



Evaluation of the effect of wheat germ meal on the development of laboratory mice

Vasyl Lyasota*

Doctor of Veterinary Sciences, Professor
Bila Tserkva National Agrarian University
09117, 8/1 Soborna Sq., Bila Tserkva, Ukraine
<https://orcid.org/0000-0002-2442-2174>

Svitlana Tkachuk

Doctor of Veterinary Sciences, Professor
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
<https://orcid.org/0000-0002-6923-1793>

Nadia Bogatko

Doctor of Veterinary Sciences, Associate Professor
Bila Tserkva National Agrarian University
09117, 8/1 Soborna Sq., Bila Tserkva, Ukraine
<https://orcid.org/0000-0002-1566-1026>

Natalia Bukalova

PhD in Veterinary Sciences, Associate Professor
Bila Tserkva National Agrarian University
09117, 8/1 Soborna Sq., Bila Tserkva, Ukraine
<https://orcid.org/0000-0003-4856-3040>

Tetyana Prylipko

Doctor of Agricultural Sciences, Professor
Higher Educational Institution "Podillia State University"
32316, 12 Shevchenko Str., Kamianets-Podilskyi, Ukraine
<https://orcid.org/0000-0002-8178-207X>

Suggested Citation:

Lyasota, V., Tkachuk, S., Bogatko, N., Bukalova, N., & Prylipko, T. (2023). Evaluation of the effect of wheat germ meal on the development of laboratory mice. *Ukrainian Journal of Veterinary Sciences*, 14(2), 76-95. doi: 10.31548/veterinary2.2023.76.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

Abstract. Nowadays, dietary supplements are increasingly used in livestock feeding, which are a valuable source of biologically active substances necessary for their full growth and development, maintaining the body's resistance and preventing numerous diseases. The most common components are proteins, vitamins and carotenoids. Thus, the relevance of scientific research is to experimentally determine the effectiveness of the newly developed product with a multi-component composition on the functional state of the animal body. The purpose of the research was to determine the effect of the new product, the dietary supplement "Wheat germ meal" on the behaviour, growth rate, and morphological and biochemical parameters of the blood of white mice. The material of the study was nonlinear white mice in the amount of 60 heads. The supplement was fed to mice for 60 days. A set of methods was used, including: an assessment of the microclimate of the laboratory animal housing, the condition of tap water for drinking mice, an assessment of their general behaviour, and a determination of haematological parameters. It was proved that during the experiment, the microclimate of the room in which the laboratory animals were kept and the indicators of tap water for their drinking corresponded to the requirements of current regulations. It is substantiated that the examined additive increases the body weight of white mice and their average daily weight gain. Therewith, the weight of the internal organs of the experimental group (thymus, thyroid gland, kidneys, liver, lacrimal gland) remained unchanged. It has been established that the component composition of the supplement affects the morphological parameters of the blood of white mice, namely, it increases the haemoglobin content, the number of red blood cells and the value of haematocrit. No changes were observed in the blood leukogram of mice. An increase in the content of total protein and globulins in the blood serum of white mice was established. A decrease in the albumin content and an increase in the activity of the enzymes alanine aminotransferase and aspartate aminotransferase occurred within the reference values for white mice. The materials of the research are of practical value for the possibility of using the examined dietary supplement in domestic animals to increase muscle strength, improve growth and development, and strengthen the immune system

Keywords: housing conditions; dietary supplement; growth intensity; blood morphological parameters; biochemical parameters

Introduction

The successful development of livestock production and its specialisation allows obtaining the maximum amount of high-quality products at minimal costs (Wang *et al.*, 2022). However, in the current market conditions, to find resource savings to ensure the profitability of the livestock sector, farms use the latest European animal husbandry technologies. Thus, the search for effective, harmless, environmentally friendly means to ensure the growth, development and increase of natural resistance of young animals

for their high preservation is currently relevant (El-Bahr *et al.*, 2020).

Using various biologically active compounds during the rearing of young animals will significantly improve the problem of their safety. For example, vitamin preparations can ensure intensive growth, development and high safety of young animals. It has been established that the protective function of probiotics and vitamin preparations is manifested by immunostimulation with increased phagocytosis activity,

synthesis of secretory IgA, interferon, increased functional activity of immunocompetent cells, induction of lymphokines, which positively affects specific and nonspecific factors of natural resistance in calves of the early postnatal period, maintaining the body's homeostasis, ensuring their normal health (Azarang *et al.*, 2020; Bayat *et al.*, 2023; Fei *et al.*, 2023). Vitamin preparations stimulate the main stages of metabolism in tissues, and contribute to the processes of restoring the functioning of vital organs (Mahdinloo *et al.*, 2022; Zaaboul & Liu, 2022).

Currently, a fairly large number of vitamin preparations have been proposed for animal husbandry, especially in industrial technologies, therefore, research on the effectiveness of their impact on the animal body, the feasibility of their use and the determination of economic efficiency of their implementation are of scientific and practical interest. Therewith, the effectiveness of biologically active preparations derived from wheat germ, which are natural medicines and catalyse cation exchange and adsorption processes, has not been sufficiently analysed. Wheat germ is known to be a highly nutritious by-product of the flour milling industry with a short shelf life. The shelf life of this product depends on the manufacturing method. Thus, the process of fermentation of different concentrations of germs reduces the activity of lipase and lipoxygenase, which are associated with the release of fatty acids (Khosroshahi *et al.*, 2022). The method of producing stabilised wheat germ by mixed fermentation (*Lactobacillus acidophilus* and *Lactobacillus plantarum*) and electrospaying process actively stabilises the enzymes (Khosroshahi *et al.*, 2023).

Since β -carotene is the main carotenoid of provitamin A found in grains such as sorghum, and when its concentration is below the target, biofortification breeding studies are being conducted (Cruet-Burgos *et al.*, 2023). The effect of vitamin preparations, including those

containing carotenoids, on the body depends on the component composition and dosage. Thus, it is important to evaluate the impact of the new composition of biologically active drugs on the animal body. These studies should begin with laboratory animals. The purpose of the research – to evaluate the effect of the dietary supplement “Wheat germ meal” on the growth and development of white mice.

Literature Review

Recently, researchers have been paying more and more attention to natural vitamin preparations containing carotenoids. Significant scientific and practical interest in these compounds is explained by their ability to prevent the development of many diseases, such as cancer, neurodegenerative diseases such as Alzheimer's disease, cerebral ischaemia, diabetes associated with obesity and hypertension, ophthalmic diseases, etc. Carotenoids can be used as food additives – nutraceutical and pharmaceutical compounds. Therewith, research is required to explore the availability of these compounds to the human body (Bhatt & Patel, 2020).

Carotenoids are not synthesised in the body of animals but accumulate from feed or are partially modified as a result of metabolic reactions. The carotenoids produced in animals are diverse in structure and play an important role as precursors of vitamin A, photoprotectors, and antioxidants, promoting reproduction and strengthening the immune system (Maoka, 2020). Nowadays, about 600 carotenoid pigments have been isolated from various sources. The prevalence and diversity of carotenoids in nature are conditioned upon both the ability of living systems to biosynthesise them and their ability to adsorb and metabolise these substances. Complex vitamin compositions in different groups and species of living organisms vary both in content and composition. Natural sources of carotenoids are very diverse:

a significant amount of them are found in herbs and green leaves, flower petals, algae, and various microorganisms (Foong *et al.*, 2021).

Marine carotenoids (astaxanthin, fucoxanthin, β -carotene, lutein, and the rare siphonaxanthin, sioxanthin, and mixol) have recently demonstrated antioxidant properties in reducing oxidative stress markers (Genç *et al.*, 2020). Currently, carotenoids can be obtained from plant materials by chemical synthesis and biotechnological means (Kalra *et al.*, 2021). The synthetic production of carotenoids increases efficiency compared to the natural metabolic system and is based on the design of a three-domain enzyme (CrtB, CrtI, CrtY) that contains the complete β -carotene pathway (Rabeharindranto *et al.*, 2019). Carotenoids are of particular interest in commercial poultry farming, both for high poultry productivity and for the production of functional food products. It is known that carotenoids can accumulate in organs and tissues, stimulating weight gain in poultry. The positive effect of lycopene on metabolic processes and live weight gain in broiler chickens has been demonstrated by other authors, and their content depends on the availability of the poultry feed (Marounek & Pebriansyah, 2018).

