Shkarban, V., Sychov, M. (2026). Inclusion of high-protein sunflower concentrate in diets of growing pigs. Agriculture and Forestry, 72 (1): 247-263. https://doi:10.17707/AgricultForest.72.1.15

DOI: 10.17707/AgricultForest.72.1.15

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INCLUSION OF HIGH-PROTEIN SUNFLOWER CONCENTRATE IN DIETS OF GROWING PIGS

SUMMARY

The search for alternative plant sources of protein for pig feeding is an urgent task of modern animal husbandry, due to economic factors and the need to optimise protein nutrition. High-protein sunflower concentrate (HPSC) is considered a promising component of compound feeds, however, its effect on growth, metabolic and haematological status of young pigs at different levels of inclusion requires further study. The study aimed to assess changes in live weight, biochemical and haematological blood parameters of piglets under the conditions of adding high-protein sunflower concentrate to the diet in amounts of 0, 4, 8 and 12% and to determine the optimal levels of such introduction. The study was conducted in the conditions of a production experiment using generally accepted methods of clinical, biochemical and haematological blood analysis. The results obtained indicate that the inclusion of high-protein sunflower concentrate causes dose-dependent changes in the metabolic profile of piglets. The most balanced adaptive reactions of the organism were observed at the level of addition to the piglet diet of 8%, which was characterised by the intensification of protein and nitrogen metabolism without signs of metabolic overload, preservation of the stability of the lipid profile and a decrease in the activity of enzymes associated with tissue stress. Haematological indicators at this level of replacement demonstrated physiological activation of erythropoiesis and adaptive shifts in the leukocyte formula, without exceeding reference values. Based on a comprehensive assessment of growth, biochemical and haematological indicators, it was established that the level of introduction of high-protein sunflower concentrate into the diet of young pigs at the level of 8% is the most appropriate for feeding piglets, as it ensures metabolic efficiency and physiological safety of the diet.

Keywords: piglets, high-protein sunflower concentrate, alternative protein sources, live weight, biochemical blood parameters, haematology

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Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.
Recieved:30/01/2026 *Accepted:26/02/2026*

INTRODUCTION

The search for alternative protein sources for feeding farm animals is a relevant direction in modern animal husbandry, driven by economic factors, limited availability of traditional protein raw materials, and the need to optimise protein nutrition (Plyska *et al*., 2021). In this context, high-protein sunflower processing products, in particular high-protein sunflower concentrate, are considered as a promising component of compound feeds and protein supplements (Sychov *et al.,* 2025; Pitera and Pitera 2025; Shkarban and Sychov 2025).

Studies show that sunflower meal can be added to the diet of pigs in amounts of 10–20% without negative effects on performance, and in some cases, the level of introduction can reach 25–50% (Cortamira *et al*., 2000; Bonos *et al*., 2017). Recent studies demonstrate that the combined replacement of soybean meal with sunflower and pea meal up to 56% allows maintaining optimal growth and health indicators in pigs during fattening, particularly under conditions of reduced crude protein levels in finishing period rations (Graziosi *et al.*, 2024). At the same time, the literature reveals considerable variability in the results, which complicates the formulation of unified recommendations regarding the use of sunflower products in pig nutrition.

A number of studies report a decrease in average daily gains and a deterioration in feed conversion with high levels of sunflower meal inclusion, especially when its share exceeds 20–30% in the diet (Povod *et al.*, 2022). At the same time, other authors do not find significant differences between diets based on sunflower and soybean meal or even record improvements in digestibility and growth, especially in the growth phase of pigs (Kim *et al*., 2020; He *et al.,* 2024). Such data inconsistency is largely explained by the variability in the chemical composition of sunflower products, which depends on the seed variety, degree of hulling, extraction method, and heat treatment parameters.

From a nutritional point of view, sunflower meal is characterised by a higher fibre content and lower lysine levels compared to soybean meal, which is traditionally considered a limiting factor for its use (Petik *et al.,* 2023). At the same time, sunflower products have a high content of methionine and other sulfur-containing amino acids, which can contribute to the optimisation of the amino acid profile of the diet, provided that lysine is corrected with synthetic analogues (Florou-Paneri *et al*., 2014; Ryvak, 2021). In addition, the presence of fibre may play not only a restrictive but also a functional role, especially for pregnant sows and animals in the finishing phase, affecting intestinal motility and the feeling of satiety.

