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# THE EFFECT OF COMPLETE AND PARTIAL REPLACEMENT OF SOYBEAN MEALS WITH HIGH-PROTEIN SUNFLOWERS CONCENTRATE ON THE DIET OF BROILER CHICKENS ON THEIR GROWTH PARAMETERS, MEAT PRODUCTIVITY AND MEAT QUALITY

## SUMMARY

Soybean meal (SBM) is the main source of protein in poultry diets, but due to its increasing price, alternative protein ingredients are needed to form a balanced and economical diet. Plant protein sources, such as high-protein sunflower concentrate (HPSC), can be a potential alternative to soybean meal in the diet of broiler chickens. The study aimed to evaluate the effect of full and partial replacement of soybean meal with high-protein sunflower concentrate in broiler chicken diets. For this purpose, 400 one-day-old broiler chickens were randomly divided into four groups (SBM (control group), HPSC, HPSC50cp and HPSC50q) of 100 birds each. The SBM control diet did not contain HPSC, while the HPSC, HPSC50cp and HPSC50q diets were based on complete, 50% crude protein and 50% quantity replacement of soybean meal with high protein sunflower concentrate, respectively. At 42 days of age, 6 broiler chickens were selected from each group of birds for slaughter and meat quality assessment. It was found that the most effective for the body gain of broiler chickens is HPSC50q, which contributes to an increase in body weight by 3.2%, pre-slaughter live weight by 3.2%, bled carcass weight by 4.7%, non-eviscerated carcass weight by 4.1%, semi-eviscerated carcass weight by 4.0% and eviscerated carcass weight by 4.4%, breast muscle weight by 6.6%, thigh by 3.7%, drumstick by 4.5% and wing by 2.0%, as well as a higher yield of bled carcass by 1.3%, non-eviscerated carcass by 0.6%, semi-eviscerated carcass by 0.6% and eviscerated carcass by 1.0% , a higher yield of edible parts of the carcass, namely breast muscles by 0.88%, thigh by 0.22% and drumstick by 0.31%. In addition, HPSC50q contributes to a decrease in the crude fat content in the breast muscles of broiler chickens by 18.8% and in the thigh muscles by 25.0%, while reducing the energy value by 7.5% and 10.6%, respectively, compared to SBM.

**Keywords**: sunflower concentrate, soybean meal, broiler chickens, live weight, slaughter yield, meat quality, chemical composition of meat

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## INTRODUCTION

Optimal growth performance of meat-type poultry depends on the supply of high-quality dietary protein with a well-balanced amino acid profile, accompanied by adequate levels of metabolizable energy, vitamins, and minerals (Ibatullin *et al.,* 2016; Sychov *et al*., 2022; Munawar *et al.,* 2025). Animal protein sources are not preferred for broiler diets due to the risk of contamination and the varying amount of protein available (Hafez and Attia, 2020). Plant-derived protein sources are commonly incorporated into the diets of meat-type poultry (Plyska *et al.,* 2021). Among them, soybean meal is regarded as the most valuable due to its high-quality protein and well-balanced amino acid composition (An and Kong, 2023).

However, despite the fact that Ukraine is an exporter of soybeans, fluctuations in its prices on the international market directly affect both the domestic market and the poultry industry as a whole (Mykhailova *et al.,* 2024). Therefore, plant protein sources such as sunflower (Helianthus annuus) meal may be a potential alternative to soybean meal in broiler chicken diets (Saleh *et al.,* 2021). At the same time, the use of sunflower meal in poultry diets is quite limited due to its high fibre content and low energy and lysine levels (Pilorgé, 2020; Jha and Mishra, 2021; Saleh *et al.,* 2021), which can be partially offset by the use of high-protein sunflower concentrates (Such *et al.,* 2024; Sychov *et al.,* 2025).

Sunflower seeds typically contain 35–40% husk and 60–65% kernel, and sunflower husk contains approximately 50% cellulose and 25% lignin (Munawar *et al.,* 2025). Sunflower meal is produced from sunflower seeds following oil extraction by means of a solvent. It contains, on average, 30–35% protein, 4.6% soluble and 22% insoluble non-starch polysaccharides.

The insoluble non-starch polysaccharides of sunflower meal consist of 41% cellulose, 25% pectic polysaccharides, 24% 4-omethyl-glucuronoxylans, 4.5% galactomannans and 5% fucoxyloglucans (Velázquez-De Lucio *et al.,* 2021). The presence of insoluble non-starch polysaccharides in broiler diets reduces their performance by reducing nutrient absorption due to increased viscosity of digestion thereby reducing feed utilisation efficiency (Jha and Mishra 2021). To reduce the content of insoluble non-starch polysaccharides in sunflower meal, one can use enzymes that break them down (Velázquez-De Lucio *et al*., 2021), or perform additional processing of the meal and use high-protein sunflower concentrates (Such *et al*., 2024).

In recent years, a lot of research has been devoted to studying the possibility of replacing soybean meal in broiler chicken diets with other plant sources of protein. In particular, DMaria de Moraes Oliveira *et al*. (2016) included up to 16% sunflower meal in the diet of broilers from the 1$^{st}$ to the 21$^{st}$ day of their growth and found that adding sunflower meal in a concentration of up to 8% does not affect the growth parameters of the bird, and increasing its content in the diet to 16% already significantly affects productivity. Berwanger *et al.* (2017) found that including up to 10% sunflower meal with an enzymatic complex in the diet can be effectively used in feeding broiler chickens during 21–42 days of growth. Yaqoob *et al.* (2023) also found no adverse effects from including sunflower meal at concentrations ranging from 3 to 9% in broiler chicken diets. Whereas in recent studies, Munawar et al. (2025) demonstrated that soybean meal can be partially replaced by up to 20% sunflower meal in broiler diets without negative effects on growth rate and nutrient digestibility during the growing and finishing periods. However, according to the authors, increasing the level of sunflower meal in the diet significantly increases viscosity of digestion and reduces nutrient digestibility.