Carotenoids – are fat-soluble compounds with subsequent digestion and absorption in the gastrointestinal tract. Their absorption begins with their release from the food matrix and dissolution in the lipid phase, and then incorporation into lipid micelles in the small intestine, which is absorbed by the mucous membrane and transported by the lymphatic system in the form of chylomicrons through the lymphatic vessels. Mostly β -carotene accumulated along the duodenal-iliac axis of the intestine and was subsequently converted to retinol and retinyl esters in its proximal section (Reboul, 2023). Natural carotenoids extracted and purified from the aquacultured marine green

macroalgae *Ulva ohnoi* and freshwater green microalgae *Haematococcus pluvialis* contributed to the regulation of the gut microbiota, affecting gut homeostasis and health (Pratap *et al.*, 2022).

The accumulation of carotenoid lycopene in tissues depends on gender, genotype and tissue type. Administration of lycopene to rats for two weeks had no adverse effect on daily weight gain, the relative weight of internal organs and serum enzyme activity and total liver lysosomal enzyme activity (Bradley *et al.*, 2022). The administration of tomato oil concentrate to rats decreased the level of triglyceride accumulation in the liver (Kimura *et al.*, 2021) and led to its faster removal from tissues with a decrease in oxidative stress (Sarker *et al.*, 2021; Akbari *et al.*, 2022) and inflammation. Feeding the algae *Dunaliella bardawil* to laboratory mice as the only source of vitamin A reduced markers of adipose tissue macrophage recruitment and plasma lipid concentrations (Surman *et al.*, 2020; Melnikov *et al.*, 2022). During the development of hypercholesterolaemia in rabbits and the regression of the process, there was a decrease in serum cholesterol levels due to lycopene, accompanied by a decrease in the concentration of lipid peroxidation products in tissues (Hassan *et al.*, 2021).

Carotenoids, in particular, lycopene, were involved in the regulation of lipid metabolism in poultry. Thus, feeding 100, 200 and 400 mg/kg of lycopene to broiler chickens increased body weight, decreased abdominal fat accumulation, and decrease triglyceride and total cholesterol levels, and serum low-density lipoprotein cholesterol in the blood (Wan *et al.*, 2021; Fathi *et al.*, 2022).

Thus, the data presented indicate that using biologically active additives containing vitamin preparations of natural origin and carotenoids in animals and poultry helped to improve the clinical condition, immunological status, and biochemical and physiological parameters

of the organism, and increased the supply of fat-soluble vitamins to the animal body.

Materials and Methods

The work was performed based on the problematic laboratory of farm animal immunology of Bila Tserkva National Agrarian University in the period from 2020 to 2021. The experiment used 60 heads of laboratory animals – nonlinear white mice (males) (*Mus musculus L*), free from pathogenic microflora, which were kept with barrier elements in an improved conventional system. The animals were divided into two groups (30 animals each): control and experimental. The experimental white mice were fed the dietary supplement Wheat Germ meal daily for 60 days at a dose of 2.0 g/head once a day in combination with the main diet. The main diet of white mice consisted of freshly crushed wheat grain and compound feed. Watering was performed by a nipple drinker.

“Wheat germ meal” dietary supplement was developed by “Bilotserkivkhlipoprodukt” collective enterprise, Bila Tserkva, Kyiv region. This supplement is a grey powdery substance obtained from wheat germ by alcohol extraction. The supplement contains a complex of biologically active substances, namely: amino acids: lysine, histidine, arginine, threonine, serine, glutamic and aspartic acid, proline, glycine, alanine, cystine, valine, methionine, isoleucine, leucine, tyrosine, phenylalanine, B vitamins, vitamin E, PP and carotenoids (1 g of the product contains B vitamins, namely vitamin B1 – 0.16 mcg/g; B2 – 0.19 mcg/g; B12 –

0.0015 mcg/g; carotenoids 4.0 mcg/g; vitamin E – 2.0 mcg/g).

At the first stage of the study, the microclimate of the room where the white mice were kept was assessed (SOU 85.2-37-736:2011..., 2011). The temperature in the room was measured by a mercury thermometer in degrees Celsius; relative humidity, % – by a hygrometer psychrometric VIT-2 (Ukraine); air velocity, m/s – by a balloon catathermometer (Ukraine); concentration of harmful gases: carbon dioxide, %; ammonia, hydrogen sulfide, mg/m³ – by a gas analyser UG-2 (Ukraine); artificial illumination (W/m²), lux – by a Benetech GM1010 luxmeter (Japan). The study of indoor microclimate indicators was conducted three times (before the start and on days 30 and 60 of the study) during the research period.

The microclimate indicators in the room where research laboratory animals are kept must be within the limits that meet the requirements of the applicable documents throughout the day and regardless of the season (SOU 85.2-37-736:2011..., 2011). Failure to comply with the requirements of regulations on indoor microclimate indicators can cause overheating of laboratory animals, loss of activity, decreased appetite and resistance. These clinical signs are not permissible during experimental studies and may result in the termination of further research. During the study, the microclimate of the room where the experimental animals – white mice – were kept was monitored. The average values of microclimate parameters for the research period are presented in Table 1.

Table 1. Microclimate parameters of the room for keeping white mice

Indicators	Sanitary and hygiene standards	Actual indicator
Temperature, °C	20-24	21.3±1.14
Relative humidity, %	55.0±2.0	54.6±3.09
Air velocity, m/s	0.3	0.25±0.01
CO ₂ concentration, %	0.15	0.14±0.002
NH ₃ concentration, mg/m ³	10	0.05±0.02

Table 1. Continued

Indicators	Sanitary and hygiene standards	Actual indicator
H ₂ S concentration, mg/m ³	5	0.002±0.02
Illuminance, lux (1 m from floor)	200	196.4±10.04
Photoperiod, h (light: dark)	12:12	12:12
Air exchange (frequency/hour)	10-15	10

Source: author's development

According to the indicators in Table 1, the microclimate parameters of the room met the sanitary and hygienic requirements (SOU 85.2-37-736:2011..., 2011). It used natural and artificial lighting – fluorescent lamps. Ventilation in the room where the animals were kept was natural, through open doors and windows.

At the second stage of the study, the tap water used to feed the laboratory animals was evaluated. These studies were conducted at the State Enterprise "Kyiv Regional Research and Production Centre for Standardisation, Metrology and Certification" according to the methodology On the approval of State sanitary norms and rules "Hygienic requirements for

drinking water intended for human consumption" (2022).

The welfare of the experimental animals depended on the quality and safety of the water they were drinking. According to the requirements of regulations, drinking water must be safe from an epidemiological standpoint, harmless in terms of organoleptic and physicochemical characteristics. Thus, it was crucial to examine these indicators for compliance with the requirements of the On the approval of State sanitary norms and rules "Hygienic requirements for drinking water intended for human consumption" (2022). The results are presented in Table 2.