The environmental aspect of using sunflower products deserves special attention. Feed rations are recognised as one of the main factors affecting pig farming environment, and the finishing period is critical in terms of nitrogen and greenhouse gas emissions (Berton *et al*., 2024). It has been proven that reducing the level of crude protein in diets with compensation with synthetic amino acids allows reducing greenhouse gas emissions by up to 20% and reducing the load on the manure disposal system (Ogino *et al.*, 2013; McAuley *et al.*, 2022). In this context, the use of local protein resources, such as sunflower meal, in low-protein diets is considered a promising tool for increasing the environmental efficiency of pig farming (Graziosi *et al*., 2024).

However, reducing crude protein and modifying protein sources may affect not only performance but also behaviour, physiology, and the gut microbiota in pigs. Some studies indicate increased aggressiveness and a higher risk of behavioural disorders under conditions of essential amino acid deficiency in low-protein diets (McAuley *et al.*, 2022; Minussi *et al.*, 2023). At the same time, experimental data indicate that the inclusion of sunflower meal only slightly affects the behavioural responses of pigs and is not accompanied by an increase in the level of stress hormones, in particular cortisol and dehydroepiandrosterone, which are considered sensitive biomarkers of animal welfare (Pollock *et al*., 2021; Graziosi *et al*., 2024). This confirms the potential safety of such diets, provided that the amino acid balance is properly balanced.

Despite a significant amount of research, the role of sunflower meal and high-protein sunflower concentrates in pig nutrition remains poorly defined. In particular, there is a lack of systematic data on optimal inclusion levels for different growth phases, the effect of the degree of concentrate purification on nutrient digestibility, the interaction of fibre with the intestinal microbiota, and the long-term consequences for animal performance and welfare. This necessitates further comprehensive studies aimed at assessing the effectiveness of introducing high-protein sunflower concentrates into the diet of young pigs, taking into account productive, metabolic, behavioural and environmental aspects.

MATERIAL AND METHODS

The research was carried out in the April-May of 2025 at the experimental facilities of the pig farm “Ternopil Bacon” LLC (Ternopil Oblast, Ukraine) and at the Problem Research Laboratory of Feed Additives, the P.D. Pshenychnyy Department of Animal Nutrition and Feed Technology, National University of Life and Environmental Sciences of Ukraine. Danish-bred weaned piglets were used as the experimental animals. All experimental procedures involving animals were performed in accordance with the provisions of the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (European Union, 2010).

Experimental design

From young pigs of the industrial herd, Danish selection (♀Landrace/Large White X ♂Dyurek) aged 24 days, 4 groups of piglets were formed (all animals were either half-brothers or half-sisters), which were kept in 10 m² pens on a slatted floor. Each pen was equipped with a 2.5 m² cover with a heating lamp, which was used in the first week of life after weaning.

The experimental pigs had ad libitum access to water, provided via stainless steel bowl drinkers at a rate of three units per pen. The piglets were fed manually using a TR-4 ROTECNA feeding device. 1 feeding device per 1 group, type of feeding - dry. Feeding principle: every morning from 9.00 to 10.00 - the remaining feed from the previous day was taken out, weighed, and a new amount of feed was poured.

The chemical composition of a high-protein sunflower concentrate used in piglet nutrition were studied and fully described in previous research (Shkarban and Sychov, 2025).

The experiment lasted 30 days in total. The experimental design is presented in Table 1.

Table 1. Experimental design

Groups	Characteristics of feed	The level of introduction of high-protein sunflower concentrate into the diet, %
1 (control)	Basic feed (BF) based on soybean meal, HPSC 0	0
Experimental 2	Basic feed (BF) based on soybean meal with the addition of high-protein sunflower concentrate, HPSC 4	4
Experimental 3	Basic feed (BF) based on soybean meal with the addition of high-protein sunflower concentrate, HPSC 8	8
Experimental 4	Basic feed (BF) based on soybean meal with the addition of high-protein sunflower concentrate, HPSC 12	12

Zootechnical records.

Throughout the rearing period, the number of piglets removed from the experiment (due to mortality and culling) was recorded. Also, every seven days, the live weight of pigs was determined on the AXIS BDU300C-0608X scales, which has weighing range - 1 -300 kg and measurement accuracy - 0,05 kg (Ukraine).

Blood sampling. Blood sampling was performed from 8 pigs (♀4 & ♂4) of each group at the end of the experiment. The sampling was performed from the axillary vein, and 1.0–1.5 ml of blood was taken into a K2 EDTA tube. Blood sampling, as well as the selection of randomised individuals, was performed according to generally accepted methods.