However, all studies reported in the scientific literature have concerned the evaluation of the efficacy of complete or partial replacement of soybean meal with sunflower meal in broiler chicken diets. This study aims to evaluate the impact of full and partial replacement of soybean meal in the diet of broiler chickens with high-protein, self-produced sunflower concentrate, as a cost-effective alternative source of protein in poultry feeding, while mitigating the limitations of the use of sunflower meal by increasing the protein content and reducing the fibre content of the concentrate.

## MATERIAL AND METHODS

### Ethics

Experiments with experimental animals were performed following the rules of the European Convention for the Protection of Vertebrate Animals (Official Journal of the European Union L276/33, 2010) and the Order of the Ministry of Economy of Ukraine «On approval of the requirements for the welfare of farm animals during their housing» of February 18, 2021, were organized. The local Commission approved the experimental protocol on Bioethics of the National University of Life and Environmental Sciences of Ukraine.

### Experimental design

The study focused on broiler chickens from the Cobb-500 crossbreed industrial herd. The experiment lasted 42 days, from the placement of day-old chickens for rearing to slaughter. During rearing, broiler chickens were kept in separate floor sections, as recommended by the crossbreed producer Cobb Broiler Management Guide, 2022).

At the age of one day, broiler chickens were divided into four groups of 100 birds each. The differences between the groups were due only to the composition of the diet used. In particular, the difference in feeding of birds of the control and experimental groups was due to the complete or partial replacement of soybean meal in the diet with high-protein sunflower concentrate. Broilers of the control (SBM) group received a complete feed based only on soybean meal, without the addition of high-protein sunflower concentrate. In the diet of broilers from the HPSC group, soybean meal was replaced entirely by sunflower concentrate. In chickens of HPSC50cp and HPSC50q groups, the diet was formulated so that the soybean meal replacement was 50% by crude protein (HPSC50cp) or by quantity (HPSC50q). The compound feeds were used in dry, pellet form.

### Poultry feeding

The experimental broiler chickens were fed complete feeds, balanced for all nutrients according to the recommended norms. The composition of the complete feed used for feeding broiler chickens is given in Tables 1–4. The chemical composition of high-protein sunflower concentrate used in broiler diets is given in Table 5.

**Table 1**. Composition and nutritional value of compound feed for broiler chickens 0-12 days old, %

| Indicator | Group of broiler chickens (%) | | | |
|---|---|---|---|---|
| | SBM | HPSC | HPSC50cp | HPSC50q |
| Corn | 36.972 | 44.352 | 43.058 | 42.311 |
| Sunflower concentrate SP44 | – | 35.648 | 25.000 | 18.850 |
| Soybean meal SP 41 | 40.599 | 0.000 | 11.942 | 18.839 |
| Wheat | 15.000 | 15.000 | 15.000 | 15.000 |
| Limestone flour Ca 35% | 1.598 | 1.517 | 1.543 | 1.557 |
| Cornflour | 1.294 | 0.690 | 0.869 | 0.972 |
| Monocalcium phosphate | 0.635 | 0.812 | 0.756 | 0.725 |
| Methionine 99.5% | 0.372 | 0.228 | 0.270 | 0.295 |
| Lysine hydrochloride | 0.309 | 0.791 | 0.651 | 0.570 |
| Salt | 0.286 | 0.017 | 0.099 | 0.146 |
| Threonine 99% | 0.156 | 0.221 | 0.202 | 0.191 |
| Premix | 0.350 | 0.350 | 0.350 | 0.350 |
| Soybean oil | 2.429 | – | – | – |
| Sodium sulfate | – | 0.374 | 0.260 | 0.194 |
| Total | 100.000 | 100.000 | 100.000 | 100.000 |
| Nutritional value of compound feed: | | | | |
| Energy, MJ | 12.70 | 12.88 | 12.67 | 12.54 |
| Crude protein, % | 22.00 | 22.00 | 22.00 | 22.00 |
| Crude fibre, % | 3.81 | 4.17 | 4.07 | 4.02 |
| Digestible lysine, % | 1.28 | 1.28 | 1.28 | 1.28 |
| Digestible methionine and cystine, % | 0.97 | 0.97 | 0.97 | 0.97 |

**Table 2.** Composition and nutritional value of compound feed for broiler chickens 13-28 days old, %

| Indicator | Group of broiler chickens | | | |
|---|---|---|---|---|
| | SBM | HPSC | HPSC50cp | HPSC50q |
| Corn | 43,346 | 49,803 | 48,896 | 48,073 |
| Sunflower concentrate SP44 | | 30,196 | 22,720 | 15,950 |
| Soybean meal SP 41 | 34,430 | | 8,384 | 15,977 |
| Wheat | 15,000 | 15,000 | 15,000 | 15,000 |
| Limestone flour Ca 35% | 1,358 | 1,290 | 1,309 | 1,325 |
| Cornflour | 2,016 | 1,501 | 1,625 | 1,740 |
| Monocalcium phosphate | 0,211 | 0,360 | 0,321 | 0,285 |
| Methionine 99.5% | 0,321 | 0,199 | 0,228 | 0,255 |
| Lysine hydrochloride | 0,315 | 0,724 | 0,625 | 0,536 |
| Salt | 0,289 | 0,053 | 0,111 | 0,163 |
| Threonine 99% | 0,142 | 0,197 | 0,184 | 0,172 |
| Premix | 0.350 | 0.350 | 0.350 | 0.350 |
| Soybean oil | 2.222 | – | – | – |
| Sodium sulfate | – | 0,327 | 0,247 | 0,174 |
| Total | 100.000 | 100.000 | 100.000 | 100.000 |
| Nutritional value of compound feed: | | | | |
| Energy, MJ | 12.98 | 13.09 | 12.94 | 12.80 |
| Crude protein, % | 20.00 | 20.00 | 20.00 | 20.00 |
| Crude fibre, % | 3.56 | 3.87 | 3.80 | 3.74 |
| Digestible lysine, % | 1.16 | 1.16 | 1.16 | 1.16 |
| Digestible methionine and cystine, % | 0.88 | 0.88 | 0.88 | 0.88 |