Table 2. Physical, chemical and epidemiological safety indicators of tap water, n=3

Indicator	Unit of measurement	Sanitary and epidemiological standards 2.2.4-171-10	In fact
1. Organoleptic characteristics			
Odour (per t=20°C)	points	≤2	1.0±0.04
Turbidity	mg/dm ³	≤1.0	0.5±0.01
Colour	deg	≤20.0	6.0±0.03
Flavour and aftertaste	points	≤2	1.0±1.25
2. Physicochemical indicators			
Hydrogen indicator	Units pH	6.5-8.5	7.5±0.06
Total stiffness	mmol/dm ³	≤7.0	7.5±0.06
Iron total	mg/dm ³	≤0.2	0.05±0.001
Chlorides	mg/dm ³	≤250	150.0±5.6
Copper	mg/dm ³	≤1.0	
Iron total	mg/dm ³	≤0.2	
Zinc	mg/dm ³	≤1.0	0.5±0.04
Manganese	mg/dm ³	0.1	0.05±0.002

Table 2. Continued

Indicator	Unit of measurement	Sanitary and epidemiological standards 2.2.4-171-10	In fact
Sulphates	mg/dm ³	≤250	27.6±1.5
3. Epidemic safety indicators			
Total coliforms	CFU/100 cm ³	absence	absence
Intestinal helminths	Cells, eggs, larvae, in 50 dm ³	absence	absence

Source: author's development

Table 2 demonstrates that for all examined indicators of quality and safety, tap water corresponded to the requirements of the current regulation (On the approval..., 2022). In the third stage of the study, the general behaviour of the animals was monitored: the “open field” test was used to measure horizontal motor activity (the number of squares crossed), vertical motor activity (the number of vertical stands) and exploratory activity (the number of times the animals peered into the “holes” – the burrowing reflex).

In addition, according to the third stage of the study, the effect of the biological activity of wheat germ meal components was assessed by the dynamics of body weight of white mice (initial body weight 14.0 g) and organ weight (thymus, thyroid gland, kidneys, liver, lacrimal gland) by weighing them on a laboratory balance HC220MS (Japan). The growth rate of white mice was calculated by the average daily growth using standard methods.

At the fourth stage of the study, the morphological parameters and leukocyte blood count and biochemical indicators of the blood serum of white mice were determined. The material for morphological and biochemical studies was peripheral blood, which was collected from white mice by decapitation with a guillotine knife under preliminary anaesthesia. Blood was taken in the morning before feeding the animals on day 60 of the research. For the assessment of morphological parameters, blood was collected in special tubes with Trilon B,

and for biochemical analysis, whole blood was collected, settled and centrifuged to obtain serum. The automatic haematological analyser MINDRAY BC-2300 (USA) was used to determine red blood cell count (RBC, 10¹²/L), haemoglobin (HGB, g/L), haematocrit (HCT, %), white blood cell count (WBC, 10⁹/L), neutrophils (NEUT, %), basophils (BASO, %), lymphocytes (LYMPH, %), eosinophils (EO, %) and monocytes (MONO, %). Serum biochemical indicators were assessed using an automatic biochemical analyser AS-120 (Japan) and a test system – Global Scientific (USA).

During the research, the provisions of the “General Ethical Principles for Animal Experiments” adopted by the First National Congress on Bioethics (Kyiv, 2001) were followed. The entire experimental part of the research was conducted according to the requirements of the international principles of the European Convention for the Protection of Vertebrate Animals Used for Experimental and Scientific Purposes (1986) and the relevant Law of Ukraine No. 3447-IV “On Protection of Animals from Cruelty” (2006, February).

The obtained digital indicators were processed statistically using the Microsoft Excel software package with the calculation of the arithmetic mean and its error ($M \pm m$), the level of reliability (P) by Student's t-test ($P < 0.05$; $P < 0.01$; $P < 0.001$).

Results and Discussion

Changes in the behaviour of laboratory animals of the experimental group and the dynamics of

their body weight compared to the control are important indicators for assessing the impact of exogenous and endogenous environmental factors (Table 3).

Table 3. Integral assessment of behavioural parameters in white mice, M \pm m, n=30

Indicator	Group	
	experimental	control
Body temperature, °C	38.00 \pm 0.85	38.2 \pm 1.01
Horizontal movement activity	32.20 \pm 1.41	32.1 \pm 1.12
Vertical movement activity	17.4 \pm 1.3	17.1 \pm 1.2
“Burrowing reflex”	12.40 \pm 1.05	12.00 \pm 1.20
Integral activity	64.0 \pm 2.0	64.1 \pm 1.9

Source: author's development

According to the results presented (Table 3), there were no changes in body temperature, horizontal, vertical, integral activity, and the “burrowing reflex” in the animals of the experimental group compared to the control group (Labunets, 2020). Changes in body

weight, average daily weight gain, and weights of some organs of experimental animals are very important indicators, the violation of which indicates the degree of pathological condition of organs and impairment of specific body functions (Table 4).

Table 4. Weight and average daily weight gain of white mice, M \pm m, n=30

Indicator	Start of research	Day of research		
		14	30	60
Body weight, g	14.0 \pm 0.85	15.00 \pm 0.44	18.00 \pm 0.84	20.10 \pm 1.03
	14.0 \pm 0.64	16.56 \pm 0.55 [▲]	20.38 \pm 0.59 [•]	23.27 \pm 1.04 [•]
Average daily weight gain, mg	–	210.00 \pm 1.02	209.00 \pm 2.72	210.00 \pm 2.86
	–	230.00 \pm 1.30 ^{**}	230.0 \pm 2.04 ^{**}	240.00 \pm 1.40 ^{**}

Notes: ^{*}P<0.05; ^{**}P<0.001 compared to the control group. [▲]P<0.01; [•]P<0.001 compared to the indicator at the beginning of the research. Numerator – control group; denominator – experimental group

Source: author's development

As a result of experimental researches, it was established (Table 4) that on day 14 after feeding the supplement, the body weight of mice of the experimental group increased by 10.4% (P<0.05), on day 30 – by 13.2% (P<0.05), and on day 60 – by 15.8% (P<0.05) compared to the control group. Therewith, the body weight of mice in the experimental group increased by 18.3% (P<0.01) on day 14, by 45.6% (P<0.001) on day 30, and by 66.2% (P<0.001) on day 60 compared to the beginning of the research.

Animals actively ate feed both from the main diet and feed additives.

The results of researches on the increase in body weight, in particular of Japanese quail, from the consumption of natural plant components of spirulina rich in vitamin A are presented by Abdel-Wahab *et al.* (2023). In addition, improvements in liver function, total lipid profile, antioxidant parameters, and immune response have been demonstrated. Therewith, Gopal *et al.* (2023) established that experimental

administration of lutein to laboratory mice significantly reduced the weight of epididymal and abdominal adipose tissue and decreased serum cholesterol levels and low-density lipoprotein cholesterol concentrations. Another carotenoid, siphonaxanthin, significantly accumulated in the mesenteric adipose tissue of male mice, but not in the epididymal and peri-renal tissue. Thus, this carotenoid effectively regulated adipogenesis and suppressed lipid accumulation (Li *et al.*, 2015).

The results presented in Table 4 demonstrate that on day 14 of the study, the average daily weight gain of mice in the experimental group increased by 9.5% ($P < 0.001$), on day 30 – by 10.0% ($P < 0.001$), and on day 60 – by 14.3% ($P < 0.001$) compared to the control group. During the entire study period, the animals of the experimental group actively ate feed.

The dynamics of the weight of the internal organs of white mice on day 60 of the experiment is presented in Table 5.

Table 5. Weight of internal organs of white mice, $M \pm m$, $n=30$

Internal organ	Experimental group	Control group
Thymus, mg	33.0±2.3	31.0±3.0
Liver, g	1.21±0.05	1.15±0.04
Spleen, g	0.18±0.02	0.18±0.03
Thyroid gland, mg	4.00±0.06	4.00±0.05
Kidneys, g	0.15±0.03	0.15±0.07

Source: author's development

According to the results obtained (Table 5), there was no statistically significant difference in the weight of internal organs of mice in the experimental and control groups.

Thus, based on the increase in body weight, average daily weight gain of mice and the weight of their internal organs, it was assumed that the growth of experimental animals was improved by increasing muscle tissue. Other researchers have found that adipose tissue hypertrophy and inflammatory processes in mice occur when there is a deficiency of β -carotenoids, an enzyme that catalyses carotenoids in the inner mitochondrial membrane (Wu *et al.*, 2021). In addition, the efficiency of β -carotene conversion to vitamin A is higher in male rats than in females (Borel *et al.*, 2021).

