of blood lipase with a change in the lipid component in the feed changes simultaneously with the activity of the enzyme in the pancreatic juice [30].

It is known that the addition of 3% rapeseed oil to the broiler diet increases the content of eicosapentaenoic acid and docosahexaenoic acid in phospholipids of the heart, which has a cardioprotective and antiarrhythmic effect on the heart muscle in animals and humans [7, 26]. With identical nutritional values, rapeseed oil significantly reduces the deposition of lipids in the liver, while soybean oil increases the amount of fat in the abdominal cavity [31].

It was found that the fatty acids prevailing in oil correlated with the parameters of meat in female chickens [32]; it was also suggested that the size of fat deposits could be changed depending on the fatty acid profile of the feed. In particular, a comparison of diets with the addition of beef fat, olive, sunflower, and flaxseed oils showed that when using supplements rich in PUFAs, broilers had fewer fat deposits than when enriching the diet with saturated or monounsaturated fatty acids [33]. On other species of farm animals, in particular, on sheep, it was shown that oil as a food additive could change the secretion of bile and pancreatic juice and the enzymatic activity of the pancreas, as well as affect the meat quality [9].

Thus, it should be noted that there is a relatively low content of saturated fatty acids (in particular, palmitic and stearic) in the vegetable oils, studied by the authors. There are large differences in the amount of linoleic, linolenic, and oleic fatty acids: a high content of linolenic acid is typical for flaxseed oil, oleic acid for rapeseed oil. The ratio of unsaturated and saturated fatty acids is also uneven: the highest is in rapeseed oil (20.8:1), the lowest is in soybean oil (5.4:1). It was established that soybean, flaxseed, and rapeseed oils in comparison with sunflower oil contributed to an increase in the live weight of chicks by 3.29, 5.3, and 7.31% with an improvement in feed conversion by 2.76, 4.91, and 6.49% due to improved metabolic processes, digestibility, and use of feed nutrients.

Thus, our experiments confirm that the effectiveness of vegetable oils depends on their fatty acid composition and the ability of digestive enzymes to adapt to the individual lipid components of the diet. This allows drawing the following conclusions. Compound feeds with the rapeseed oil containing 0.23% erucic acid contribute to an increase in the live weight of broiler chicks at 14, 21, and 28 days of age by 1.97, 10.51, and 2.85%, respectively. By the end of rearing, the advantage over the control in terms of average live weight in broilers from the group which received the rapeseed oil was 7.31% with an improvement in feed conversion by 6.49%. Rapeseed oil contributes to the high digestibility of protein and fat in feed (an increase in indicators by 2.74 and 3.08%, respectively) with better assimilation of lysine, which became the physiological basis for the intensive growth of broiler chicks of this group as compared to the control. The effect of dietary vegetable oils on the blood lipid profile, the activity of digestive enzymes and alkaline phosphatase we revealed is an evidence of the modulation of metabolic processes when replacing the lipid component of the feed. The observed changes are specific for the type of oil and are determined by its fatty acid composition.