**Data Collection**

During the rearing period, the number of broiler chickens removed (due to mortality and culling) was recorded, and their live weight was measured every seven days using “Total Control” scales (Italy). At 42 days of age, 6 broiler chickens were selected from each group of birds for slaughter (3 male and 3 female; selected analogues by average weight in the group) and their pre-slaughter live weight, weight of bled carcass, non-eviscerated carcass, semi-eviscerated carcass and eviscerated carcass, as well as the weight of edible parts - breast, thigh, drumstick, wing, heart, liver and gizzard were determined.

**Table 3.** Composition and nutritional value of compound feed for broiler chickens 29-35 days old, %

| Indicator | Group of broiler chickens | | | |
|---|---|---|---|---|
| | SBM | HPSC | HPSC50cp | HPSC50q |
| Corn | 46.380 | 52.276 | 51.530 | 50.687 |
| Sunflower concentrate SP44 | – | 27.724 | 21.590 | 14.650 |
| Soybean meal SP 41 | 31.606 | – | 6.880 | 14.663 |
| Wheat | 15.000 | 15.000 | 15.000 | 15.000 |
| Limestone flour Ca 35% | 1.258 | 1.196 | 1.210 | 1.227 |
| Cornflour | 2.386 | 1.912 | 2.015 | 2.131 |
| Monocalcium phosphate | 0.089 | 0.226 | 0.195 | 0.159 |
| Methionine 99.5% | 0.278 | 0.166 | 0.190 | 0.218 |
| Lysine hydrochloride | 0.259 | 0.635 | 0.554 | 0.463 |
| Salt | 0.290 | 0.072 | 0.120 | 0.173 |
| Threonine 99% | 0.091 | 0.142 | 0.131 | 0.119 |
| Premix | 0.348 | 0.348 | 0.348 | 0.348 |
| Soybean oil | 2.015 | – | – | – |
| Sodium sulfate | – | 0.303 | 0.237 | 0.162 |
| Total | 100.000 | 100.000 | 100.000 | 100.000 |
| Nutritional value of compound feed: | | | | |
| Energy, MJ | 13.06 | 13.17 | 13.05 | 12.90 |
| Crude protein, % | 19.00 | 19.00 | 19.00 | 19.00 |
| Crude fibre, % | 3.46 | 3.74 | 3.68 | 3.62 |
| Digestible lysine, % | 1.06 | 1.06 | 1.06 | 1.06 |
| Digestible methionine and cystine, % | 0.82 | 0.82 | 0.82 | 0.82 |

As part of the study, the chemical composition of meat obtained from birds selected for slaughter was analyzed using methods described in AOAC (2000) immediately after slaughter. To determine moisture content, meat samples were dried at 110°C for 24 hours by the drying method (AOAC, 950.46) using a Termolab CHOL 58/350 drying oven (Ukraine). The weight was recorded, and the moisture content was calculated. In dry matter, the following was determined: raw ash – by burning the sample in a muffle furnace at a temperature of 550±20 °C for 4 hours (AOAC, 920.153). A SNOL-8.2/1100 muffle furnace (Republic of Lithuania) was used for combustion. The Kjeldahl method (AOAC, 928.08) was used to determine crude protein; a Gerhardt Turbotherm TT–625 (Germany) was used for ashing meat, and a Gerhardt Vapodest–300 (Germany) was used for distillation. Nitrogen was converted to crude protein by multiplying with a factor of 6.25. The analysis was carried out following the steps of cleavage, distillation and titration. Crude fat content was determined by Soxhlet extraction (AOAC, 991.36) by extracting samples with ether by melting the fat in it, using a Velp Scientifica UDK139 (Italy). Benzene was used as an extractant. Nitrogen-free extractives were determined by calculation based on the difference between the percentage of dry matter of crude protein, crude fat and crude ash. To determine the energy value of chicken meat, an IKA C 2000 basic Version 1 calorimeter (Germany) was used.

**Table 4.** Composition and nutritional value of compound feed for broiler chickens 36-42 days old, %

| Indicator | Group of broiler chickens | | | |
|---|---|---|---|---|
| | SBM | HPSC | HPSC50cp | HPSC50q |
| Corn | 49.247 | 54.687 | 54.096 | 53.236 |
| Sunflower concentrate SP44 | – | 25.313 | 20.450 | 13.370 |
| Soybean meal SP 41 | 28.868 | – | 5.454 | 13.394 |
| Wheat | 15.000 | 15.000 | 15.000 | 15.000 |
| Limestone flour Ca 35% | 1.235 | 1.177 | 1.188 | 1.208 |
| Cornflour | 2.672 | 2.238 | 2.320 | 2.438 |
| Monocalcium phosphate | 0.061 | 0.186 | 0.161 | 0.124 |
| Methionine 99.5% | 0.215 | 0.113 | 0.132 | 0.160 |
| Lysine hydrochloride | 0.202 | 0.546 | 0.482 | 0.388 |
| Salt | 0.291 | 0.091 | 0.129 | 0.183 |
| Threonine 99% | 0.040 | 0.087 | 0.078 | 0.065 |
| Premix | 0.284 | 0.284 | 0.284 | 0.284 |
| Soybean oil | 1.885 | – | – | – |
| Sodium sulfate | | 0.278 | 0.226 | 0.150 |
| Total | 100.000 | 100.000 | 100.000 | 100.000 |
| Nutritional value of compound feed: | | | | |
| Energy, MJ | 13.15 | 13.23 | 13.13 | 12.99 |
| Crude protein, % | 18.00 | 18.00 | 18.00 | 18.00 |
| Crude fibre, % | 3.35 | 3.61 | 3.56 | 3.50 |
| Digestible lysine, % | 0.96 | 0.96 | 0.96 | 0.96 |
| Digestible methionine and cystine, % | 0.74 | 0.74 | 0.74 | 0.74 |