In addition, it is essential to evaluate the combined effect of the supplement components on different parts of haemopoiesis. Ashrafzadeh *et al.* (2022) explored

Haematococcus Pluvialis, a green algae that is a source of astaxanthin (a beta-carotenoid compound). This compound has several biological and pharmacological properties, including antioxidant, anti-inflammatory, anti-tumour, anti-diabetic, hepatoprotective and neuroprotective effects. The authors have proven the effect of each of these properties of the supplement based on the study of the molecular mechanisms of the Nrf2 signalling pathway, which is responsible for maintaining the redox balance in the physiological state and the effect of astaxanthin on it.

In addition, Bachir *et al.* (2020) established that feeding rats with the algae *Spirulina platensis*, which contains carotenoids, leads to a slight increase in the number of leukocytes. Therewith, there was a tendency to decrease the level of neutrophils and lymphocytes.

The effect of the components of the dietary supplement “Wheat germ meal” on blood morphological indicators is presented in Table 6.

Table 6. Morphological indicators and leukocyte blood formula of white mice, M±m, n=30

Indicator	Group	
	experimental	control
Haemoglobin (HGB), g/L	94.30±1.53*	86.90±2.18
Red blood cells (RBC), 10 ¹² /L	8.60±0.14**	8.00±0.12
Haematocrit (HCT), %	45.20±1.06*	41.60±1.09
White blood cells (WBC), 10 ⁹ /L	6.40±0.50	6.50±0.40
Nucleated neutrophils (NEUT), %	3.10±0.18	3.00±0.25
Segmented neutrophils (NEUT), %	19.80±2.60	20.10±1.80
Basophils (BASO), %	0.20±0.004	0.20±0.003
Lymphocytes (LYMPH), %	56.30±2.09	55.0±3.01
Eosinophils (EO), %	2.45±0.16	2.98±0.24
Monocytes (MONO), %	5.60±1.02	5.90±2.45

Notes: *P<0.05; **P<0.01 compared to the control group of animals

Source: author's development

Using the supplement promoted the activation of erythropoiesis in the body of laboratory mice. It was demonstrated by an increase in haemoglobin level by 8.51% (P<0.05) and red blood cell count by 7.5% (P<0.01) and haematocrit by 3.6% (P<0.05).

Gunal *et al.* (2021) established that one of the functions of carotenoids, in particular lutein and zeaxanthin, is to improve mitochondrial function by reducing inflammation and activating the erythroid link of haemopoiesis. Kadek *et al.* (2021) theorised that vitamin A, E and β -carotene deficiency adversely affects calf health and increases mortality due to low levels of α -tocopherol and β -carotene. The authors proved that the paranteral administration of vitamins A and E and β -carotene to pregnant cows increased the haemoglobin content, haematocrit and red blood cell count in calves. In addition, it was established that beta-carotene is an effective antioxidant for the protection of red blood cells and has a specific effect on the level of phospholipids. It intensifies metabolic processes in the body by increasing the plasticity of cell membranes and cell membrane organoids. It is due to the antagonistic effect of

phospholipids on cholesterol, which causes the stiffness and stability of the cell membrane.

It is known that white blood cells and their subpopulations are biomarkers of inflammatory reactions in the body, and their determination in the experiment is mandatory (Agbuduwe & Basu, 2020). In this study, leukocytes and their populations were determined using an automatic haematology analyser. Nowadays, it is a modern research method. For example, Hofmann & Schmucker (2021) determined the number of leukocytes using automatic differentiation, which allowed obtaining results for three or five or more populations. By measuring the volume of leukocytes, they were divided into three populations and differentiated into fractions of neutrophils and lymphocytes, and fractions of medium-sized blood cells. It is more difficult to methodically differentiate leukocytes into five populations. The authors found that by combining flow cytometry with an assessment of the physicochemical and biochemical properties of leukocytes, this result can be achieved.

As can be observed from Table 6, the number of leukocytes, neutrophils, basophils and

lymphocytes in the blood of experimental mice did not differ statistically from the number of these cells in the blood of animals of the control group. Therewith, the number of leukocytes in the blood of experimental mice decreased slightly. Shevchenko *et al.* (2021) found that feeding carotenoids such as lycopene and astaxanthin to laying hens led to a decrease in the number of leukocytes and haemoglobin content in the blood.

The state of metabolic regulation is assessed by determining the concentration of individual components. For this purpose, a biochemical analysis of blood serum was performed and the indicators that can be used to determine the state of liver and immune system functioning were determined. Studies on the effect of “Wheat germ meal” on the biochemical indicators of the blood serum of white mice on day 60 of the study are presented in Table 7.

Table 7. Biochemical indicators of blood serum of white mice, M±m, n=30

Indicators, units.	Experiment	Control
Total protein (T-Pro), g/L	66.0±1.02*	61.3±1.48
Albumin (ALB), %	51.0±2.10	58.0±3.18
Globulins (Glob), %	49.0±1.83*	42.0±2.64
Alanine aminotransferase (ALT), IU/L	112.46±14.76	102.8±16.57
Aspartate aminotransferase (AST), IU/L	161.30±15.28	158.6±17.89
Total cholesterol, mmol/L	2.0±1.1	2.0±1.2

Notes: * $P < 0.05$ compared to the control group

Source: author’s development

The dietary supplement examined “Wheat germ meal” is a powerful source of protein. According to the research, wheat germ has a higher protein content than flour. Iusan (2022) determined that proteins are more balanced in terms of the amino acid spectrum (close to the reference value), while flour and grains contain proteins with an unbalanced composition of essential amino acids.

The total content of proteins in the blood serum indicates the state of protein metabolism in the body of experimental mice. According to the results presented in Table 7, it was established that under the influence of a biologically active dietary supplement, the content of total protein increased by 7.7% ($P < 0.05$) and globulins by 7.0% ($P < 0.05$). It can be assumed that a significant increase in these indicators is the main factor in increasing the intensity of growth and development of laboratory animals.

Thus, the tested additive affects the immune properties of the mice.

In addition, other researchers have found a similar effect of various carotenoids on the antioxidant status and immunity of animals. Thus, Plaza *et al.* (2020) concluded that the concentration of carotenoids (xanthophylls) correlated with the concentration of α -, β -, and γ -globulins in the blood. Aziz *et al.* (2023) substantiated a significant increase in the content of total protein and globulins, improvement of antioxidant status and immunity under the influence of carotenoids.

Lin *et al.* (2016) proved that such a powerful antioxidant carotenoid as axanthactin plays an important role in modelling the immune response. In this case, the researchers used primary cultured mouse lymphocytes both *in vitro* and *ex vivo* to assess the immunomodulatory effect of astaxanthin on cytokine production.

Treatment of mice with astaxanthin significantly increased the production of interferon and interleukin. It indicated the ability of astaxanthin to modulate the immune response of lymphocytes *in vitro* and that it partially exerts its immunomodulatory effect *ex vivo* by increasing the production of interferon and interleukin without inducing cytotoxicity.

Hassan *et al.* (2022) proved the effect of dietary supplementation with an extract of a tomato by-product containing carotenoids on increasing total plasma protein and globulins. In general, this supplementation had a positive effect on growth intensity, increased antioxidant status of the studied animals and reduced mortality.

Durge *et al.* (2022) established the importance of carotenoids for animals living in artificial conditions. Feeding these animals with lutein supplements caused an increase in superoxide dismutase activity and immunoglobulin concentration in the blood serum and a decrease in malondialdehyde and cortisol. The researchers concluded that this improved the antioxidant status and immunity and reduced stress in the experimental animals.

According to the results of the experiment, the hepatoprotective effect of the studied supplement was proved. This effect was manifested in the activation of transamination processes, as there was an increase in serum aspartate and alanine aminotransferase activity, which indicates an improvement in the energy and plastic functions of the body, the development of the main metabolic pathways of its functioning. Therewith, there was no statistically significant difference between the activity of aspartate and alanine aminotransferase in the blood of mice of the experimental and control groups.

Therewith, Shibabaw *et al.* (2019) found that an increase in hepatic marker enzymes above the reference values occurs in the event of metabolic disorders, as the liver plays a key

role in regulating the metabolism of carbohydrates, lipids and proteins. However, the hepatoprotective effect of carotenoids has been proven in the case of toxic effects on the body of animals. For example, El-Beltagi *et al.* (2020) used crude spirulina extract and pomegranate juice in a rat experiment to prevent carbon tetrachloride-induced hepatotoxicity. The authors established that the infusion of a toxic substance caused a significant increase in the activity of liver marker enzymes. In the case of *Spirulina platensis* and pomegranate juice administration to animals, a decrease in the activity of liver marker enzymes was observed.