Haematological methods. Haematological parameters of pig blood were determined on the IDEXX ProCyte Dx haematological analyser (IDEXX Europe

B.V.) at the LLC "Veterinary Diagnostics Centre". The following parameters were determined: erythrocyte, leukocyte, and platelet counts—by impedance change (conductometric method); haemoglobin concentration—by the spectrophotometric method.

Biochemical parameters and enzyme activity of piglet blood serum were determined on an automatic Beckman Coulter biochemical analyser (USA) in the laboratory of LLC "Centre for Veterinary Diagnostics" using the manufacturer's original test systems and commercial diagnostic kits High Technology Inc. (USA). Determination of the main serum metabolites (High Technology Inc., USA). The following reagent sets were used to determine the concentrations of metabolites: glucose – set HT-G242 (method: glucose oxidase, endpoint; λ=500 nm); total protein – HT-T251 (biuret reaction, endpoint; λ=540 nm); albumin – HT-A203 (reaction with bromocresol green; λ=630 nm); creatinine – HT-C225 (Jaffe method, kinetic; λ=510 nm); urea – HT-U254 (Trinder/uricase method, endpoint; λ=520 nm); inorganic phosphorus – HT-P244 (ammonium molybdate method; λ=340 nm). calcium – HT-C216 (orthocresolphthalein method, endpoint; λ=570 nm); ALT (alanine aminotransferase) – HT-A206 (IFCC method, kinetic; λ=340 nm). The methods were performed according to the instructions of the kit manufacturer.

Statistical analysis

Biometric data processing was carried out on a PC using Statistica 10 software.

The significance of differences between groups was assessed using one-way analysis of variance (ANOVA) and the Tukey–Kramer multiple comparison test as a post hoc procedure. The normality of the sample data distribution was tested using the Shapiro-Wilk test and P-plot. If the data distribution was significantly different from normal, the nonparametric Mann-Whitney U-test was used. Differences between groups were considered significant at $p<0.05$.

RESULTS AND DISCUSSION

The experimental piglets were fed complete feed, balanced for all nutrients according to the recommended norms (CVB, 2023). The composition of the feed used for feeding young pigs is given in Tables 2–4.

Live weight indicators changed depending on the addition of high-protein sunflower concentrate to the diet (Table 5): with 8% introduction, a significant increase in live weight of piglets at 75 days of age by 1.2 kg or 3.6% ($p<0.05$) was noted compared to the control group, while the introduction levels of 4 and 12% did not cause statistically significant differences. Such a moderate but significant advantage at the intermediate introduction level is consistent with the data of studies in which high-protein sunflower meal or concentrate or its fractions provided improved gains during the growing and fattening period of pigs due to the sufficient content of digestible protein and energy (Povod *et al.*, 2022; (Kropiwiec *et al.*, 2025).

Table 2. Composition of rations, %

Indicator	Age, days				
	24–44	45–75			
	Group of pigs / % introduction of high-protein sunflower concentrate				
	1–4 HPSC 0	HPSC 0	HPSC4	HPSC8	HPSC12
Wheat	36.02	40.00	40.00	40.00	40.00
Barley	25.00	27.42	26.06	24.92	23.67
Sunflower concentrate 44 CP	0.00	0.00	4.00	8.00	12.00
Soybean meal 45 CP	16.59	22.04	19.18	16.29	13.31
Wheat bran	1.00	2.00	2.00	2.00	2.00
Soybean oil	4.00	3.85	4.10	4.30	4.55
Whey (dry)	3.84	0.00	0.00	0.00	0.00
Whey fat concentrate	3.58	0.00	0.00	0.00	0.00
Source of functional fibre	2.00	0.00	0.00	0.00	0.00
Animal proteins	2.87	0.00	0.00	0.00	0.00
Limestone flour Ca 35%	0.85	1.26	1.24	1.08	1.06
Salt	0.50	0.66	0.66	0.66	0.66
Monocalcium phosphate	0.76	0.61	0.62	0.63	0.64
DL-Methionine 99.5%	0.28	0.18	0.16	0.14	0.10
L-Lysine hydrochloride	0.49	0.43	0.46	0.49	0.52
L-Threonine 99%	0.28	0.19	0.19	0.18	0.17
L-Tryptophan	0.08	0.06	0.05	0.05	0.05
L-Valine	0.04	0.04	0.03	0.01	0.00
Premix (acidifier, absorbent, trace elements, vitamins, enzymes)	1.82	1.20	1.25	1.25	1.27
Total	100.00	100.00	100.00	100.00	100.00

In the initial period of the study (24–44 days), the absolute body weight gains of piglets in all groups remained at the same level (Fig. 1). At the same time, in the period of 45–75 days, differences due to the composition of the diet were recorded. In particular, in animals of the 3rd group, which were fed a diet with the introduction of 8% high-protein sunflower concentrate, the absolute body weight gain exceeded the indicators of the control group by 1.17 kg or 5.9% ($p<0.05$). In general, for the entire period of growing in this group of young animals, the absolute gain was higher by 1.11 kg or 4.2% ($p<0.05$). In contrast, the use of diets with the introduction of 4 and 12% high-protein sunflower concentrate did not cause statistically significant differences in body weight gains.

