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USE OF HIGH-PROTEIN SUNFLOWER CONCENTRATE IN LAYING HENS FEEDING

SUMMARY

This study aimed to investigate the chemical composition and digestibility of nutrients in high-protein sunflower concentrate, as well as its effectiveness in feeding laying hens.

Researchers determined the chemical composition of high-protein sunflower concentrate using the Wende method, and evaluated the digestibility of nutrients in high-protein sunflower concentrate in two modifications: by the direct method and by the process of inert substances. As an inert substance, lignin provided a natural component of plant-based feed. The energy nutritional value of high-protein sunflower concentrate was calculated in joules of metabolic energy based on the content of digestible protein, fat, fibre, and BER, as determined in a physiological experiment. The object of research was the laying hens of the Lohman Brown industrial herd.

The digestibility of nutrients in high-protein sunflower concentrate for laying hens, as determined by the direct method and the inert matter method, namely crude protein - 92.5-92.7%, crude fat - 84.6-84.9%, crude fibre - 7.0-9.0%, nitrogen-free extractives - 75.1-75.5%, organic matter - 76.4-76.7%, neutral detergent fibre - 64.0-64.9%, and acid detergent fibre- 5.2-7.0%. A comparison of different methods for determining digestibility showed minimal differences between them.

Results suggest that the energy nutritional value, calculated based on the difference between the consumed and released energy (direct method), was 1.295 MJ/100 g. The value computed using the regression equation (classical method) ranged from 1.168 to 1.175 MJ/100 g. The metabolic energy of high-protein sunflower concentrate, calculated using the sum of digestible substances, was

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1.162-1.170 MJ/100 g. The total energy value of high-protein sunflower concentrate for laying hens is 11.621-12.948 MJ/kg. Using high-protein sunflower concentrate in feeding laying hens increases egg production by 1.5% (P<0.05). Replacing soybean meal in the diet of laying hens with high-protein sunflower concentrate did not affect the quality of their eggs, except for yolk colour, which improved by 1.3 points or 14.3% (P<0.05). As for feed consumption, results suggest that laying hens whose diet had high-protein sunflower meal added had lower feed consumption by 1.26-1.30% (p<0.05), which resulted in lower feed consumption by 2.4% (P<0.05) for the production of 1 kg of egg mass.

Keywords: high-protein sunflower concentrate, chemical composition, digestibility of nutrients, energy nutritional value, laying hens, laying, feed consumption

INTRODUCTION

Protein is one of the most expensive components of poultry diets, and at the same time, its availability is becoming increasingly limited worldwide (Vlaicu *et al.,* 2024). The dominant source of protein in poultry diets is soybean meal (Aguirre *et al.,* 2024; FAO, 2023; Marchal *et al.,* 2024), which typically has a high digestibility coefficient (Najmadeen *et al.,* 2024). However, the cost of soybean meal is constantly increasing, and its availability can fluctuate due to factors such as price, conflicts, or pandemics (Marchal *et al.,* 2024). Additionally, diets that exclude soybean meal in chicken feeding have a lower environmental impact (Fiorilla *et al.,* 2024; Montalbán *et al.,* 2024). Therefore, scientists are constantly working to improve poultry diets (Ibatullin *et al.,* 2022; Ibatullin *et al.,* 2022; Plyska *et al.,* 2021; Sychov *et al.,* 2024), and in light of the described factors, there is growing interest in using more local alternatives to soybean meal, one of which is sunflower.

Sunflower is a widely cultivated crop, the third largest in the world in oilseed production (Giolitti & Mederos, 2024). Sunflower meal is a byproduct of the oilseed industry and can serve as an alternative source of protein in poultry feed (Saleh *et al.,* 2021). The crude protein content of sunflower meal typically exhibits a high dispersion, ranging from 23% to 44%, depending mainly on the quality of the dehulling procedure. However, the high fibre and low energy content of sunflower meals limit their use in poultry diets due to their low concentration of lysine and threonine, as well as various polyphenolic compounds (Such *et al.,* 2024).