In addition, El-Baz *et al.* (2020) administered equal doses of *Dunaliella salina*, a microalgae rich in carotenoids, to rats with induced liver fibrosis. These researchers found a significant decrease in serum aspartate and alanine aminotransferase activity. As a result, the development of fibrosis, centrilobular necrosis and inflammatory cell infiltration of the rat liver was suppressed. Thus, this study of the toxic effect of wheat germ meal components proved the improvement of the functional state of the liver.

As can be observed from Table 7, there was no statistically significant difference in the content of total cholesterol in the blood serum of experimental mice with that in the control group. It indicated activation of metabolism due to anabolic processes. In general, cholesterol in the body of animals is synthesised both independently and with feed and is established during the synthesis of corticosteroid hormones, bile acids and vitamin D. It is a polycyclic lipophilic compound found in cells that affects the permeability of cell membranes. The reference limits of this component in the blood serum for white mice are 1.0-3.4 mmol/L. The results are consistent with those of Kawamura *et al.* (2021), who proved the effect of anabolic nutrient-rich foods (astaxanthin, β -carotene,

and resveratrol) on muscle mass gain. It appeared to be a consequence of activation of the mTOR/p70S6K protein signalling in muscle tissue, which increased muscle mass rather than adipose tissue.

Thus, carotenoids in the mammalian body are involved in the regulation of adipose tissue metabolism and inflammation, affect the reduction of body weight and total cholesterol levels and increase high-density lipoprotein content, as found in the study by Dutta *et al.* (2023). In addition, Cao *et al.* (2021) proved that the carotenoid astaxanthin, which is associated with the regulation of redox reactions, helps reduce oxidative stress, inflammation, and cell death, and increases lipid metabolism. Melnikov *et al.* (2022) proved that the administration of a high-fat diet to male mice and the simultaneous introduction of β -carotene led to a 30% reduction in plasma cholesterol and triacylglycerol concentrations compared to a group of mice supplemented with vitamin A alone. According to the study by Soltani *et al.* (2021) macrophages originating from specific white blood cells, monocytes, affect reducing serum cholesterol levels. They were catalysed by the components of phytochemicals, including polyphenols, alkaloids and carotenoids, which were used in preclinical studies. In other words, macrophages provided both nonspecific protection (or innate immunity) and specific protection (or acquired immunity) in vertebrates.

The effect of the examined additive on the natural resistance of animals can be explained based on the fact that it contains a complex of biologically active substances, namely amino acids, vitamins and carotenoids, which have a tonic, adaptogenic and antioxidant effect. Since the supplement contains the most carotenoids among other components – 4.0 mcg/g – it was assumed that the beneficial intestinal microflora of mice was regulated, competing with strains of opportunistic bacteria. Therewith,

it is possible that conditionally pathogenic microflora was displaced from the intestinal microbial population and the development of pathogenic microorganisms was restrained. The assumptions made are consistent with the results of Yang *et al.* (2021) based on the study of the intestinal microbiota of mice. The authors have demonstrated that β -carotene increases the relative abundance of the genera *Akkermansia*, *Candidatus Stoqueficus* and *Faecalibaculum*, but reduces the relative abundance of *Alloprevotella* and *Helicobacter*. In addition, Pratap *et al.* (2022) determined that significant changes with an increase in the bacterial classes *Bacteroidia*, *Bacilli*, *Clostridia* and *Verrucomicrobia* were observed after feeding mice with ulvan and astaxanthin. Kuang *et al.* (2022) proved that high levels of beneficial bacteria such as *Clostridiaceae* were present in the intestinal microflora of sensitised mice after β -carotene administration, while the number of pathogenic bacteria such as *Streptococcaceae* decreased. The authors substantiated that after the administration of β -carotene to mice, there was a stimulation of recovery processes in the intestinal mucosa and normalisation of the intestinal microbiota.

Thus, the anti-inflammatory effect of β -carotene, its ability to regulate immune system and improve intestinal microflora of animals have been experimentally confirmed.

Conclusions

In the experimental study of the dietary supplement Wheat Germ Bran at a dose of 2.0 g/head, a positive effect of its components, in particular carotenoids, on the growth and development of white laboratory mice was proved. The microclimate parameters in the laboratory animal housing, physical and chemical parameters, and indicators of epidemiological safety of tap water corresponded to the requirements of regulations. Feeding “Wheat germ meal” at a dose

of 2.0 g/head did not cause adverse reactions in mice, promoted the activation of transamination processes, which improved the metabolism of the animal body, intensified muscle growth, and, as a result, provided an increase in body growth energy. The experimental animals consumed food and water well, and their behaviour was characterised by activity and mobility. The body weight of mice fed with the dietary supplement increased during the experiment both in comparison with the control group of animals (day 14 – by 10.4%; day 30 – by 13.2%; day 60 – by 15.8%) and with the baseline values at the beginning of the study: 14th day – by 18.3%; 30th day – by 45.6%; 60th day – by 66.2%. During the experiment, the average daily weight gain of mice increased: on day 14 – by 9.5%; on day 30 – by 10.0%; on day 60 – by 14.3%. Using the dietary supplement promoted the activation of

erythrocytopoiesis. The haemoglobin level increased by 8.51%, the number of red blood cells – by 7.5% and the haematocrit value – by 3.6%. The number of leukocytes, neutrophils, basophils, lymphocytes, eosinophils and monocytes in the blood of animals fed the supplement did not change. The components of the dietary supplement increased serum total protein by 7.7% and globulins by 7.0%, and increased metabolic rate against the background of activation of anabolic processes. In the future, it is planned to explore the components of the intestinal microbiota of white mice fed this dietary supplement.

Acknowledgements

None.

Conflict of Interest

None.

References

- [1] Abdel-Wahab, A.A., Elnesr, S.S., & Abdel-Kader, I.A. (2023). Effect of dietary supplementation of Jerusalem Artichoke extract on performance, blood biochemistry, antioxidant parameters, and immune response of growing Japanese quail. *Journal Animal Physiology and Animal Nutrition*, 107(3), 920-927. doi: [10.1111/jpn.13783](https://doi.org/10.1111/jpn.13783).
- [2] Agbuduwe, C., & Basu, S. (2020). Haematological manifestations of COVID-19: From cytopenia to coagulopathy. *European Journal of Haematology*, 105(5), 540-546. doi: [10.1111/ejh.13491](https://doi.org/10.1111/ejh.13491).
- [3] Akbari, B., Baghaei-Yazdi, N., Bahmaie, M., & Abhari, F.M. (2022). The role of plant-derived natural antioxidants in reduction of oxidative stress. *BioFactors*, 48(3), 611-633. doi: [10.1002/biof.1831](https://doi.org/10.1002/biof.1831).
- [4] Ashrafizadeh, M., Ahmadi, Z., Yaribeygi, H., & Sathyapalan, T. (2022). Astaxanthin and Nrf2 signaling pathway: A novel target for new therapeutic approaches. *Mini Reviews in Medicinal Chemistry*, 22(2), 312-321. doi: [10.2174/1389557521666210505112834](https://doi.org/10.2174/1389557521666210505112834).
- [5] Azarang, A., Farshad, O., Ommati, M.M., Jamshidzadeh, A., Heidari, R., Abootalebi, S.N., & Gholami, A. (2020). Protective role of probiotic supplements in hepatic steatosis: A rat model study. *BioMed Research International*, 2020, article number 5487659. doi: [10.1155/2020/5487659](https://doi.org/10.1155/2020/5487659).
- [6] Aziz, N.M., Mohammed, S.J., & Saleh, B.M. (2023). Effect of broccoli stem and leaves on some biochemical and hormonal parameters in Kurdi (Karadi) ewe. *Caspian Journal Environmental Science*, 21(2), 301-309. doi: [10.22124/CJES.2023.6493](https://doi.org/10.22124/CJES.2023.6493).
- [7] Bayat, M., Daei, S., Ziamajidi, N., Abbasalipourkabir, R., & Nourian, A. (2023). The protective effects of vitamins A, C, and E on zinc oxide nanoparticles (ZnO NPs)-induced liver oxidative stress in male Wistar rats. *Drug and Chemical Toxicology*, 46(2), 209-218. doi: [10.1080/01480545.2021.2016809](https://doi.org/10.1080/01480545.2021.2016809).