**Table 5.** Chemical composition of high-protein sunflower concentrate, g/kg

| Indicator | Contents | |
|---|---|---|
| | for natural moisture | on dry matter |
| Moisture | 74.1±0.37 | – |
| Crude protein | 439.3±0.68 | 474.5±0.72 |
| Crude fat | 9.7±0.08 | 10.5±0.06 |
| Crude fibre | 73.9±0.43 | 79.8±0.52 |
| Crude ash | 68.2±0.27 | 73.7±0.31 |
| NFE | 334.7±1.23 | 361.5±1.11 |
| NDF | 223.7±0.89 | 241.6±0.97 |
| ADF | 78.6±0.31 | 84.9±0.26 |
| Lignin | 10.5±0.11 | 11.3±0.09 |

Meat quality assessment was performed 24 hours after slaughter on samples of breast muscle and thigh muscle taken during post-slaughter processing of carcasses and storage in a cold room at a temperature of 4–6 °C. The water holding capacity of breast and thigh meat samples of broiler chickens was determined according to the method described by Barbut S. (2024). A 1 g portion of the meat sample was centrifuged in an Eppendorf 5804R centrifuge (Germany) at 1000 rpm for 15 minutes at 4 °C without NaCl. The extracted water content was then measured and calculated as a percentage of the initial mass of the meat sample. The active acidity of meat was determined using a pH meter "pH-161" (Romania) using two types of electrodes – E536BNC and E531BNC. Cooking losses were determined by cooking meat samples (breasts and thighs) at 90°C for 30 minutes in a hot water bath, followed by cooling to room temperature. The weight of the sample before (W1) and after (W2) cooking was recorded to calculate cooking losses using the following formula 1:

$$Cooking\ loss, \% = \frac{W_1 - W_2}{W_1} \times 100 \quad (1)$$

**Statistical analysis**

The methods of variational statistics processed the obtained digital results by using software Statistica 10. The significance of differences between groups was assessed using a one-way analysis of variance (ANOVA) and the Tukey-Kramer multiple comparisons test as a post-hoc testing tool. Checking the distribution of sample data for normality was performed using the Kolmogorov-Smirnov test. If the data distribution was likely to differ from normal, the non-parametric Mann-Whitney U-test was used. Differences between groups were considered significant at P<0.05.

## RESULTS AND DISCUSSION

The effect of using high-protein sunflower concentrate in feeding broiler chickens on their viability, body weight and growth rate

The survival of the broiler chicken population throughout the study period corresponded to the regulatory level recommended by the breeder of the cross (Cobb Broiler Management Guide 2022), with no apparent effect of diet composition (Table 6).

**Table 6.** Broiler chicken survival depending on the level of replacement of soybean meal in the diet with high-protein sunflower concentrate (%, x ± SE, n = 100/group)

| Age period, days | Group of broiler chickens | | | |
|---|---|---|---|---|
| | SBM | HPSC | HPSC50cp | HPSC50q |
| 1–7 | 100.0±0.00 | 100.0±0.00 | 100.0±0.00 | 99.0±0.10 |
| 8-14 | 99.0±0.09 | 99.0±0.09 | 98.0±1.40 | 98.0±1.71 |
| 15-21 | 98.0±1.40 | 98.0±1.40 | 98.0±1.40 | 98.0±1.40 |
| 22-28 | 98.0±1.40 | 98.0±1.40 | 97.0±1.71 | 98.0±1.40 |
| 29–35 | 97.0±1.71 | 97.0±1.71 | 97.0±1.71 | 97.0±1.71 |
| 36–42 | 96.0±1.96 | 97.0±1.71 | 96.0±1.96 | 96.0±1.96 |

With regard to broiler body weight, changes were observed under the influence of partial substitution of soybean meal with high-protein sunflower concentrate in the diet (Table 7).

**Table 7.** Body weight of broiler chickens depending on the level of replacement of soybean meal with high-protein sunflower concentrate in the diet (g, x±SE, n=100/group)

| Age, days | Group of broiler chickens | | | |
|---|---|---|---|---|
| | SBM | HPSC | HPSC50cp | HPSC50q |
| 1 | 42.3±0.30[a] | 42.3±0.38[a] | 42.0±0.34[a] | 42.2±0.34[a] |
| 7 | 226.6±1.01[a] | 219.6±1.94[b] | 226.2±1.54[a] | 229.7±1.06[c] |
| 14 | 572.6±2.63[a] | 542.6±4.31[b] | 568.3±3.98[a] | 581.3±2.15[c] |
| 21 | 1190.9±18.22[a] | 1137.6±20.33[a] | 1190.8±21.82[a] | 1244.7±19.60[b] |
| 28 | 1837.3±27.71[a] | 1782.5±29.05[a] | 1845.4±28.93[a] | 1954.8±25.99[b] |
| 35 | 2601.6±30.11[a] | 2513.1±34.69[a] | 2579.1±33.77[a] | 2707.8±34.47[b] |
| 42 | 3367.3±31.08[a] | 3278.2±35.69[a] | 3342.3±36.74[a] | 3476.4±34.12[b] |

Note: a, b, c - indicate values that differ significantly in one row of the table ($P<0.05$).