Sunflower meal contains a diverse fibre composition, including both structural and water-soluble fractions. Its structural, insoluble fibre, which can be found mainly in the shell, can stimulate the development of the stomach and thus increase digestion time in the upper gastrointestinal tract. Proper stomach functioning also stimulates the secretion of pancreatic enzymes, improving the digestibility of starch, lipids and other food components (Jha & Mishra, 2021). The water-soluble fraction of sunflower fibre is primarily composed of β-glucans, which can increase the viscosity of intestinal contents, potentially leading to reduced nutrient absorption and an imbalance of the microbiota in the small intestine (Tejeda & Kim, 2021). Current knowledge about the specific effects of sunflower fibre on digestion and intestinal health in poultry is limited, and the maximum levels of its content for different poultry species and age categories remain unknown (Lannuzel *et al.,* 2022). However, the high fibre content limits the use of sunflower meals in chicken diets (Jha & Mishra, 2021; Pilorgé, 2020; Such *et al.,* 2024). At the same time, these limitations are described mainly for broilers, while the use of sunflower meal does not negatively influence the performance parameters of laying hens (Koçer *et al.,* 2021; Saleh *et al.,* 2021), a fact that the more developed digestive system of laying hens in terms of intestinal capacity than broilers may explain. Laying hens have a lower protein requirement than broiler chickens, which allows for the complete or partial replacement of soybean meal with sunflower meal (Gül *et al.,* 2025).

In addition, most experiments on determining the digestibility of nutrients were conducted on broiler chickens, and limited data are available from studies on laying hens (Lemme *et al.*, 2004). In particular, according to Such N. *et al.* (2024), feeding sunflower meal in an amount of 30% does not have a negative effect on the digestibility of amino acids in laying hens. At the same time, Saleh A. A. *et al.* (2021) note that increasing the level of sunflower meal in the diet of laying hens from 50 to 100 g/kg also does not have a negative effect on their body weight gain, feed intake and egg weight, but contributes to an increase in egg production and feed conversion, and is also accompanied by an improvement in yolk color, a decrease in cholesterol levels in egg yolk and an increase in the content of vitamin E, calcium, linoleic acid, linoleic acid and oleic acid. However, to achieve optimal body weight at the beginning of the laying period, young birds are raised with restricted feeding and a light program. The low daily feed intake is an important difference between broiler chickens and young laying hens, which may affect protein digestibility. In the case of laying hens, protein, energy and calcium requirements vary throughout the day due to the synthesis of egg components, which alter the feeding habits of the hens, as well as the effects of longer periods of darkness and restricted feeding (Lu *et al.,* 2021; Molnár *et al.,* 2018).

MATERIAL AND METHODS

The research was conducted in the conditions of the experimental base of the problematic research laboratory of feed additives of the P.D. Pshenychnyy Department of Animal Nutrition and Feed Technology National University of Life and Environmental Sciences of Ukraine and Poultry R&D Centre AVA Group during period from May 2024 to March 2025. The object of the study was laying hens of the industrial herd "Lohmann Brown". Experiments with experimental animals were carried out in accordance with the rules of the European Convention for the Protection of Vertebrate Animals (European Union, 2010).

Chemical composition of high-protein sunflower concentrate.

Chemical composition of high-protein sunflower concentrate according to the rules of the European Convention for the Protection of Vertebrate Animals (European Union, 2010). Current methodologies, as determined by Commission Regulation (EC) No. 2009, guided the laboratory analyses of feed and litter. To determine dry matter, researchers dried the material in a drying cabinet at a temperature of 65±2 °C for total moisture and 105±2 °C for hygroscopic moisture, using a "Termolab CHOL58/350" drying cabinet (Ukraine).

In dry matter, researchers determined the raw ash by burning the sample in a muffle furnace at a temperature of 550 ± 20 °C. These researchers further used a "SNOL-8.2/1100" muffle furnace (Republic of Lithuania) for combustion; nitrogen, by the Kjeldahl method (for ash of feed, "Gerhardt Turbotherm TT-625" (Germany), for distillation - "Gerhardt Vapodest-300" (Germany). Researchers then converted the nitrogen content to crude protein by multiplying it by a factor of 6.25. Urine nitrogen was separated from faecal nitrogen by the Dyakov method; crude fat by the Soxhlet method, using "Velp Scientifica UDK139" (Italy). Researchers used Benzene as an extractant; crude fiber - by the Henneberg and Stomann method, washing the sample in diluted sulfuric acid and potassium hydroxide, using "Gerhardt FibreBag-System FBS6" (Germany); nitrogen-free extractives - calculated by the difference between the organic matter content and the sum of crude protein, crude fat and crude fiber; neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin - by the Van Soest method. NDF - by boiling a feed sample in a neutral detergent (sodium lauryl sulfate). ADF – by boiling a feed sample in an acidic detergent (cetyl trimethyl ammonium bromide). After treating the sample with highly concentrated (72%) sulfuric acid, researchers determined the NDF, ADF and lignin using "Gerhardt FibreBag-System FBS6" (Germany).