- [8] Bachir, S., Sharif, M.K., Javed, M.S., Amjad, A., Khan, A.A., Shan, F.-ul-H., & Khalil, A.A. (2020). Safety assessment of *Spirulina platensis* through sprague dawley rats modeling. *Food Science Technology*, 40(2), 376-381. doi: [10.1590/fst.41918.376-381](https://doi.org/10.1590/fst.41918.376-381).
- [9] Bhatt, T., & Patel, K. (2020). Carotenoids: Potent to prevent diseases. *Natural Products and Bioprospecting*, 10, 109-117. doi: [10.1007/s13659-020-00244-2](https://doi.org/10.1007/s13659-020-00244-2).
- [10] Borel, P., Troadec, R., Damiani, M., Halimi, C., Nowicki, M., Guichard, P., Margier, M., Astier, J., Grino, M., Reboul, E., & Landrier, J.-F. (2021). β -Carotene bioavailability and conversion efficiency are significantly affected by sex in rats. *Molecular Nutrition & Food Research*, 65(22), article number 210065. doi: [10.1002/mnfr.202100650](https://doi.org/10.1002/mnfr.202100650).
- [11] Bradley, M., Arballo, J., Black, M., Erdman, J., & Amengual, J. (2022). Tissue lycopene accumulation in transgenic mice lacking one or both carotenoid cleaving enzymes. *Current Developments in Nutrition*, 6(1), article number 55. doi: [0.1093/cdn/nzac049.001](https://doi.org/0.1093/cdn/nzac049.001).
- [12] Cao, Y., Yang, L., Qiao, X., Xue, C., & Xu, J. (2021). Dietary astaxanthin: an excellent carotenoid with multiple health benefits. *Critical Reviews in Food Science and Nutrition*, 63(18), 3019-3045. doi: [10.1080/10408398.2021.1983766](https://doi.org/10.1080/10408398.2021.1983766).
- [13] Cruet-Burgos, C., Morris, G.P. & Rhodes, D.H. (2023). Characterization of grain carotenoids in global sorghum germplasm to guide genomics-assisted breeding strategies. *BMC Plant Biology*, 23, article number 165. doi: [10.1186/s12870-023-04176-0](https://doi.org/10.1186/s12870-023-04176-0).
- [14] Durge, S.M., Das, A., Saha, S.K., Pande, A., Thakuria, D., Saxena, A., Bhardvaj, Y., & Verma, A.K. (2022). Dietary lutein supplementation improves immunity and antioxidant status of captive Indian leopards (*Panthera fusca*). *Zoo Biology*, 41(4), 328-339. doi: [10.1002/zoo.21671](https://doi.org/10.1002/zoo.21671).
- [15] Dutta, D., Nayak, A., & Dutta, D. (2023). Reconnoitring the usage of agroindustrial waste in carotenoid production for food fortification: A sustainable approach to tackle vitamin A deficiency. *Food Bioprocess Technology*, 16, 467-491. doi: [10.1007/s11947-022-02888-z](https://doi.org/10.1007/s11947-022-02888-z).
- [16] El-Bahr, S., Shousha, S., Shehab, A., Khattab, W., Ahmed-Farid, O., Sabike, I., El-Garhy, O., Albokhadaim, I., & Albosadah, K. (2020). Effect of dietary microalgae on growth performance, profiles of amino and fatty acids, antioxidant status, and meat quality of broiler chickens. *Animals*, 10, article number 76. doi: [10.3390/ani10050761](https://doi.org/10.3390/ani10050761).
- [17] El-Baz, F.K., Salama, A.A.A., & Hussein, R.A. (2020). *Dunaliella salina* microalgae oppose thioacetamide-induced hepatic fibrosis in rats. *Toxicology Reports*, 7, 36-45. doi: [10.1016/j.toxrep.2019.10.017](https://doi.org/10.1016/j.toxrep.2019.10.017).
- [18] El-Beltagi, H.S., Dhawi, F., Ashoush, I.S., & Ramadan, K.M.A. (2020). Antioxidant, anti-cancer and ameliorative activities of *Spirulina platensis* and pomegranate juice against hepatic damage induced by CCl₄. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 48(4), 1941-1956 doi:[10.15835/48412151](https://doi.org/10.15835/48412151).
- [19] Reboul, E. (2023). Proteins involved in fat-soluble vitamin and carotenoid transport across the intestinal cells: New insights from the past decade. *Progress in Lipid Research*, 89, article number 101208. doi: [10.1016/j.plipres.2022.101208](https://doi.org/10.1016/j.plipres.2022.101208).
- [20] European Convention for the Protection of Vertebrate Animals Used for Experimental and Scientific Purposes. (1986, March). Retrieved from http://zakon4.rada.gov.ua/laws/show/994_137.
- [21] Fathi, M., Tanha, T., & Saedyan, S. (2022). Influence of dietary lycopene on growth performance, antioxidant status, blood parameters and mortality in broiler chicken with cold-induced ascites. *Archives of Animal Nutrition*, 76(1), 50-60. doi: [10.1080/1745039X.2022.2046451](https://doi.org/10.1080/1745039X.2022.2046451).