Table 3. Chemical composition of rations

Indicator	Age, days				
	24–44	45–75			
	Group of pigs / % introduction of high-protein sunflower concentrate				
	1–4 HPSC 0	HPSC 0	HPSC4	HPSC8	HPSC12
Net energy, MJ	9.8	9.8	9.8	9.8	9.8
Crude protein, g	165.000	160.527	164.453	168.434	172.000
Crude fat, g	70.000	52.586	55.248	57.369	59.942
Crude fiber, g	41.80	34.17	35.53	36.95	38.30
Calcium, g	5.5	6.5	6.5	6	6
Available Phosphorus, g	4.0	3.5	3.5	3.5	3.5
Sodium, g	3.0	2.5	2.5	2.5	2.5
SID Lysine, g	11.6	10.1	10.1	10.1	10.1
SID Methionine+Cystine, g	6.96	6.06	6.06	6.06	6.06
SID Threonine, g	7.540	6.565	6.565	6.565	6.565
SID Tryptophan, g	2.55	2.22	2.22	2.22	2.22
SID Valine, g	7.54	6.565	6.565	6.565	6.565

Table 4. Dietary content of vitamins and minerals

Indicator	Age, days				
	24–44	45–75			
	Group of pigs / % introduction of high-protein sunflower concentrate				
	1–4 HPSC 0	HPSC 0	HPSC4	HPSC8	HPSC12
Vitamins:					
A, IU	12000				
D, IU	2000				
E, mg	100				
K, mg	2				
Minerals:					
Iron, mg	80				
Copper, mg	177				
Zinc, mg	120				
Manganese, mg	72				
Iodine, mg	0.8				
Selenium, mg	0.39				

Table 5. Live weight of piglets, g

Age, days	Group of pigs			
	HPSC 0	HPSC4	HPSC8	HPSC12
	n=25	n=25	n=28	n=28
24	6.4±0.15[a]	6.5±0.15[a]	6.6±0.14[a]	6.4±0.16[a]
44	13.0±0.29[a]	13.3±0.32[a]	13.1±0.17[a]	13.2±0.19[a]
75	33.1±0.34[a]	33.0±0.42[a]	34.3±0.36[b]	32.1±0.43[a]

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

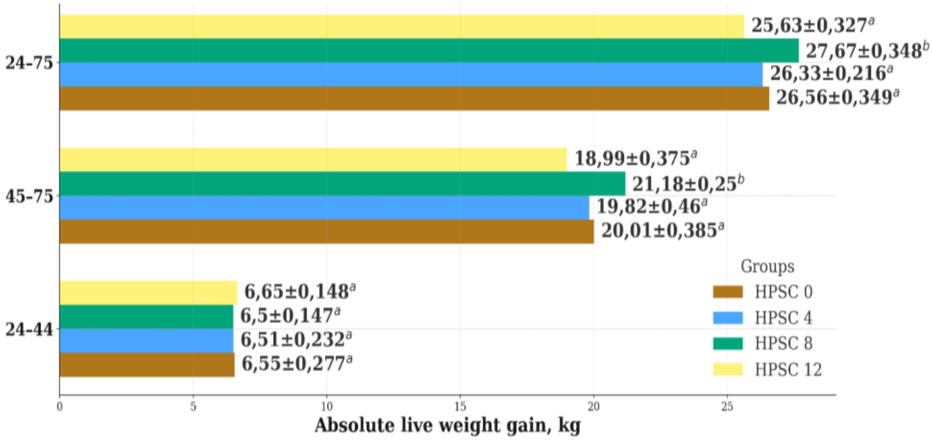

Fig. 1. Absolute body weight gains of piglets, kg

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

Regarding average daily body weight gain in piglets, a similar pattern was observed (Fig. 2).