Energy nutritional value of high-protein sunflower concentrate.

Researchers calculated the energy nutritional value of high-protein sunflower concentrate in Joules of metabolic energy, based on the content of digestible protein, fat, fibre and nitrogen-free extractives (NFE) determined in the physiological experiment, in the following way:

1. Direct method:

$ME_{\mathrm{direct}} = GE_{feed} - GE_{droppings}$,

where: GE_{feed} - gross energy of feed; $GE_{droppings}$ – gross energy of droppings.

2.Regression equation (classical):

$ME_{\mathrm{classical}} = 17{,}84\ dP + 39{,}78\ dF + 17{,}71\ dF + 17{,}71\ dNFE$,

Where: dP - digestible protein, g; dF - digestible fat, g; dF - digestible fibre, g; dNFE - digestible nitrogen-free extractives, g.

3.According to the total of digestible nutrients:

$ME_{\mathrm{TDN}} = SDN \times K \times 0{,}96$, Where SDN is the sum (g) of digestible nutrients (protein, fat × 2.25, fibre and NFE), K is a coefficient equal to 18.43 kJ per gram of SDN; 0.96 is the ratio between digestible and metabolizable energy.

Digestibility of nutrients of high-protein sunflower concentrate.

Researchers conducted digestibility tests on high-protein sunflower concentrate nutrients using two methods: the direct method and the inert substances method (Table 1). Lignin served as an inert substance and a natural component of plant-based feeds for chickens kept in individual cages. The area per head was 0.2 m^2, the feeding front was 25 cm, and the watering was 3 cm. The experiment lasted 10 days on chickens aged 280-291 days. The physiological experiment consisted of two periods: preparatory and primary. During the preparatory period of the experiment, which lasted five days, the birds consumed the studied feed under the new detention conditions, allowing for the establishment of their feed consumption levels.

Table 1. Scheme of a physiological experiment to determine the digestibility of nutrients of high-protein sunflower concentrate in laying hens, n=12

Method for determining digestibility	Experiment periods	Duration, days	Feeding	Age, days
Direct	preparatory	5	high-protein sunflower concentrate	280-285
	accounting	5	high-protein sunflower concentrate	286-291
Inert substances	preparatory	5	high-protein sunflower concentrate	280-285
	accounting	5	high-protein sunflower concentrate	286-291

In the direct method of determining digestibility, during the accounting period, careful recordkeeping of the feed consumed by each animal, its residues, and the excreted droppings took place. The droppings were collected from each bird separately in a suitable container, weighed, and then stored in glass jars, preserving them with a solution of hydrochloric acid. Researchers took samples of the consumed feed and the food and stored them daily in jars in the refrigerator. Researchers calculated the digestibility coefficients of crude protein, fat, fibre, NFE and neutral-detergent and acid-detergent fibre using the formula:

$$\mathrm{DC} = \frac{DNF}{NC_{feed}} \times 100$$

where DC - is the digestibility coefficient, %; DNF - digestible nutrient of feed, g; NC_{feed} – nutrient content in the consumed feed, g.

When determining the digestibility of high-protein sunflower concentrate by the inert substance method, it was not necessary to accurately weigh the consumed feed and excreted litter. By using indicator substances, it is possible to avoid the need for quantitative accounting of excreted faeces and consumed feed. Indicators are substances that can be fed or administered to animals, but they remain completely inert in the digestive tract and are excreted, mixing evenly with the faeces. Feeds contain internal indicators that determine the digestibility of nutrients in the diet (lignin, plant chromogens, silicic acid). External indicators are added to the feed after thorough mixing (chromium or iron oxide, polyethene) and enable the determination of both the digestibility coefficient and the amount of feed consumed and excreted in faeces. In our studies, we utilized an internal indicator of plant-based feeds, namely lignin.