- [22] Fei, Y., Chen, Z., Han, S., Zhang, S., Zhang, T., & Lu Y. (2023). Role of prebiotics in enhancing the function of next-generation probiotics in gut microbiota. *Critical Reviews in Food Science and Nutrition*, 63(8), 1037-1054. doi: [10.1080/10408398.2021.1958744](https://doi.org/10.1080/10408398.2021.1958744).
- [23] Foong, L.C., Loh, C.W.L., Ng, H.S., & Lan, J.C.-W. (2021). Recent development in the production strategies of microbial carotenoids. *World Journal Microbiology and Biotechnology*, 37, article number 12. doi: [10.1007/s11274-020-02967-3](https://doi.org/10.1007/s11274-020-02967-3).
- [24] Genç, Y., Bardakci, H., Yücel, Ç., Karatoprak, G.Ş., Akkol, E.K., Barak, T.H., & Sobarzo-Sánchez, E. (2020). Oxidative stress and marine carotenoids: Application by using nanoformulations. *Marine Drugs*, 18(8), article number 423. doi: [10.3390/md18080423](https://doi.org/10.3390/md18080423).
- [25] Gopal, S.S., Sukhdeo, S.V., Vallikannan, B., & Ponesakki, G. (2023). Lutein ameliorates high-fat diet-induced obesity, fatty liver, and glucose intolerance in C57BL/6J mice. *Phytotherapy Research*, 37(1), 329-341. doi: [10.1002/ptr.7615](https://doi.org/10.1002/ptr.7615).
- [26] Gunal, M.Y., Sakul, A.A., Caglayan, A.B., Erten, A., Kursun, A.E.D, Kilic, E., & Sahin, K. (2021). Protective effect of lutein/zeaxanthin isomers in traumatic brain injury in mice. *Neurotoxicity Research*, 39, 1543-1550. doi: [10.1007/s12640-021-00385-3](https://doi.org/10.1007/s12640-021-00385-3).
- [27] Hassan, F.A., Elkassas, N., Salim, I., El-Medany, S., Aboelenin, S.M., Shukry, M., Taha, A.E., Peris, S., Soliman, M., & Mahrose, K. (2021). Impacts of dietary supplementations of orange peel and tomato pomace extracts as natural sources for ascorbic acid on growth performance, carcass characteristics, plasma biochemicals and antioxidant status of growing rabbits. *Animals*, 11(6), article number 1688. doi: [10.3390/ani11061688](https://doi.org/10.3390/ani11061688).
- [28] Hassan, F., Abd-ElMola, L., Mobarez, S., Othman, D., Zedan, A., Mekawy, A., Mansour, A.M., & Mahrose, K. (2022). Influence of tomato processing by-product extract as dietary supplementation on growth performance, carcass characteristics and antioxidant status of growing rabbits under high ambient temperature. Retrieved from <https://www.tandfonline.com/doi/abs/10.1080/10495398.2022.2065283>.
- [29] Hofmann, T., & Schmucker, S. (2021). Characterization of chicken leukocyte subsets from lymphatic tissue by flow cytometry. *Cytometry A*, 99(3), 289-300. doi: [10.1002/cyto.a.24214](https://doi.org/10.1002/cyto.a.24214).
- [30] Iusan, L. (2022). Improving the recipes of extruded soryz mixes using wheat germ sciences of Europe. *Technical Sciences*, 94, 86-90. doi: [10.5281/zenodo.6616429](https://doi.org/10.5281/zenodo.6616429).
- [31] Kadek, R., Mikulková, K., Filípek, J., & Illek, J. (2021). The effect of parenteral application of vitamin A, vitamin E, and β -carotene to pregnant cows on selected indices in their calves. *Acta Veterinaria Brno*, 90, 135-143. doi: [10.2754/avb202190020135](https://doi.org/10.2754/avb202190020135).
- [32] Kalra, R., Gaur, S., & Goel, M. (2021). Microalgae bioremediation: A perspective towards wastewater treatment along with industrial carotenoids production. *Journal of Water Process Engineering*, 40, article number 101794. doi: [10.1016/j.jwpe.2020.101794](https://doi.org/10.1016/j.jwpe.2020.101794).
- [33] Kawamura, A., Aoi, W., Abe, R., Kobayashi, Y., Kuwahata, M., & Higashi, A. (2021). Astaxanthin-, β -Carotene-, and resveratrol-rich foods support resistance training-induced adaptation. *Antioxidants*, 10(1), article number 113. doi: [10.3390/antiox10010113](https://doi.org/10.3390/antiox10010113).
- [34] Khosroshahi, E.D., Razavi, S.H., Kiani, H., & Aghakhani, A. (2023). Mixed fermentation and electrospray drying for the development of a novel stabilized wheat germ powder containing highly viable probiotic cultures. *Food Science & Nutrition*, 11(5), 2176-2185. doi: [10.1002/fsn3.3092](https://doi.org/10.1002/fsn3.3092).
- [35] Khosroshahi, E.D., Razavi, S.H., & Kaini, H., & Aghakhani, A. (2022). Improvement of stability and antioxidant activity of wheat germ by mixed fermentation versus single fermentation. *Journal Food Sciences Technology*, 59(7), 2905-2912. doi: [10.1007/s13197-021-05316-w](https://doi.org/10.1007/s13197-021-05316-w).

- [36] Kimura, M., Tamura, S., Ishiyama, S., & Mochizuki, K. (2021). Feeding rats medium-chain triglycerides and tomato powder increases liver lycopene content and reduces the expression of genes related to lipid metabolism in the liver. *ACS Food Sciences Technology*, 1(6), 993-1001. doi: [10.1021/acsfoodscitech.0c00155](https://doi.org/10.1021/acsfoodscitech.0c00155).
- [37] Kuang, H., Ma, Y., & Liu, Y. (2022). Protective effect of β -carotene on OVA-induced food allergy in mice by strengthening intestinal epithelial barrier function and regulating intestinal microflora. *Food Function*, 13, 12330-12341. doi: [10.1039/D2FO02272A](https://doi.org/10.1039/D2FO02272A).
- [38] Labunets, I.F. (2020). Peculiarities of behavior in mice of different lines and sexes with a model of parkinsonism. *Physiological Journal*, 66(1), 18-24.
- [39] Law of Ukraine No. 3447-IV "About protection of animals from cruelty". (2006, February). Retrieved from <https://zakon.rada.gov.ua/laws/show/3447-15#Text>.
- [40] Li, Z.S., Noda, K., Fujita, E., Manabe, Y., Hirata, T., & Sugawara, T. (2015). The green algal carotenoid siphonaxanthin inhibits adipogenesis in 3T3-L1 preadipocytes and the accumulation of lipids in white adipose tissue of KK-Ay mice. *The Journal of Nutrition*, 145(3), 490-498. doi: [10.3945/jn.114.200931](https://doi.org/10.3945/jn.114.200931).
- [41] Lin, K.-H., Lin, K.-C., Lu, W.-J., Thomas, P.-A., Jayakumar, T., & Sheu, J.-R. (2016). Astaxanthin, a carotenoid, stimulates immune responses by enhancing IFN- γ and IL-2 secretion in primary cultured lymphocytes in vitro and ex vivo. *International Journal Molecular Science*, 17(1), article number 44. doi: [10.3945/jn.114.200931](https://doi.org/10.3945/jn.114.200931).
- [42] Mahdinloo, S., Hemmati, S., Valizadeh, H., Mahmoudian, M., Mahmoudi, J., Roshangar, L., Sarfraz, M., & Zakeri-Milani, P. (2022). Synthesis and preparation of vitamin A coupled butein-loaded solid lipid nanoparticles for liver fibrosis therapy in rats. *International Journal of Pharmaceutics*, 625, article number 122063. doi: [10.1016/j.ijpharm.2022.122063](https://doi.org/10.1016/j.ijpharm.2022.122063).
- [43] Maoka, T. (2020). Carotenoids as natural functional pigments. *Journal of Natural Medicines*, 74, 1-16. doi: [10.1007/s11418-019-01364-x](https://doi.org/10.1007/s11418-019-01364-x).
- [44] Marounek, M., & Pebriansyah, A. (2018). Use of carotenoids in feed mixtures for poultry: A review. *Agricultura Tropica et Subtropica*, 51(3), 107-111. doi: [10.2478/ats.2018.0011](https://doi.org/10.2478/ats.2018.0011).
- [45] Melnikov, N., Kamari, Y., Kandel-Kfir, M., Barshack, I., Ben-Amotz, A., Harats, D., Shaish, A., & Harari, A. (2022). β -Carotene from the alga *dunaliella bardawil* decreases gene expression of adipose tissue macrophage recruitment markers and plasma lipid concentrations in mice fed a high-fat diet. *Marine Drugs*, 20(7), article number 433. doi: [10.3390/md20070433](https://doi.org/10.3390/md20070433).
- [46] Order of the Ministry of Health of Ukraine No. 400 On the Approval of State Sanitary Norms and Rules "Hygienic Requirements for Drinking Water Intended for Human Consumption". (May, 2022). Retrieved from <https://zakon.rada.gov.ua/laws/show/z0452-10/>.
- [47] Plaza, P.I., Blanco, G., Wiemeyer, G., López-Rull, I.L., Hornero-Méndez, D., Donázar, J.A., Hiraldo, F., & Lambertucci, S.A. (2020). Plasma carotenoids and immunity in a despotic avian scavenger. *The Journal of Experimental Zoology*, 333(8), 569-578. doi: [10.1002/jez.2397](https://doi.org/10.1002/jez.2397).
- [48] Pratap, K., Majzoub, M.E., Taki, A.C., Hernandez, S.M., Magnusson, M., Glasson, C.P.K., de Nys, R., Thomas, T., Lopata, A.L., & Kamath, S.D. (2022). The algal polysaccharide ulvan and carotenoid astaxanthin both positively modulate gut microbiota in mice. *Foods*, 11(4), article number 565. doi: [10.3390/foods11040565](https://doi.org/10.3390/foods11040565).