## REFERENCES


1. Subbotina M.A. *Tekhnika i tekhnologiya pishchevykh proizvodstv: sbornik nauchnykh rabot* [Technique and technology of food production: collection of research papers]. Kemerovo, 2009, v. 4: 54-57 (in Russ.).
2. Rogov I.A., Antipova L.V., Dunchenko N.I. *Khimiya pishchi* [The chemistry of food]. Moscow, 2007 (in Russ.).
3. Bukin Yu.V. *Nezamenimye zhirnye kisloty: prirodnye istochniki, metabolizm, fiziologicheskie funktsii i znachenie dlya zdorov'ya* [Essential fatty acids: natural sources, metabolism, physiological functions, and health benefits]. Moscow, 1999 (in Russ.).
4. Lobanov V.G., Shcherbin V.V. *Izvestiya vuzov. Pishchevaya tekhnologiya*, 2003, 4: 21-23 (in Russ.).
5. Skoryukin A.N., Nechaev A.N., Kochetkova A.A., Baryshev A.G. *Maslozhirovaya promyshlennost'*, 2002, 2: 26-27 (in Russ.).
6. Titov V.N. *Voprosy pitaniya*, 1999, 3: 34-41 (in Russ.).
7. Gregory M.K., Geier M.S., Gibson R.A., James M.J. Effect of dietary canola oil on long-chain omega-3 fatty acid content in broiler hearts. *J. Anim. Physiol. Anim. Nutr.*, 2014, 98(2): 235-238 (doi: 10.1111/jpn.12072).
8. Jones P., Senanayake V.K., Pu S., Jenkins D., Connelly P.W., Lamarche B., Couture P., Charest A., Baril-Gravel L., West S.G. DHA-enriched high–oleic acid canola oil improves lipid profile and lowers predicted cardiovascular disease risk in the canola oil multicenter randomized controlled trial. *The American Journal of Clinical Nutrition*, 2014, 100(1): 88-97 (doi: 10.3945/ajcn.113.081133).
9. Kowalik B., Majewska M.P., Miltko R., Bełżecki G. The effect of supplementing sheep with rapeseed and linseed oils on the activity of pancreatic digestive enzymes. *J. Anim. Physiol. Anim. Nutr.*, 2018, 102(5): 1194-1198 (doi: 10.1111/jpn.1293).
10. Ye Z., Cao C., Li R., Cao P., Li Q., Liu Y. Lipid composition modulates the intestine digestion rate and serum lipid status of different edible oils: a combination of in vitro and in vivo studies. *Food & Function*, 2019, 10(3): 1490-1503 (doi: 10.1039/c8fo01290c).
11. Vertiprakhov V.G., Grozina A.A. *Veterinariya*, 2018, 12: 51-54 (doi: 10.30896/0042-4846.2018.21.12.51-54).
12. Batoev Ts.Zh. *Fiziologiya pishchevareniya ptits* [Physiology of digestion in birds]. Ulan-Ude, 2001 (in Russ.).
13. Abbasi M.A., Ghazanfari S., Sharifi S.D., Ahmadi Gavlighi H. Influence of dietary plant fats and antioxidant supplementations on performance, apparent metabolizable energy and protein digestibility, lipid oxidation and fatty acid composition of meat in broiler chicken. *Veterinary Medicine and Science*, 2020, 6(1): 54-68 (doi: 10.1002/vms3.212).
14. Selina T.V. *Ptitsevodstvo*, 2015, 7: 43-46 (in Russ.).
15. Mal'tseva N.A., Yadrishchenskaya O.A., Selina T.V. *Ptitsevodstvo*, 2016. 7: 11-13 (in Russ.).
16. YAzeva L.I., Filippova G.I., Fedina N.I. *Voprosy pitaniya*, 1989, 3: 45-50 (in Russ.).
17. Manterys A., Franczyk-Zarow M., Czyzynska-Cichon I., Drahun A., Kus E., Szymczyk B., Kostogrys R.B. Haematological parameters, serum lipid profile, liver function and fatty acid profile of broiler chickens fed on diets supplemented with pomegranate seed oil and linseed oil. *British Poultry Science*, 2016, 57(6):771-779 (doi: 10.1080/00071668.2016.1219977).
18. O'Shea E.F., Cotter P.D., Stanton C., Ross R.P., Hill C. Production of bioactive substances by intestinal bacteria as a basis for explaining probiotic mechanisms: bacteriocins and conjugated linoleic acid. *International Journal of Food Microbiology*, 2012, 152: 189-205 (doi: 10.1016/j.ijfoodmicro.2011.05.025).
19. British Nutrition Foundation (BNF). *The Report BNF Task Force*. Chapman &Hall, 1992, London.
20. Subotina M.A. *Vestnik KuzGTU*, 2009, v. 2: 86-90 (in Russ.).
21. Marzec M.E., Wojtysiak D., Połtowicz K, Nowak J. ToF-SIMS spectrometry to observe fatty acid profiles of breast tissues in broiler chicken subjected to varied vegetable oil diet. *Journal of Mass Spectrometry,* 2019, 55(3): 1-8 (doi: 10.1002/jms.4486).
22. Khatun J., Loh T.C., Akit H., Foo H.L., Mohamad R. Fatty acid composition, fat deposition, lipogenic gene expression and performance of broiler fed diet supplemented with different sources of oil. *Journal of Animal Science,* 2017, 88(9): 1406-1413 (doi: 10.1111/asj.12775).
23. Long S., Xu Y., Wang C., Li C., Liu D., Piao X. Effects of dietary supplementation with a combination of plant oils on performance, meat quality and fatty acid deposition of broilers. *Asian Australasian Journal of Animal Sciences*, 2018, 31(11): 1773-1780 (doi: 10.5713/ajas.18.0056).
24. Aardsma M.P., Mitchell R.D., Parsons C.M. Relative metabolizable energy values for fats and