Table 2. Scheme of laying hens' feeding, %

Characteristic	Diet							
	Pre-Layer (Week 18–5 % prod.)		Layer Phase 1 (Week 19 – approx. 50*; egg mass above 59 g/hen/day)		Layer Phase 2 (Approx. week 50–70*; egg mass above 55 g/hen/day)		Layer Phase 3 (Approx. after week 70)	
	1	2	1	2	1	2	1	2
Energy, kcal	2700	3014	2725	2902	2725	2903	2725	2911
Crude protein	17.50	17.50	16.50	16.50	15.80	15.80	14.80	14,80
Crude fat	2.52	2.49	2.99	2.4	2.778	2.439	2.51	2.49
Crude fiber	4.03	3.55	2.39	3.33	2.35	3.23	2.44	3.06
Calcium	2.2	2.2	3.57	3.57	3.67	3.67	3.75	3.75
Phosphorus	0.4	0.4	0.37	0.37	0.34	0.34	0.32	0.32
Sodium	0.17	0.17	0.16	0.17	0.15	0.17	0.15	0.17
Chlorine	0.25	0.32	0.217	0.333	0.2	0.32	0.21	0.32
Digestible Lysine	0.70	0.70	0.71	0.71	0.67	0.67	0.64	0.64
Digestible Methionine+Cystine	0.63	0.63	0.64	0.64	0.6	0.6	0.58	0.58
Digestible Threonine	0.533	0.5	0.5	0.5	0.48	0.47	0.45	0.45
Choline, mg/kg	600	600	600	600	600	600	600	600
Composition, %								
Corn	50.380	52.793	50.540	51.102	52.506	52.718	55.208	55.263
Sunflower concentrate SP44	-	25.764	-	23.553	-	21.757	-	18.971
Soybean meal SP 45	17.817	-	23.700	-	21.822	-	18.295	-
Wheat	15.000	15.000	15.000	15.000	15.000	15.000	15.000	15.000
Limestone flour Ca 36%	1.332	1.443	5.160	5.345	5.338	5.525	5.586	5.766
Sunflower meal SP35	10.471	-	-	-	-	-	0.911	-
Soybean premix	5.000	-	5.000	-	5.000	-	5.000	-
Premix concentrate	-	5.000	-	5.000	-	5.000	-	5.000
Soybean oil	-	-	0.600	-	0.334	-	-	-
Total	100	100	100	100	100	100	100	95

Researchers calculated the digestibility coefficient for one indicator by applying the formula:

$$\mathrm{DC} = \left(1 - \frac{IM_{feed} \times NC_{fecal}}{IM_{fecal} \times NC_{feed}}\right) \times 100$$

where DC - is the digestibility coefficient, %; IM_{feed} – content of inert matter in feed, %; NC_{fecal} - nutrient content in feces, %; IM_{fecal} - content of inert matter in feces, %; NC_{feed} - nutrient content in feed, %.

Hens' productivity and egg quality

During the experiment, the chickens were provided with drinking water and complete feed (Table 2) and kept (Table 3) in accordance with the requirements (Ibatullin *et al.,* 2020; Kryvenok *et al.,* 2017; Management guide, 2024; VNTP-APK-04.05, 2005).

Table 3. Scheme of the experiment to determine the productivity of laying hens and the quality of the eggs obtained, n=120

Characteristic	Group of hens	
	1 (control)	2
Population of laying hens, total, birds	120	120
Cage dimensions: - length, cm - depth, cm - area, cm^2	 60 62 3720	
Hens are placed in 1 cage, birds	10	
Area availability, cm^2/birds	372,0	
Nipples in the cage, pcs.	1	
Feeding front, cm	7,1	

During the 44-week productive period, the number of eggs laid by the laying hens in each group and their egg-laying intensity were determined daily. Researchers calculated the survival rate of the population daily by deducting the number of mortalities and cullings. Once a week, researchers measured the mass of eggs and the live weight of laying hens from specific marked cages, using a sample of at least 100 birds ($n \geq 100$). Researchers examined the eggs in groups for their mass (g/pc.), yolk colour, thickness, integrity and strength of the shell. Their physical and morphological parameters were measured using the "Digital EGG Tester DET-6000" device. The intensity of the egg yolk colour was determined in parallel using the DSM or Roche colour fan.