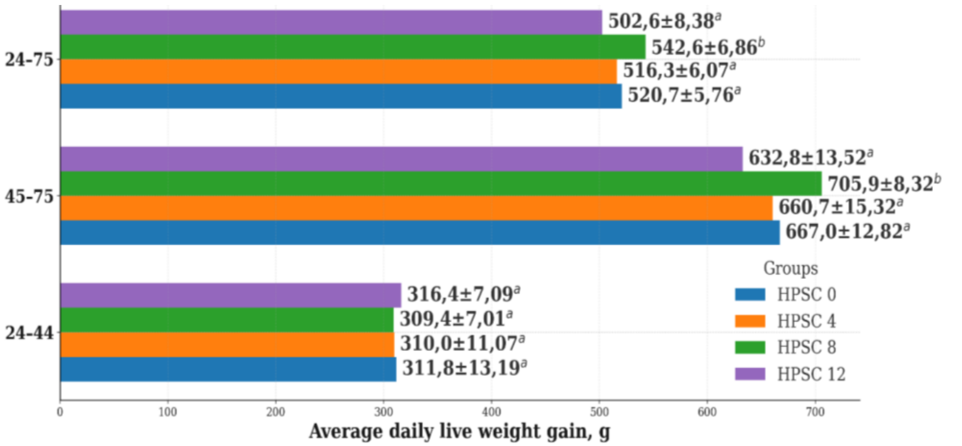

Fig. 2. Average daily body weight gains of piglets depending on the level of introduction of high-protein sunflower concentrate into the diet, kg

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

During the 45–75th day of growth, statistically significant differences were observed due to diet composition. In particular, in animals of Group 3, which were fed a diet containing 8% high-protein sunflower concentrate, the average daily body weight gain exceeded that of the control group by 39.9 g, or 5.8% ($p<0.05$). As a result, over the entire period of growth, the average daily body weight gain in this group was higher by 21.9 g or 4.2% ($p<0.05$) compared to the control. At the same time, the use of diets with the introduction of 4 and 12% of the specified concentrate did not cause significant changes.

At the same time, the productive indicators varied with the level of introduction of high-protein sunflower concentrate into the main diet. In particular, the introduction of 8% of high-protein sunflower concentrate into the diet contributed to an increase in the live weight of piglets at 75 days of age by 3.6% ($p<0.05$), absolute gains - by 5.9% for the period 45–75 days ($p<0.05$) and by 4.2% for the entire growing period ($p<0.05$). The average daily gains in this group exceeded the control values by 5.8% ($p<0.05$) at the age of 45–75 days and by 4.2% ($p<0.05$) on average for the entire growing period.

Therefore, an inclusion level of 8% high-protein sunflower concentrate proved to be optimal, as it resulted in a significant increase in body weight and growth rate of piglets. However, according to Cheng *et al.* (2024), the inclusion level of high-protein sunflower concentrate can reach up to 50% without adversely affecting performance.

The effect of including high-protein sunflower concentrate in the diet of piglets on the biochemical parameters of their organism.

Biochemical blood parameters are an important indicator of the physiological state of the animal body and reflect the level of metabolic processes occurring under the influence of feeding. The study of changes in the biochemical composition of the blood of pigs makes it possible to assess not only their general health, but also the efficiency of using nutrients in the diet (Sheptukha and Masiuk, 2025; Osadcha *et al.*, 2023). In this context, the study of the effect of adding high-protein sunflower concentrate to the diet is of particular interest, since such a correction of feeding can affect the course of protein, lipid and carbohydrate metabolism, and therefore - on animal productivity. Therefore, at the subsequent stage, the biochemical parameters of piglet blood serum were analysed according to diet composition (Table 6). It was found that the introduction of high-protein sunflower concentrate into the diet of young pigs is accompanied by an increase in total protein and urea in their blood serum. In particular, at the level of introduction of 8%, an increase in the level of total protein by 17.8 % ($p<0.05$) was observed. While the addition of 12% is accompanied by an increasing increase in serum total protein by 22.9% ($p<0.05$).

The observed increase in total protein levels resulting from the inclusion of high-protein sunflower concentrate in the diet can be explained by the fact that this concentrate is characterised by an enhanced content of available protein and amino acids, due to a reduced crude fiber level. Therefore, when fed with it, piglets receive more protein compounds, which stimulate the synthesis of serum proteins (albumins and globulins). This leads to an increase in the level of total protein in the blood serum (Binev *et al.*, 2025).