- [49] Rabeharindranto, H., Castaño-Cerezo, S., Lautier, T., Garcia-Alles, L.F., Treitz, C., Holey, F., & Truan, G. (2019). Enzyme-fusion strategies for redirecting and improving carotenoid synthesis in *S. cerevisiae*. *Metabolic Engineering Communications*, 8, article number e00086. doi: [10.1016/j.mec.2019.e00086](https://doi.org/10.1016/j.mec.2019.e00086).
- [50] Sarker, M.T., Wan, X., Yang, H., & Wang, Z. (2021). Dietary lycopene supplementation could alleviate aflatoxin b1 induced intestinal damage through improving immune function and antioxidant capacity in broilers. *Animals*, 11(11), article number 3165. doi: [10.3390/ani11113165](https://doi.org/10.3390/ani11113165).
- [51] Shevchenko, L.V., Nedosekov, V.V., Davydovych, V.A., Rozhdestveskaya, T.N., & Drozdova, E.I. (2021). Impact of lycopene and astaxanthin on hematological and immunological parameters of laying hens. *IOP Conference Series: Earth and Environmental Science*, 839, article number 042004. doi: [10.1088/1755-1315/839/4/042004](https://doi.org/10.1088/1755-1315/839/4/042004).
- [52] Shibabaw, T., Dessie, G., Molla, M.D., Zerihun, M.F., & Ayelign, B. (2019). Assessment of liver marker enzymes and its association with type 2 diabetes mellitus in Northwest Ethiopia. *BMC Research Notes*, 12(1), article number 707. doi: [10.1186/s13104-019-4742-x](https://doi.org/10.1186/s13104-019-4742-x).
- [53] Soltani, S., Boozari, M., Cicero, A.F.G., Jamialahmadi, T., & Amirhossein Sahebkar, A. (2021). Effects of phytochemicals on macrophage cholesterol efflux capacity: Impact on atherosclerosis. *Phytotherapy Research*, 35(6), 2854-2878. doi: [10.1002/ptr.6991](https://doi.org/10.1002/ptr.6991).
- [54] SOU 85.2-37-736:2011. (2012). *Veterinary drugs. Determination of acute toxicity*. Kyiv: Ministry of Agricultural Policy.
- [55] Surman, S.L., Penkert, R.R., Sealy, R.E., Jones, B.G., Marion, T.N., Vogel, P., & Hurwitz, J.L. (2020). Consequences of vitamin A deficiency: Immunoglobulin dysregulation, squamous cell metaplasia, infectious disease, and death. *International Journal of Molecular Sciences*, 21(15), article number 5570. doi: [10.3390/ijms21155570](https://doi.org/10.3390/ijms21155570).
- [56] Wan, X., Yang, Z., Ji, H., Li, N., Yang, Z., Xu, L., Yang, H., & Wang, Z. (2021). Effects of lycopene on abdominal fat deposition, serum lipids levels and hepatic lipid metabolism-related enzymes in broiler chickens. *Animal Bioscience*, 34(3), 385-392. doi: [10.5713/ajas.20.0432](https://doi.org/10.5713/ajas.20.0432).
- [57] Wang, H., Hu, Y., Yan, H., Liang, Y., Guo, X., & Ye, J. (2022). Trade-off among grain production, animal husbandry production, and habitat quality based on future scenario simulations in Xilinhot. *Science of The Total Environment*, 817, article number 153015. doi: [10.1016/j.scitotenv.2022.153015](https://doi.org/10.1016/j.scitotenv.2022.153015).
- [58] Wu, L., Lu, P., Guo, X., Song, K., Lyu, Y., Bothwell, J., Wu, J., Hawkins, O., Clarke, S.L., Lucas, E.A., Smith, B.J., Chohanadisai, W., Hartson, S.D., Ritchey, J.W., Wang, W., Medeiros, D.M., Li, S., & Lin, D. (2021). β -carotene oxygenase 2 deficiency-triggered mitochondrial oxidative stress promotes low-grade inflammation and metabolic dysfunction. *Free Radical Biology and Medicine*, 164, 271-284. doi: [10.1016/j.freeradbiomed.2021.01.003](https://doi.org/10.1016/j.freeradbiomed.2021.01.003).
- [59] Yang, X., He, Z., Hu, R., Yan, J., Zhang, Q., Li, B., Yuan, X., Zhang, H., He, J., & Wu, S. (2021). Dietary β -Carotene on postpartum uterine recovery in mice: Crosstalk between gut microbiota and inflammation. *Frontiers in Immunology*, 12, article number 744425. doi: [10.3389/fimmu.2021.744425](https://doi.org/10.3389/fimmu.2021.744425).
- [60] Zaaboul, F., & Liu, Y. (2022). Vitamin E in foodstuff: Nutritional, analytical, and food technology aspects. *Comprehensive Reviews in Food Science and Food Safety*, 21(2), 964-998. doi: [10.1111/1541-4337.12924](https://doi.org/10.1111/1541-4337.12924).

Оцінка впливу шроту зародків пшениці на розвиток лабораторних мишей

Василь Петрович Лясота

Доктор ветеринарних наук, професор
Білоцерківський національний аграрний університет
09117, Соборна площа, 8/1, м. Біла Церква, Україна
<https://orcid.org/0000-0002-2442-2174>

Світлана Алімівна Ткачук

Доктор ветеринарних наук, професор
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
<https://orcid.org/0000-0002-6923-1793>

Надія Михайлівна Богатко

Доктор ветеринарних наук, доцент
Білоцерківський національний аграрний університет
09117, Соборна площа, 8/1, м. Біла Церква, Україна
<https://orcid.org/0000-0002-1566-1026>

Наталія Володимирівна Букалова

Кандидат ветеринарних наук, доцент
Білоцерківський національний аграрний університет
09117, Соборна площа, 8/1, м. Біла Церква, Україна
<https://orcid.org/0000-0003-4856-3040>

Тетяна Миколаївна Приліпко

Доктор сільськогосподарських наук, професор
Заклад вищої освіти «Подільський державний університет»
32316, вул. Шевченка, 12, м. Кам'янець-Подільський, Україна
<https://orcid.org/0000-0002-8178-207X>

Анотація. Нині в годівлі свійських тварин все частіше застосовують дієтичні добавки, які є цінним джерелом біологічно активних речовин, необхідних для їх повноцінного росту та розвитку, підтримання резистентного стану організму та профілактики численних захворювань. У їх складі найпоширенішими компонентами є білки, вітаміни та каротиноїди. Тому, актуальність наукового дослідження полягає в експериментальному визначенні ефективності впливу новоствореного продукту з багатокомпонентним складом на функціональний стан організму тварин. Мета дослідження стосувалася визначення впливу нового продукту, дієтичної добавки «Шрот зародків пшениці» на поведінку, інтенсивність росту, морфологічні та біохімічні показники крові білих мишей. Матеріалом дослідження слугували нелінійні білі миші у кількості 60 голів. Добавку мишам згодовували впродовж 60 діб. Застосовували комплекс методів, які включали: оцінку стану мікроклімату приміщення з утримання лабораторних тварин, стану водопровідної води для напування мишей, оцінку їх загальної поведінки та визначали гематологічні показники. Доведено, що впродовж

експерименту мікроклімат приміщення, в якому утримувалися лабораторні тварини і показники водопровідної води для їх напування, відповідали вимогам чинних нормативних документів. Обґрунтовано, що досліджувана добавка призводить до збільшення маси тіла білих мишей та їх середньодобових приростів. При цьому, маса внутрішніх органів тварин дослідної групи (тимус, щитоподібна залоза, нирки, печінка, слезінка) залишалася без змін. З'ясовано, що компонентний склад добавки впливає на морфологічні показники крові білих мишей, а саме призводить до збільшення вмісту гемоглобіну, кількості еритроцитів і величини гематокриту. У лейкограмі крові мишей не відмічалось змін. Встановлено збільшення вмісту загального білка та глобулінів в сироватці крові білих мишей. Зниження вмісту альбумінів і підвищення активності ферментів – аланінамінотрансферази та аспартатамінотрансферази відбувалося в межах референтних значень для білих мишей. Матеріали статті становлять практичну цінність для можливості застосування досліджуваної дієтичної добавки свійським тваринам для збільшення м'язової сили, покращення росту і розвитку та зміцнення імунітету

Ключові слова: умови утримання; дієтична добавка; інтенсивність росту; морфологічні показники крові; біохімічні показники