Statistical analysis

Researchers assessed the significance of the difference between groups using one-way analysis of variance (ANOVA) and the Tukey-Kramer multiple comparisons test as a post-hoc testing tool. The distribution of sample data was checked for normality using the Kolmogorov-Smirnov test. If the data distribution significantly differed from normal, researchers used the nonparametric Mann-Whitney U test, considering the differences between groups significant at $p<0.05$.

RESULTS AND DISCUSSION

Chemical composition of high-protein sunflower concentrate

Table 4 reflects the chemical composition of high-protein sunflower concentrate. The content of crude protein in high-protein sunflower concentrate was 38.1%, crude fat - 1.1%, crude fibre - 8.5%, NDK – 23.2% and ADF - 8.4%. The high-protein sunflower meal proposed in this study had a crude protein content of 38.1%, which is close to the crude protein content of sunflower cake (23-39%) and sunflower meal (32-38%) (Ibatullin *et al.*, 2016), obtained from sunflowers grown in Ukraine. Despite sunflower meal from sunflowers grown in the Polissya zone having a crude protein content of 34% (Karpus *et al.*, 1994), and in the Forest-Steppe and Steppe zones, respectively, 32% and 39% (Karpus *et al.*, 1993; Karpus *et al.*, 1995), we obtained sunflower concentrate containing 4, 6% and 1% higher levels of crude protein with reports indicating crude protein content in sunflower meal that ranges from 45.2-48.9% (Tomaszewska *et al.,* 2018), and in sunflower concentrates ranged from 42-49% (Kyrkelanov *et al.*, 2020; Laudadio *et al.*, 2014)

Table 4. Chemical composition of high-protein sunflower concentrate, g/kg

Chemical composition	Contents	
	for natural moisture	on dry matter
Moisture	76.0±1.04	-
Crude protein	380.7±3.12	412.0±2.74
Crude fat	10.9±0.32	11.8±0.43
Crude fiber	85.0±1.36	92.0±1.12
Raw ash	77.1±0.65	83.4±0.72
NFE	370.3±2.74	400.8±3.11
NDF	232.3±1.21	251.4±1.30
ADF	84.0±0.78	90.4±1.06
Lignin	11.3±0.15	12.2±0.19

. The lower protein content in domestic products likely results from the limited use of nitrogen fertilizers in the soil. In summary, researchers demonstrated that the crude protein content in the studied samples of high-protein sunflower concentrate was within the maximum values of cakes and meals of Ukrainian origin and 10-29% lower than the values reported by foreign researchers.

The crude fat content in the studied sunflower concentrate was 1.1%, which is lower compared to the literature data described for sunflower grown in Ukraine (1.85-4.25%) (Ibatullin *et al.,* 2016) and abroad (2.9-3.8%) (Jurgens & Bregendahl, 2007). The content of structural carbohydrates in the studied sunflower concentrate was: crude fiber - 8.5%, NDK - 23.2% and ADF - 8.4%, which is lower than the average values for sunflower meal produced in Ukraine - crude fiber - 12.4317.26%; NDK – 30.23–35.02% and ADF - 24.15-30.45% (Ibatullin et al., 2016).

Nutrient digestibility of high-protein sunflower concentrate in laying hens.

Table 5 reflects the nutrient digestibility coefficients of high-protein sunflower concentrate for laying hens. The digestibility of crude protein was relatively high, almost 93%, and crude fat was 85%.Nitrogen-free extractives reported 75-76% digestibility, which is quite typical for adult poultry, indicating a high degree of utilization of starch, sugar, and hemicelluloses. Crude fibre digested 7-9%, showing the digestibility coefficients of structural carbohydrates to be low.

Table 5. Digestibility of nutrients of sunflower protein concentrate in laying hens' body, %, n=12

Chemical composition	Determination method	
	direct	inert substances
Crude protein	92.5±0.33	92.7±0.32
Crude fat	84.6±1.09	84.9±1.09
Crude fiber	7.0±0.62	9.0±1.11
NFE	75.1±2.10	75.5±2.16
Organic matter	76.4±0.85	76.7±1.12
NDF	64.9±0.68	64.0±1.81
ADF	5.2±1.72	7.0±0.68

The digestibility of NDK was 64-65%, and ADF was 5-7%. Thus, the digestibility of hemicelluloses, as determined by the Van Soest method, was 57-60%. The digestibility coefficient of organic matter of high-protein sunflower concentrate in laying hens was 76-77%. No indicator statistically confirmed the difference between the determinations by different methods.