Table 6. Biochemical parameters of blood serum of young pigs, n=8/group

Indicator	Group of pigs				RI[1]
	HPSC 0	HPSC4	HPSC8	HPSC12	
Total protein, g/l	48.4 ± 1.29^{a}	51.8 ± 2.14^{a}	57.0 ± 3.67^{b}	59.5 ± 3.98^{b}	33–63
Albumin, g/l	33.3 ± 0.83^{a}	33.3 ± 0.98^{a}	32.5 ± 0.63^{a}	33.3 ± 0.73^{a}	20–39
Glucose, mmol/l	4.7 ± 0.09^{a}	5.1 ± 0.39^{a}	4.8 ± 0.11^{a}	4.7 ± 0.06^{a}	5.1–8.3
Creatinine, μmol/l	98.8 ± 2.99^{a}	112.3 ± 9.39^{a}	102.3 ± 1.65^{a}	103.8 ± 2.81^{a}	73–111
Urea, mmol/l	1.8 ± 0.36^{a}	2.3 ± 0.31^{a}	3.2 ± 0.56^{b}	3.5 ± 0.59^{b}	0.5–3.8
Uric acid, μmol/L	2.0 ± 0.27^{a}	1.8 ± 1.16^{a}	2.0 ± 0.27^{a}	1.8 ± 0.16	–
Calcium, mmol/l: - general - ionised	 2.8 ± 0.07^{a} 1.3 ± 0.01^{a}	 2.8 ± 0.05^{a} 1.3 ± 0.03^{a}	 2.7 ± 0.03^{a} 1.3 ± 0.03^{a}	 2.9 ± 0.04^{a} 1.4 ± 0.02^{a}	 2.4–3.3 –
Total phosphorus, mmol/l	5.6 ± 0.11^{a}	5.5 ± 0.04^{a}	5.9 ± 0.07^{a}	5.8 ± 0.03^{a}	2.6–4.0

Notes: a, b – express traits fundamentally different in one table row (P<0.05); 1RI - reference intervals according to Egeli et al. 1998

In addition, an increase in serum urea levels was observed. In particular, when high-protein sunflower concentrate was introduced into the diet in an amount of 8%, an increase in urea levels was observed by 77.8% ($p<0.05$), and when 12% was introduced - by 94.4% ($p<0.05$). This may be due to an increase in the level of available protein entering the body, which leads to an increased formation of amino acid catabolites. Part of the nitrogen that is not used for tissue protein synthesis is transformed into urea (the main end product of nitrogen metabolism in the body of pigs). Therefore, an increase in urea levels is recorded in serum (Park *et al.*, 2021).

The observed rise in serum urea likely reflects intensified nitrogen turnover and metabolic adaptation to increased protein supply, while at the same time potentially signaling a higher renal and metabolic nitrogen burden. Importantly, urea values remained within established physiological ranges and were not accompanied by adverse changes in liver enzyme activity or growth performance at the 8% inclusion level, suggesting that nitrogen utilisation was physiologically acceptable. However, the further increase in urea at the 12% inclusion level, without additional productive benefits, may indicate reduced efficiency of protein utilisation and supports the conclusion that 8% represents the metabolically optimal inclusion level.

The introduction of high-protein sunflower concentrate into the diet of young pigs also affected the activity of blood serum enzymes, namely AST (Table 7). Thus, at the level of introduction of high-protein sunflower concentrate in the amount of 8%, a decrease in AST activity was observed by 13.4% ($p<0.05$), and at the introduction of 12% - by 15.8% ($p<0.05$).

Table 7. Serum enzyme activity of young pigs, n=8/group

Enzyme, U/l	Group of pigs				RI[1]
	HPSC 0	HPSC4	HPSC8	HPSC12	
ALT	53.8±3.18[a]	55.5±1.71 [a]	54.3±6.85 [a]	55.8±6.91 [a]	15–108
AST	75.5±3.28 [a]	72.5±3.25 [a]	65.4±3.79[b]	63.6±3.94[b]	8–84

Notes: a, b – express traits fundamentally different in one table row (P<0.05); 1RI - reference intervals according to (Egelie et al. 1998)

AST is an enzyme involved in the transamination of amino acids, and its activity in the blood is frequently associated with the condition of the liver and muscle tissues. An increase in AST levels usually signals cell damage or excessive load on protein metabolism. Therefore, a decrease in its activity may indicate a more balanced amino acid supply and less stress on cells. When feeding high-protein sunflower concentrate, the body receives a sufficient amount of readily available amino acids (Roshanay *et al.*, 2024). This ensures a more efficient course of protein synthesis without the need for excessive activation of transamination enzyme systems, which leads to a decrease in AST activity. In addition, a decrease in AST activity may reflect a positive adaptive effect of the diet - stabilisation of nitrogen metabolism and a decrease in the intensity of catabolic processes in tissues (Xinlan *et al.*, 2025). Therefore, the decrease in AST activity in the blood serum of pigs due to the addition of high-protein sunflower concentrate to the diet is explained by the optimisation of protein metabolism and a decrease in the metabolic load on the liver and muscles, which indicates the beneficial effect of this feed component.