In particular, at the beginning of the studies, namely at one-day age, the weight of broiler chickens was the same in all groups and met the recommendations of the cross producer (Cobb Broiler Management Guide, 2022). However, starting from the second week of growing, broilers of the group HPSC50q were characterised by higher body weight. In particular, at the end of the first week of growing, broilers of the HPSC50q group were characterised by higher body weight by 1.4% ($p<0.05$), in the second week - by 1.5% ($p<0.05$), in the third week - by 4.5% ($p<0.05$), in the fourth week - by 6.4% ($p<0.05$), in the fifth week - by 4.1% ($p<0.05$), compared to the birds of the control group. The final live weight of broiler chickens of the HPSC50q group at 42 days of growing was higher by 3.2% ($p<0.05$), compared to the birds of the SBM group. While the live weight of broiler chickens of the HPSC and HPSC50cp groups at the end of the growing period was at the same level as the control SBM group.

The effect of using high-protein sunflower concentrate on the slaughter quality of broiler chickens

Partial replacement of sunflower meal with high-protein sunflower concentrate in the diet of broiler chickens significantly affected their meat productivity (Table 8). In particular, broiler chickens of the group HPSC50q were characterised by a higher pre-slaughter live weight by 3.2% ($p<0.05$), the weight of the bled carcass by 4.7% ($p<0.05$), the non-eviscerated carcass by 4.1% ($p<0.05$), the semi-eviscerated carcass by 4.0% ($p<0.05$) and the eviscerated carcass by 4.4% ($p<0.05$), compared to the group SBM. As for the mass of edible parts of the carcass of broiler chickens, the effect of partial replacement of sunflower meal with high-protein sunflower concentrate in their diet is also clearly visible. In particular, broiler chickens of the group HPSC50q were characterised by a greater mass of breast muscles by 6.6 % ($p<0.05$), thighs by 3.7 % ($p<0.05$), shins by 4.5 % ($p<0.05$) and wings by 2.0 % ($p<0.05$), compared to the group SBM.

**Table 8.** Slaughter qualities of broiler chickens depending on the level of replacement of soybean meal with high-protein sunflower concentrate in the diet (g, x±SE, n=6/group)

| Indicator, g | Group of broiler chickens | | | |
|---|---|---|---|---|
| | SBM | HPSC | HPSC50cp | HPSC50q |
| Weight: | | | | |
| – pre-slaughter live | 3364.9±31.60[a] | 3272.2±34.83[a] | 3340.6±31.33[a] | 3471.8±33.89[b] |
| – bled carcass | 3196.7±32.07[a] | 3106.2±34.22[a] | 3206.0±35.47[a] | 3348.2±33.90[b] |
| – non-eviscerated carcass | 3062.1±33.84[a] | 2989.3±33.44[a] | 3050.5±33.22[a] | 3186.8±32.59[b] |
| – semi-eviscerated carcass | 2927.5±34.62[a] | 2854.3±34.88[a] | 2914.8±32.22[a] | 3043.5±35.38[b] |
| – eviscerated carcass | 2572.4±36.39[a] | 2483.3±33.08[a] | 2563.3±16.38[a] | 2686.2±34.77[b] |
| Weight of edible parts: | | | | |
| – breast muscles | 918.6±18.35[a] | 908.4±17.23[a] | 919.7±19.91[a] | 979.0±19.61[b] |
| – thigh | 469.4±6.26[a] | 456.5±5.12[a] | 468.4±6.57[a] | 486.7±5.34[b] |
| – drumstick | 315.6±4.87[a] | 307.9±2.10[a] | 314.7±1.89[a] | 336.0±4.16[b] |
| – wing | 255.3±1.62[a] | 251.6±1.72[a] | 253.6±1.67[a] | 260.4±1.51[b] |
| – heart | 14.4±0.12[a] | 13.4±0.09[a] | 14.0±0.14[a] | 14.2±0.08[a] |
| – liver | 47.1±0.51[a] | 45.8±0.49[a] | 47.1±0.34[a] | 47.4±0.58[a] |
| – gizzard | 25.9±0.28[a] | 25.2±0.27[a] | 26.1±0.29[a] | 26.2±0.31[a] |

Note: a, b - indicate values that significantly differed in one row of the table ($P < 0.05$).

**Table 9.** Slaughter yield of broiler chickens depending on the level of replacement of soybean meal with high-protein sunflower concentrate in the diet (%, x±SE, n=6/group)

| Indicator | Group of broiler chickens | | | |
|---|---|---|---|---|
| | SBM | HPSC | HPSC50cp | HPSC50q |
| Carcass output: | | | | |
| – bled carcass | 95.1±0.27[a] | 95.0±0.25[a] | 95.8±0.29[a] | 96.4±0.24[b] |
| – non-eviscerated carcass | 91.2±0.11[a] | 91.4±0.08[a] | 91.3±0.11[a] | 91.8±0.10[b] |
| – semi-eviscerated carcass | 87.1±0.12[a] | 87.4±0.11[a] | 87.3±0.09[a] | 87.7±0.08[b] |
| – eviscerated carcass | 76.4±0.12[a] | 76.5±0.16[a] | 76.7±0.17[a] | 77.4±0.15[b] |
| Yield of edible parts: | | | | |
| – breast muscles | 27.32±0.176[a] | 27.76±0.189[a] | 27.53±0.134[a] | 28.20±0.122[b] |
| – thigh | 13.80±0.079[a] | 13.95±0.078[a] | 14.02±0.088[a] | 14.02±0.074[b] |
| – drumstick | 9.37±0.036[a] | 9.41±0.028[a] | 9.42±0.023[a] | 9.68±0.038[b] |
| – wing | 7.57±0.061[a] | 7.69±0.078[a] | 7.59±0.072[a] | 7.50±0.051[a] |
| – heart | 0.40±0.008[a] | 0.41±0.007[a] | 0.42±0.009[a] | 0.41±0.004[a] |
| – liver | 1.42±0.052[a] | 1.40±0.045[a] | 1.41±0.037[a] | 1.37±0.041[a] |
| – gizzard | 0.76±0.008[a] | 0.77±0.007[a] | 0.78±0.009[a] | 0.75±0.008[a] |

Note: a, b - indicate values that significantly differed in one row of the table ($P < 0.05$).