In the described study, the significant increase in crude protein digestibility in laying hens fed high-protein sunflower concentrate was evidence that these diets met the requirements of the birds and was possibly due to the reduction of anti-nutritional factors in the product used. After all, sunflower is known to contain chlorogenic acid, which inhibits trypsin activity by 30%, and during the manufacture of high-protein sunflower concentrate, approximately 43% of the chlorogenic acid is destroyed by heating the product at 100 °C or 135 °C for five hours (Saleh *et al.,* 2021). On the other hand, similar to soybean, cottonseed and rapeseed meal, one of the advantages of sunflower concentrate is that it does not contain high levels of anti-nutritional factors (Hadidi *et al.,* 2024). According to Bedford M. and Classen H. (1992), the crude fibre content of sunflower meal can be three times higher than that of soybean meal. Additionally, sunflower hull fibre is highly resistant to bacterial degradation in the gastrointestinal tract. However, reducing the fibre content of sunflower concentrate through heat treatment (Laudadio & Tufarelli, 2011), fractionation (Vidosavljević *et al.,* 2025), grinding, or air classification (Saleh *et al.,* 2020a, 2020b) can overcome this problem.

On the other hand, variations in chemical composition, processing method, levels of fusion, bird age and feed preparation methods used in different studies may explain the inconsistent results. Despite some conflicting findings, previous studies suggest that sunflower concentrate is an excellent source of protein in poultry diets, enabling them to maintain optimal performance levels (Pirgozliev *et al.,* 2023). Other considerations to improve feed efficiency include low fibre content, feed pelleting, the use of oils, the addition of lysine, determining protein solubility, and the addition of enzymes that correspond to the content of non-starch polysaccharides in sunflower. Therefore, the quality factors of sunflower concentrates that affect nutrient digestibility in laying hens require further research (Ravindran, 2021).

Total energy nutritional value of high-protein sunflower concentrate.

To calculate the total energy nutritional value of high-protein sunflower concentrate in our study, researchers used the chemical composition and digestibility coefficients. They then calculated the digestible nutrient content in the studied feed and, using these indicators, determined the total energy nutritional value for laying hens using various methods (Table 6).

Table 6. Total energy nutritional value of high-protein sunflower concentrate for laying hens, MJ/kg, n=12

Direct method	Determination method	
	direct	inert substances
ME_{direct}	12.948±0.1558	12.948±0.1558
$ME_{classical}$	11.678±0.1586	11.751±0.1698
ME_{TDN}	11.621±0.1584	11.694±0.1695

The indicator calculated based on the difference between consumed and released energy (direct method) was 1.295 MJ/100 g. The energy nutritional value computed using the regression equation (classical method) was 1.168–1.175 MJ/100 g. The indicator was lower than the previous calculation method by 9.2-9.8%. The exchangeable energy of high-protein sunflower concentrate, calculated using the total of digestible substances, was 1.162-1.170 MJ/100 g. The indicator was lower than that obtained by the direct method by 9.7-10.2%. The difference in energy nutritional value, calculated using the digestibility coefficients obtained from physiological experiments conducted by the direct method and the inert substance method, was slight, approximately 0.6%, and not statistically significant. Our results are consistent with those reported by other scientists in studies describing the maximum and minimum indicators for Ukraine, with a maximum level of 12.6 MJ/kg and a minimum of 10.66 MJ/kg

(Ibatullin *et al.,* 2016). In addition, scientists from the University of Iowa give slightly lower indicators of the energy nutritional value of sunflower meal, namely 8.678-9.385 MJ/kg (Jurgens & Bregendahl, 2007).

Laying hens' productivity and egg quality.

The use of high-protein sunflower concentrate in laying hen feed, which met the requirements of the cross developer (Table 7), did not affect their safety. At the same time, researchers observed a slight increase in egg production in hens whose diet included the studied sunflower concentrate.