The effect of supplementing the diet of piglets with high-protein sunflower concentrate on the haematological parameters of their organism

Haematological parameters are sensitive indicators of the physiological state and metabolic processes in the animal body. They reflect the intensity of hematopoiesis, the level of oxygen-transport function of the blood and the state of the immune system. In this regard, the study of the effect of introducing high-protein sunflower concentrate into the diet of young pigs on the haematological parameters of piglets is important for assessing the adaptive capabilities of the organism and determining the optimal structure of diets (Nseabasi *et al.*, 2013). This study showed that the introduction of high-protein sunflower concentrate into the diet of piglets affected the concentration of erythrocytes and hemoglobin in their blood (Fig. 3). In particular, the introduction of the concentrate in an amount of 8% was accompanied by an increase in the concentration of hemoglobin in the peripheral blood of piglets by 9.5 g/l or 8.5% ($p<0.05$), and 12% by 11.8 g/l or 10.6% ($p<0.05$). In addition, an increase in the concentration of erythrocytes in the blood of piglets was detected. Thus, the introduction of high-protein sunflower concentrate in the diet in the amount of 8% was accompanied by an increase in the concentration of erythrocytes in the blood of piglets by 1.3 1012/l or 23.2% (p<0.05), and by 12% by 1.5 1012/l or 26.8% (p<0.05).

The described changes in the erythrocyte chain of piglets can be explained by increased intake of protein and amino acids (especially methionine and arginine) into their bodies, which contributes to more active haemoglobin synthesis (Prudyus, 2024). This can lead to an increase in the number of erythrocytes and an increase in haemoglobin concentration. The result of this process is an improvement in the oxygen-transport function of the blood.

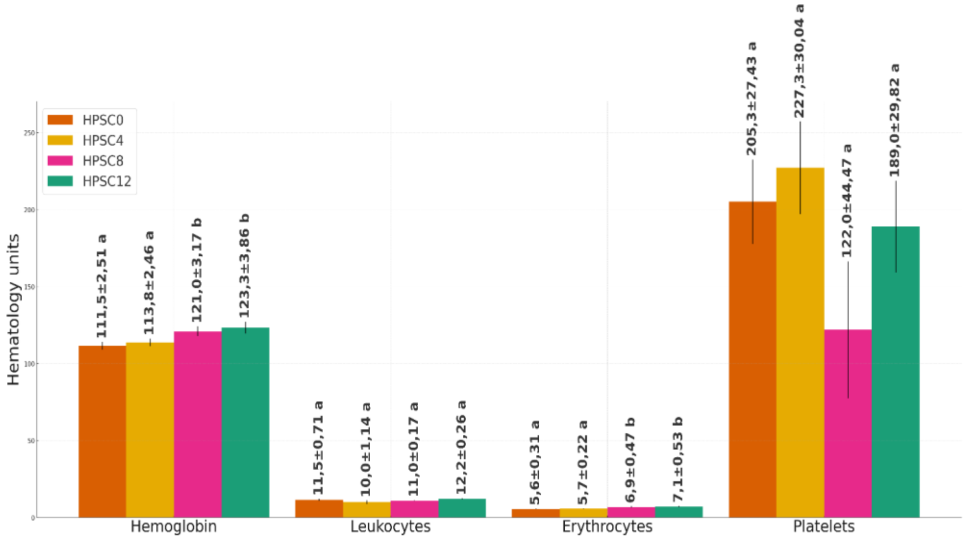

Fig. 3. Haematological blood parameters of young pigs, n=8/group

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

When using diets with a high-protein sunflower concentrate of 8% in the diet of piglets, an increase was observed, within the physiological norm, in the concentration of neutrophils in their peripheral blood by 7.5% (p<0.05), and 12% - by 8.5% (p<0.05) (Table 8). The indicated increase in the number of neutrophils occurred due to an increase in the concentration of the segmented granulocyte fraction, namely: by adding high-protein sunflower concentrate to the diet in the amount of 8% by 8.5% (p<0.05), and 12% - by 9.0% (p<0.05). Overall, the increase in neutrophil levels following the addition of varying amounts of high-protein sunflower concentrate occurred at the expense of a decrease in lymphocyte concentration. In particular, with the introduction of the concentrate in the amount of 8%, a decrease in the concentration of lymphocytes was observed by 7.3% (p<0.05), and with 12% - by 8.1% (p<0.05). In addition, the inclusion of the high-protein sunflower concentrate at 8% in the diet decreased monocyte concentration by 4,4% (P<0.05).