It was found that the slaughter yield of broiler chickens changed under the influence of partial replacement of sunflower meal in the diet with high-protein sunflower concentrate (Table 9). In particular, broiler chickens of the group HPSC50q were characterised by a higher yield of bled carcass by 1.3% ($p<0.05$), non-eviscerated carcass by 0.6 % ($p<0.05$), semi-eviscerated carcass by 0.6 % ($p<0.05$) and eviscerated carcass by 1.0 % ($p<0.05$), as well as a higher yield of edible parts of the carcass, namely breast muscles by 0.88 % ($p<0.05$), thighs by 0.22 % ($p<0.05$) and drumsticks by 0.31 % ($p<0.05$), compared to the group SBM.

The effect of using high-protein sunflower concentrate on the meat quality of broiler chickens

Studies of the effect of partial replacement of soybean meal in the diet of broiler chickens with high-protein sunflower concentrate on meat quality indicators (Table 10) did not reveal any changes in the technological properties of chicken meat. Some of the identified minor differences in meat quality parameters related only to the complete replacement of soybean meal in the diet of broiler chickens with high-protein sunflower concentrate. In particular, in the HPSC group, a decrease in muscle tissue loss during heat treatment of the breast muscles by 0.9% ($p<0.05$) and thigh muscles by 1.4% ($p<0.05$) was observed.

**Table 10.** Meat quality of broiler chickens depending on the level of replacement of soybean meal with high-protein sunflower concentrate in the diet (x±SE, n=6/group)

| Indicator | Group of broiler chickens | | | |
|---|---|---|---|---|
| | SBM | HPSC | HPSC50cp | HPSC50q |
| Breast muscles | | | | |
| Active acidity, pH | 6.1±0.02$^{a}$ | 6.1±0.02$^{a}$ | 6.1±0.03$^{a}$ | 6.1±0.04$^{a}$ |
| Water holding capacity, % | 39.3±0.38$^{a}$ | 39.6±0.24$^{a}$ | 39.1±0.31$^{a}$ | 39.5±0.28$^{a}$ |
| Muscle tissue loss during heat treatment (cooking), % | 29.2±0.28$^{a}$ | 28.3±0.33$^{b}$ | 28.8±0.35$^{a}$ | 29.0±0.43$^{a}$ |
| Thigh muscles | | | | |
| Active acidity, pH | 6.2±0.02$^{a}$ | 6.2±0.03$^{a}$ | 6.2±0.03$^{a}$ | 6.2±0.04$^{a}$ |
| Water holding capacity, % | 40.3±0.13$^{a}$ | 40.4±0.29$^{a}$ | 40.7±0.48$^{a}$ | 40.0±0.39$^{a}$ |
| Muscle tissue loss during heat treatment (cooking), % | 22.8±0.49$^{a}$ | 21.4±0.31$^{b}$ | 22.2±0.42$^{a}$ | 22.5±0.26$^{a}$ |

Note: a, b - indicate values that significantly differed in one row of the table ($P < 0.05$).

The effect of using high-protein sunflower concentrate on the chemical composition of broiler chicken meat

The results of the study of the effect of complete and partial replacement of soybean meal in the diet of broiler chickens with high-protein sunflower concentrate on the chemical composition of meat are given in Table 11. It was found that both with complete and partial replacement of soybean meal with high-protein sunflower concentrate, a decrease in the content of crude fat in the breast muscles and thigh muscles of broiler chickens was observed.

**Table 11.** Chemical composition of breast and thigh muscles of broiler chickens depending on the level of replacement of soybean meal with high-protein sunflower concentrate in the diet (g/100 g, x±SE, n=6/group)