Table 7. Laying performance of hens under the influence of adding high-protein sunflower concentrate to the diet, n=120

Characteristic	Group of hens		Cross-country developer requirements (Management guide, 2024)
	1 (control)	2	
Population of laying hens, total, birds	120	120	–
Livestock preservation, % - at 52 weeks of age - at 62 weeks of age	 94.2±0.12[a] 93.3±0.09[a]	 94.3±0.05[a] 93.2±0.11[a]	 93–95 93–95
Eggs received, total, eggs - at 52 weeks of life - at 62 weeks of life	 24276 31632	 24648 32100	–
Egg mass obtained, kg. - at 52 weeks of life - at 62 weeks of life	 1607.1 2135.2	 1634.2 2163.5	–
Egg production per initial layer, eggs - for 52 weeks of life - for 62 weeks of life	 202.3±0.24[a] 263.6±0.42[a]	 205.4±0.21[b] 267.5±0.24[b]	 205.2 263.4
Egg production per average laying hen, eggs - at 52 weeks of life - at 62 weeks of life	 214.8±0.17[a] 282.4±0.09[a]	 218.1±0.11[b] 286.6±0.06[b]	–
Egg weight, g - at 52 weeks of age - at 62 weeks of age	 66.2±0.17[a] 67.5±0.12[a]	 66.3±0.14[a] 67.4±0.24[a]	 66.3 67.3
Body weight, kg - at 52 weeks of age - at 62 weeks of age	 1.895±0.04[a] 1.971±0.34[a]	 1.892±0.07[a] 1.974±0.36[a]	 1.876–2.074 1.900–2.100
Feed consumption: - at 52 weeks of age, g/bird/day - at 62 weeks of age, g/ bird /day - total, kg - for the production of 1 kg of egg mass, kg	 118.7±0.14[a] 122.8±0.56[a] 4449.33 2.08±0.003[a]	 117.2±0.10[b] 121.2±0.12[b] 4398.17 2.03±0.001[b]	 110–120 110–120 – 2.0–2.1

Notes: a, b – express traits fundamentally different in one row of the table ($P<0.05$).

Thus, egg production per initial layer at the age of 52 weeks increased by 1.53% ($p < 0.05$), and at the age of 62 weeks, by 1.48% ($p < 0.05$). The egg production per average layer at the age of 52 weeks in hens that consumed a diet with high-protein sunflower concentrate was higher by 1.54% ($p<0.05$), and at the age of 62 weeks, by 1.49% ($p<0.05$). This seemingly insignificant difference in egg production resulted in an increase in gross egg production over 44 weeks of the productive period by 468 pieces and a higher egg mass yield of 28.3 kg. There was no difference between the groups in egg mass and body weight of laying hens.

Regarding feed consumption, laying hens whose diet contained high-protein sunflower meal showed a decreased feed consumption by 1.26-1.30% ($P<0.05$), resulting in a 2.4% ($P<0.05$) decrease in feed consumption for the increased production of 1 kg of egg mass.

In addition, results show that replacing soybean meal in the diet of laying hens with high-protein sunflower concentrate did not affect the quality of their eggs (Table 8) except for yolk colour, which improved by 1.3 points or 14.3% ($P<0.05$).

As for the effect of using high-protein sunflower concentrate on the performance of laying hens, the results of the current study showed that its feeding contributed to an increase in egg production by 1.5%, feed efficiency by 1.30%, and also resulted in a 2.4% lower feed cost per kg of egg mass, which is consistent with many other studies (Cufadar & Ceylan, 2018; Tsuzuki *et al.,* 2003; Saleh *et al.,* 2021; Sunil, 2019; Alencar *et al.,* 2022). However, conclusions available in the literature on the likely impact of including sunflower concentrate in laying hens' diets and feed efficiency in laying hens are contradictory. Thus, several previous studies have shown that adding sunflower meal to the diet of chickens did not harm live weight, feed intake, egg production, and feed conversion ratio (Baghban-Kanani *et al.,* 2018; Laudadio *et al.,* 2014; Marami *et al.,* 2022; Shi *et al.,* 2010; Such *et al.,* 2024). Scientists attribute the increase in egg production to using diets containing high-protein components and allowing laying hens to maintain a stable body weight (Jahan *et al.,* 2024). However, to assess the economic efficiency of egg production using sunflower concentrate, the increase in feed conversion ratio is more important (Jahan *et al.,* 2024; Saleh *et al.,* 2021). The normal functioning of the digestive system in poultry requires a significant amount of fibre (Jha & Mishra, 2021); however, due to the low energy content required by laying hens, their diets contain limited high-fibre ingredients (Saleh *et al.,* 2021). The appropriate amount of crude fiber in a real laying hen diet is between 35 and 45 g/kg (Shi *et al.,* 2010). Based on the degree of hulling, the rudimentary fiber of sunflower meal is the most critical component in the diet of chickens, however, due to the inverse correlation between the crude fiber content and the crude protein content of sunflower meal, removing the hulls through various fractionation processes (like in the the sunflower concentrate used) reduces fiber content and increases the protein content simultaneously (Vidosavljević et al., 2022)