oils in young broilers and adult roosters. *Poultry Science*, 2017, 96(7): 2320-2329 (doi: 10.3382/ps/pex028).

25. Konuskan D.B., Arslan M., Oksuz A. Physicochemical properties of cold pressed sunflower, peanut, rapeseed, mustard and olive oils grown in the Eastern Mediterranean region. *Saudi Journal Biological Sciences*, 2019, 26(2): 340-344 (doi: 10.1016/j.sjbs.2018.04.005).
26. Toomer O.T., Livingston M.L., Wall B., Sanders E., Vu T.C., Malheiros R.D., Livingston K.A., Carvalho L.V., Ferket P.R. Meat quality and sensory attributes of meat produced from broiler chickens fed a high oleic peanut diet. *Poultry Science*, 2019, 98(10): 5188-5197 (doi: 10.3382/ps/pez258).
27. Lai W., Huang W., Dong B., Cao A., Zhang W., Li J., Wu H., Zhang L. Effects of dietary supplemental bile acids on performance, carcass characteristics, serum lipid metabolites and intestinal enzyme activities of broiler chickens. *Poultry Science*, 2018, 97(1): 196-202 (doi:10.3382/ps/pex2880).
28. Hu X.Q., Wang W.B., Liu L., Wang C., Feng W., Luo Q.P., Han R., Wang X.D. Effects of fat type and emulsifier in feed on growth performance, slaughter traits, and lipid metabolism of Cherry Valley ducks. *Poultry Science*, 2019, 98(11): 5759-5766 (doi: 10.3382/ps/pez369).
29. Muralidharan J., Galiè S., Hernández-Alonso P., Bullu M., Salas-Salvadu J. Plant-based fat, dietary patterns rich in vegetable fat and gut microbiota modulation. *Frontiers in Nutrition*, 2019, 6: 157 (doi: 10.3389/fnut.2019.00157).
30. Vertiprakhov V.G., Grozina A.A., Fisinin V.I. The exocrine pancreatic function in chicken (*Gallus gallus* L.) fed diets supplemented with different vegetable oils. *Agricultural Biology* [*Sel'skokhozyaistvennaya biologiya*], 2020, 55(4): 726-737 (doi: 10.15389/agrobiology.2020.4.726eng).
31. Scaife J.R., Moyo J., Galbraith H., Michie W., Campbell V. Effect of different dietary supplemental fats and oils on the tissue fatty acid composition and growth of female broilers. *British Poultry Science*, 1994, 35(1):107-118 (doi: 10.1080/00071669408417675).
32. Skřivan M., Marounek M., Englmaierová M., Čermák L., Vlčková J., Skřivanová E. Effect of dietary fat type on intestinal digestibility of fatty acids, fatty acid profiles of breast meat and abdominal fat, and mRNA expression of lipid-related genes in broiler chickens. *PLoS ONE*, 2018, 19; 13(4): e0196035 (doi: 10.1371/journal.pone.0196035).
33. Baião N.C., Lara L.J.C. Oil and fat in broiler nutrition. *Brazilian Journal of Poultry Science*, 2005, 7(3): 129-141 (doi: 10.1590/S1516-635X2005000300001).