| Indicator | Group of broiler chickens | | | |
|---|---|---|---|---|
| | SBM | HPSC | HPSC50cp | HPSC50q |
| Breast muscles | | | | |
| Total moisture | 75.95±0.298$^{a}$ | 77.19±0.161$^{a}$ | 77.19±0.189$^{a}$ | 76.06±0.227$^{a}$ |
| Dry matter | 24.05±0.112$^{a}$ | 22.81±0.109$^{a}$ | 22.81±0.098$^{a}$ | 23.94±0.123$^{a}$ |
| Crude fat | 6.11±0.143$^{a}$ | 5.04±0.128$^{b}$ | 5.02±0.171$^{bc}$ | 4.96±0.158$^{bcd}$ |
| Crude protein | 82.68±1.014$^{a}$ | 83.69±1.765$^{a}$ | 83.77±1.561$^{a}$ | 83.04±1.547$^{a}$ |
| Crude ash | 8.50±0.145$^{a}$ | 9.57±0.151$^{a}$ | 9.06±0.303$^{a}$ | 9.25±0.176$^{a}$ |
| NFE | 2.71±0.326$^{a}$ | 1.70±0.227$^{a}$ | 2.15±0.211$^{a}$ | 2.74±0.288$^{a}$ |
| Energy value, kcal | 102.3±0.356$^{a}$ | 94.8±0.362$^{b}$ | 94.9±0.412 $^{bc}$ | 94.6±0.374 $^{bcd}$ |
| Thigh muscles | | | | |
| Total moisture | 72.42±0.567$^{a}$ | 70.51±0.381$^{a}$ | 70.73±0.286$^{a}$ | 73.30±0.468$^{a}$ |
| Dry matter | 27.58±0.234$^{a}$ | 29.49±0.211$^{a}$ | 29.27±0.221$^{a}$ | 26.70±0.196$^{a}$ |
| Crude fat | 26.63±0.311$^{a}$ | 20.83±0.423$^{b}$ | 20.78±0.499 $^{bc}$ | 19.96±0.394$^{bcd}$ |
| Crude protein | 60.09±1.290$^{a}$ | 63.72±1.344$^{a}$ | 63.30±1.187$^{a}$ | 63.43±1.343$^{a}$ |
| Crude ash | 8.09±0.665$^{a}$ | 9.29±0.782$^{a}$ | 9.34±0.593$^{a}$ | 9.80±0.658$^{a}$ |
| NFE | 5.19±0.617$^{a}$ | 6.16±0.679$^{a}$ | 6.58±0.716$^{a}$ | 6.81±0.711$^{a}$ |
| Energy value, kcal | 142.4±0.735$^{a}$ | 128.4±0.712$^{b}$ | 128.6±0.656 $^{bc}$ | 127.3±0.557$^{bcd}$ |

Note: a, b, c, d - indicate values that significant differed in one row of the table ($P < 0.05$)

In particular, chickens in the HPSC group had a lower crude fat content in the breast muscles by 17.5% ($p<0.05$) and thigh muscles by 21.8% ($p<0.05$), compared to the SBM group. Broilers in the HPSC50cp group had a 17.8% ($p<0.05$) lower crude fat content in the breast muscles and 22.0% ($p<0.05$) lower crude fat content in the thigh muscles compared to the control group. Broilers in the HPSC50q group had an 18.8% ($p<0.05$) lower crude fat content in the breast muscles and a 25.0% ($p<0.05$) lower crude fat content in the thigh muscles compared to the SBM group. In addition, the decrease in fat content in the meat of broiler chickens, resulting from the full or partial replacement of sunflower meal in their diet with high-protein sunflower concentrate, led to a decrease in the energy value of the chicken meat. In particular, in the HPSC group, in the diet of which soybean meal was replaced entirely with sunflower concentrate, there was a lower energy value in the breast muscles by 7.3% ($p<0.05$) and in the thigh muscles by 9.8% ($p<0.05$) compared to the SBM group.

In broilers of the HPSC50cp group, a lower energy value of the breast muscles was observed by 7.2% ($p<0.05$) and of the thigh muscles by 9.7% ($p<0.05$) compared to the SBM group. Broilers in the HPSC50q group, however, exhibited lower energy content in the breast muscles by 7.5% ($p<0.05$) and in the thigh muscles by 10.6% ($p<0.05$) compared with the SBM group.

## DISCUSSION

Soybean meal is widely used as a protein source in poultry feeds (Barboza Martignone *et al.,* 2024). Despite the fact that Ukraine is an exporter of soybeans, fluctuations in its prices on the international market put pressure on local markets

(Attia *et al*., 2022). Given the need for an alternative source of protein and certain undesirable consequences of using sunflower meal in poultry feeding, we used a new feed product – high-protein sunflower concentrate, and investigated the effectiveness of its complete or partial replacement of soybean meal in the diet of broiler chickens.

This study showed that replacing soybean meal with high-protein sunflower concentrate at a concentration of 50% by volume in the diet of broiler chickens does not have a negative impact on the viability of the birds and contributes to an increase in their body weight at 42 days of age by 3.2% ($p<0.05$). The data obtained are consistent with the results described by Kyrkelanov *et al*. (2020), who describe the successful replacement of soybean meal with high-protein sunflower meal at levels of 5–8–12% and 15–20–22%, respectively, during the starter–grower–finisher periods of growing broiler chickens. In contrast to these results, scientists describe that replacing soybean meal with sunflower meal either has no effect at all or has a negative effect on the growth parameters of broilers. In particular, a recent study by Munawar *et al.* (2025) showed that replacing soybean meal with sunflower meal at a level of up to 20% with enrichment of 100 g/ton of the NSPase enzyme did not have a negative effect on the body weight of broilers. These results are consistent with the data described by Bilal *et al.* (2017), who studied the effectiveness of using sunflower meal in diets with or without the NSPase enzyme and did not find a significant effect on body weight of different concentrations of soybean meal replacement. Similarly, Yaqoob *et al.* (2022), who studied the possibility of replacing soybean meal with sunflower meal at 3%, 6% and 9% in combination with multienzymes, did not observe significant differences in growth parameters of broiler chickens depending on the level of sunflower meal introduction. However, other studies have documented that replacing soybean meal with sunflower meal up to 16% in the diet can negatively affect growth parameters and feed efficiency in 21-day-old broilers, which is explained by the high content of fibre and insoluble non-starch polysaccharides in sunflower meal (DMaria de Moraes Oliveira *et al.,* 2016). Berwanger *et al*. (2017) reported that adding more than 10% sunflower meal to the broiler diet negatively affected the growth performance of broiler chickens during the $21^{st}$–$42^{nd}$ day of growth. They explained this adverse effect by an increase in the viscosity of the digested material due to the high content of insoluble non-starch polysaccharides in the diet. These differences can be explained by the fact that, in all the studies described, the sunflower product used to replace soybean meal was sunflower meal, which typically contains 30–34% crude protein, whereas in the present study a high-protein sunflower concentrate with a crude protein content of 44% was used.