Table 8. Parameters of some characteristics of hen eggs under the influence of adding high-protein sunflower concentrate to the diet, n=30

Characteristic	Group of hens	
	1 (control)	2
Longitudinal diameter of the egg, cm	6.97±0.234[a]	6.94±0.187[a]
Transverse diameter of egg, cm	5.18±0.126[a]	5.19±0.174[a]
Egg shape index, %	74.32±1.234[a]	74.78±1.342[a]
Shell thickness, mm	0.391±0.002[a]	0.389±0.004[a]
Shell strength, kHertz	3.986±0.047[a]	3.985±0.034[a]
Protein height, cm	0.79±0.036[a]	0.81±0.029[a]
Yolk height, cm	2.16±0.065[a]	2.22±0.048[a]
Yolk diameter, cm	4.49±0.032[a]	4.54±0.027[a]
Yolk index, %	48.12±1.211[a]	48.90±1.198[a]
Yolk color, points	9.1±0.048[a]	10.4±0.052[b]

Notes: a, b – express traits fundamentally different in one table row ($P<0.05$).

Therefore, the use of sunflower meal, which has a high protein and low fibre content, and the addition of lysine contribute to improved feed intake by laying hens, as well as increased egg production. Additionally, some studies have confirmed that sunflower meal can be effectively incorporated into the diets of laying hens at a concentration of up to 40% with a guaranteed increase in egg production (Seidavi *et al.,* 2022), providing optimal maintenance conditions (Osadcha & Pavlovych, 2023).

In this study, feeding high-protein sunflower concentrate to laying hens did not affect the quality parameters of the eggs obtained from them, which is consistent with the data of some researchers (Saleh *et al.,* 2021) and, at the same time, contradicts several others (Shi *et al.,* 2010; Baghban-Kanani *et al.,* 2018; Tsuzuki *et al.,* 2003; Koçer *et al.,* 2021), who described, although insignificant, changes in egg quality indicators when introducing different levels of sunflower meal into the diet. Meanwhile, we found an improvement in yolk color under the influence of feeding the tested high-protein sunflower concentrate to laying hens, which confirms the data of Laudadio *et al.* (2014) and Ditta *et al.* (2022) which described the improvement of egg yolk color when feeding laying hens' sunflower meal with low fiber content. As for this study, the effect on the colour assessment of the yolk may be related to the number of natural pigments in the sunflower concentrate. On the other hand, adding vegetable fat affects the colour of egg yolk, as it accelerates the absorption of pigment and fat-soluble vitamins (Costa *et al.,* 2008). Thus, De Morais Oliveira *et al.* (2016) showed that the amount of lipids in the diet with sunflower meal increases the absorption of pigment, which leads to an improvement in yolk colour. Conversely, some other studies (Shi *et al.,* 2010; Tsuzuki *et al.,* 2003) did not confirm the positive effect of feeding laying hens' sunflower meal on egg yolk colour.

CONCLUSIONS

High-protein sunflower concentrate is an effective feed ingredient in the feeding of laying hens. It is characterized by total energy value 11.621-12.948 MJ/kg, digestibility of crude protein - 92.5-92.7%, crude fat - 84.6-84.9%, crude fiber - 7.0-9.0%, nitrogen-free extractives - 75.1-75.5%, organic matter - 76.4-76.7%, neutral detergent fiber - 64.0-64.9% and acid detergent fiber - 5.2-7.0%.

Replacing soybean meal with high-protein sunflower concentrate in compound feed for laying hens provides an increase in egg production by 1.5% ($P<0.05$) with an improvement in yolk color by 14.3% ($P<0.05$), feed efficiency by 1.30% ($P<0.05$), and also leads to a decrease in feed costs for the production of 1 kg of egg mass by 2.4% ($P<0.05$).

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