Table 8. Leukocyte formula of peripheral blood of piglets, n=8/group

Indicator	Group of pigs / % introduction of high-protein sunflower concentrate				RI
	HPSC 0	HPSC4	HPSC8	HPSC12	
Eosinophils	2.0±0.27 [a]	2.3±0.42 [a]	2.0±0.26 [a]	1.5±0.19 [a]	0.02–3.08
Neutrophils	37.8±2.39 [a]	38.8±2.42 [a]	45.3±2.86 [b]	46.3±3.26 [b]	19.50–48.24
including: – segmented granulocytes – band granulocytes	34.3±2.41 [a] 3.5±0.63 [a]	35.8±2.54 [a] 3.0±0.46 [a]	42.8±2.96 [b] 2.5±0.33 [b]	43.3±2.95 [b] 3.0±0.26 [a]	– –
Lymphocytes	55.7±1.88	54.6±1.95 [a]	48.4±2.83 [b]	47.6±2.94 [b]	46.75–76.63
Monocytes	4.5±0.19 [a]	4.3±0.16 [a]	4.3±0.16 [b]	4.6±0.17 [a]	3.67–11.50
Basophils	0.0	0.0	0.0	0.0	0.00–0.15

Notes: a, b – express traits fundamentally different in one table row (P<0.05); RI - reference intervals according to Præstegaard et al. 2025

Changes in the leukocyte count in pigs fed high-protein sunflower concentrate can be explained by several interrelated factors. The high content of available protein and the balanced amino acid composition of the concentrate stimulate protein synthesis in the bone marrow and liver, where immune system cells are formed and regulated. This may stimulate leukopoiesis and affect the relative proportions of specific leukocyte populations (neutrophils, lymphocytes, and monocytes) (Osadcha and Pavlovych 2023; Binev *et al.* 2025). Another process that explains these changes is the adaptive immune response. The transition to a new diet composition – even without pathogenic factors – is a kind of stress for the piglet organism and a stimulus for the immune system. In response, neutrophil or lymphocyte counts may increase slightly, reflecting the activation of the nonspecific and cellular branches of the immune system (Saco and Bassols, 2022; Osadcha *et al*. 2023). However, the detected quantitative changes occurred within the physiological norm, which indicates normal adaptation, and not inflammatory or infectious processes. Therefore, changes in the leukocyte formula when feeding high-protein sunflower concentrate are a consequence of more active protein metabolism, stimulation of the immune system and adaptive processes of the body to an increased supply of available protein, and provided that the indicators remain within physiological limits, they are regarded as a normal protective and adaptive reaction.

CONCLUSIONS

The introduction of 8% high-protein sunflower concentrate into the diet contributed to an increase in the live weight of piglets at 75 days of age by 3.6% ($p<0.05$), absolute gains by 5.9% for the period 45–75 days ($p<0.05$) and by 4.2% for the entire growing period ($p<0.05$). Average daily gains in this group exceeded the control values by 5.8% ($p<0.05$) at the age of 45–75 days and by 4.2% ($p<0.05$) on average for the entire growing period.

At this level of concentrate addition (8%), a significant increase ($p<0.05$) in the concentration of total protein by 17.8% and urea by 77.8% was established. At the same time, a significant decrease ($p<0.05$) in the activity of aspartate aminotransferase by 13.4% was noted. The haematological profile under the conditions of adding high-protein sunflower concentrate in an amount of 8% to the diet is characterised by a significant increase ($p<0.05$) in the concentration of haemoglobin by 8.5% and the number of erythrocytes by 23.2%. In the leukocyte formula, a significant increase ($p<0.05$) in the proportion of neutrophils by 7.5% was noted, mainly due to segmented forms, with a corresponding significant decrease ($p<0.05$) in the proportion of lymphocytes by 7.3%.

The results obtained provide a scientific basis for recommending the inclusion of high-protein sunflower concentrate at a level of 8% in piglet diets as a metabolically safe and physiologically appropriate means of partially replacing soybean meal.

ACKNOWLEDGEMENTS

The research was carried out within the framework of the state scientific theme of the Ministry of Education and Science of Ukraine 04493706 No. 0124U000924.

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