The increase in body weight of broiler chickens at slaughter age, caused by replacing 50% of soybean meal in their diet with high-protein sunflower concentrate, contributed to an increase in pre-slaughter live weight by 3.2% ($p<0.05$), the mass of the bled carcass by 4.7% ($p<0.01$), the non-eviscerated carcass by 4.1% ($p<0.01$), the semi-eviscerated carcass by 4.0% ($p<0.05$) and the eviscerated carcass by 4.4% ($p<0.05$), the mass of the breast muscles by 6.6% ($p<0.05$), the thighs by 3.7% ($p<0.05$), the drumsticks by 4.5% ($p<0.05$) and the wings by 5.1 g or 2.0% ($p<0.05$). The difference in pre-slaughter live weight, carcass weight, and individual edible parts of the carcass of broiler chickens may be due to differences in the amino acid profile or biological value of different protein meals, namely soybean and sunflower (Rehman *et al.* 2002). According to Penchev *et al.* (2022), partial replacement of soybean meal with high-protein sunflower meal does not have a significant effect on the carcass characteristics of broiler chickens. At the same time, the authors note that complete replacement of soybean meal with high-protein sunflower meal causes a decrease in carcass weight.

As for the chemical composition, this study found that 50% replacement of soybean meal with high-protein sunflower concentrate contributes to a decrease in the crude fat content in the breast muscles of broiler chickens by 18.8% ($p<0.05$) and thigh muscles by 25.0% ($p<0.05$) while reducing the energy value by 7.5% ($p<0.05$) and 10.6% ($p<0.05$), respectively.

Scientists attribute the reduction in muscle fat content in broilers fed oilseed concentrate to the high availability of long-chain fatty acids in the feed, namely the higher efficiency of conversion of long-chain fatty acids C20:5(n-3) compared to C22:6(n-3) (Kim and Voy, 2021). Diets enriched with various fatty acids have a strong effect on the deposition of polyunsaturated fatty acids in tissue lipids (Kralik et al., 2025). At the same time, the mechanism of modification of adipose tissue deposition by the presence of polyunsaturated fatty acids in the feed is not yet fully understood. The aforementioned reduction in fat content in chicken meat is a significant positive consequence of replacing soybean meal with high-protein sunflower concentrate, as chicken meat is a valuable source of protein, lipids, and minerals for the human body. It also contains bioactive components (vitamins, antioxidants, essential amino acids, trace elements), important in metabolic processes that contribute to the optimal health of consumers (Cartoni Mancinelli *et al*., 2022). There are many scientific studies on the fatty acid content of broiler meat (Long *et al.,* 2020; Ali *et al.,* 2023; Kralik *et al.,* 2023; Qaid *et al.,* 2023), particularly focused on improving the fatty acid profile, usually the polyunsaturated fractions (Dal Bosco *et al.* 2022). Broiler meat with increased content of N-3 polyunsaturated fatty acids (PUFA) is already considered a functional product (Kralik *et al.,* 2025).

At the same time, in the literature, researchers often describe the negative impact of replacing soybean meal with sunflower meal, which is manifested by a decrease in the crude protein content in the meat of broiler chickens. Thus, Penchev *et al.* (2022), who studied the complete and partial replacement of soybean meal with high-protein sunflower meal, noted a decrease in crude protein, moisture, and crude ash in the breast muscles of broilers. A similar negative effect on the content of crude protein and moisture in meat was also described by Aregheore (1998). The authors note that replacing 30% of soybean meal with sunflower meal in the diet of broiler chickens causes a decrease in the moisture and crude protein content of the meat. Similarly, Jankowski *et al.* (2011) found, although insignificant, a negative effect of replacing soybean meal with sunflower meal on the crude protein and crude ash content of turkey meat. In contrast, Laudadio *et al.* (2013) found no difference in the chemical composition of turkey meat when soybean and sunflower meal were used in their feeding, which confirmed the study of Slavica *et al.* (2006).

## CONCLUSIONS

It has been established that the most effective way for the body of broiler chickens is to replace 50% of the soybean meal in their diet with high-protein sunflower concentrate. This contributes to an increase in the final body weight by 3.2% ($p<0.05$), pre-slaughter live weight by 3.2% ($p<0.05$), the weight of the bled carcass by 4.7% ($p<0.05$), the non-eviscerated carcass by 4.1% ($p<0.05$), the semi-eviscerated carcass by 4.0% ($p<0.05$) and the eviscerated carcass by 4.4% ($p<0.05$), the weight of the breast muscles by 6.6% ($p<0.05$), the thigh by 3.7% ($p<0.05$), the drumstick by 4.5% ($p<0.05$) and the wing by 2.0% ($p<0.05$), as well as a higher yield of the bled carcass by 1.3% ($p<0.05$), the non-eviscerated carcass by 0.6% ($p<0.05$), semi-eviscerated carcass - by 0.6% ($p<0.05$) and eviscerated carcass - by 1.0% ($p<0.05$), higher yield of edible parts of the carcass, namely breast muscles - by 0.88% ($p<0.05$), thighs - by 0.22% ($p<0.05$) and drumsticks - by 0.31% ($p<0.05$). In addition, 50% replacement of soybean meal with high-protein sunflower concentrate contributes to a decrease in the crude fat content in the breast muscles of broiler chickens by 18.8% ($p<0.05$) and thigh muscles by 25.0% ($p<0.05$) with a decrease in energy value by 7.5% ($p<0.05$) and 10.6% ($p<0.05$), respectively, compared to the control group, whose birds received a standard diet with soybean meal in the composition. Thus, in view of the above results, established that the most effective way for the broiler chickens is to replace 50% of the soybean meal in their diet with high-protein sunflower concentrate.

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