The effect of the protein-vitamin-mineral mixture "innovation−bac" in the water supply system of broiler chickens

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Abstract. A study was conducted to study the effect of a new protein−vitamin−mineral mixture "Innovation−BAC" from the hydrolyzed larva of Hermetia Illucens L. as part of the drinking water of the diet on meat productivity, quality and safety of meat raw materials in the cultivation of broiler chickens of the «COBB 500» cross. The optimal doses of PVMM "Innovation−BAC" for the introduction of broiler poultry into the watering system were confirmed: 5.0 ml/10 l − up to 21 days and 10.0 ml/10 l − from 22 to 37 days of cultivation. The economic significance of the use of Innovation−BAC as part of the drinking water of the «COBB 500» cross broiler diet was realized in production tests, where the cost of poultry meat was reduced by 42.3%, which can free up resources for other production purposes on poultry farms and large complexes supplying environmentally friendly meat raw materials for food.

1 Introduction

Innovative strategies in meat and poultry farming are currently relevant [5; 6; 9]. Researcher Artakhov A.B. (2021, p. 61) recalls "the emergence of the entomoindustry, which may further lead to a decrease in the relative cost of food" [1].

In November 2023, the Ministry of Industry and Trade of the Russian Federation added fly larvae to the list of agricultural products as part of the "Development of the concept for the development of the domestic bio industry and bio resource base and its interaction with other sectors of the economy", and now the larva can be officially grown in Russia. By 2030, according to the press service of the Ministry of Agriculture, the domestic industry for growing marine products will need more than 610 thousand tons of feed. Their main components are fishmeal and fat. For import substitution and to cover the needs of new production facilities, 110-150 thousand tons of fishmeal and 55-70 thousand tons of fish oil are needed. Biotechnologies make it possible to provide the population with

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environmentally friendly food without antibiotics in any climatic zone in unlimited quantities [2].

The authors, Phaengphairee, P., Boontiam, W., Wealleans, A. et al. (2023, P. 1), in describing their research on the replacement of antibiotics with Hermetia illucens larvae: "To contain the worsening problem of antibiotic resistance, the biologically active properties of full-fat flour from the larvae of the black soldier fly (BSFL) and probiotics were proposed from several strains (Bacillus subtilis, N. B. licheniformis and Saccharomyces cerevisiae) as effective alternatives to feed antibiotics" [11].

Sogari G. (2018, 2019) and co-authors advocate for the expansion of the insect products market worldwide. The authors are Odunayo T. and Barsony P. (2020, P.130) investigated a new possibility of protein-energy nutrition of animals and insect-based feeds: "Insects have a high protein level... and an optimal amino acid profile..."[10]. Insects, according to D. Menozzi, G. Sogari, M. Veneziani, E. Simoni, C. Mora, (2017, P. 27), are a source of nutrients "with low environmental impact" [8].

2 Materials and methods

The object for the production testing of PVMM "Innovation−BAC" was selected broiler chickens of the "COBB 500" cross from the first day of life. The protein−vitamin−mineral mixture "Innovation−BAC" is a product of hydrolysis of the larvae of the black lion fly and is an opaque suspension with a neutral odor, brown in color, soluble in water, without signs of a substandard product. Before testing on poultry, the chemical composition of PVMM "Innovation−BAC", produced in 2024 on the basis of LLC Scientific Production Association "Innovation", was clarified. PVMM "Innovation−BAC" was introduced into drinking water through a dosing device (Dosatron) into the watering system for experimental poultry in a low concentration due to the fact that the mixture contains Bacteriocins peptides with high antimicrobial activity, which was confirmed by the authors Mathur H., et al., (2018), who introduced a similar an additive in nano molar concentrations.

Production testing on a large number of broiler poultry was carried out at the Papov Safarbiy Bakhcherievich peasant farm (Republic of Adygea, Koshekhable village, Koshekhablsky district, Krasnodar Territory, Russia) in order to study meat productivity, quality and safety of broiler meat. Broiler poultry were kept outdoors, with free access to feed and drinking water. Two groups (n=8000) of "COBB 500" cross broilers were involved in two thousandth production sections (Table 1).

The growing period lasted 41 days, from April to May 2024. From day 1 to 42, the poultry of the first control group − section was provided with a diet with drinking water without additives and standard full-fledged compound feed, as in the first experiment, according to the growth periods: start (0-14), growth (15-28) and finish (29-42). The broilers of the experimental group − section were injected with PVMM "Innovation−BAC" in drinking water at a dose of 0.5 l / 1.0 t of water. In the period from 22 to 37 days – at a dose of 1.0 l / 1 t of water. In the last five days of testing, from day 38 to day 42, the broilers of the experimental section were supplied with drinking water without additives, as in the control section. The compound feed of the diet is full-fledged standard. The indicators of the control slaughter of broilers selected by random sampling, 100 heads from each group − section, were taken into account.

Table 1. The scheme of production testing of PVMM Innovation–BAC in the broiler watering system, n=8000.

Group	Features of feeding and watering age period, days		
	7 − 21	**22 − 37**	**38 − 42**
Section 1 − control	Basic diet (full-fledged mixed feed); drinking water	Basic diet (full-fledged compound feed); drinking water	Basic diet (full-fledged compound feed); drinking water
Section 2 − experienced	Basic diet (full−fledged compound feed); drinking water + optimal* amount of PVMM "Innovation-BAC", ml per 1000 liters, through a dosing device medicator	Basic diet (full−fledged compound feed); drinking water + optimal* amount of PVMM "Innovation-BAC", ml per 1000 liters, through a dosing device medicator	Basic diet (full-fledged compound feed); drinking water

Note: * − the optimal dose of PVMM "Innovation−BAC", injected into drinking water in an amount of 5.0 ml / 10 l − up to 21 days and 10.0 ml / 10 l − from 22 to 37 days of cultivation.

In the Argus testing center of the Department of Toxicology and feed quality of the Krasnodar Scientific Center of Animal Science and Veterinary Medicine, the main physico-chemical parameters, protein quality index, safety (content of residual amounts of toxic substances) of broiler meat were determined. The amino acid composition was studied at the Kuban State Agrarian University, at the Department of Biotechnology.

The chemical composition of PVMM Innovation−BAC included, in percentage: dry matter – 63.3±1.22; crude protein − 46.55±1.13; crude fat − 10.10±1.06; crude ash − 6.09±1.12; chitin − 0.06±0.02; chitosan − 0.50±0.05; potassium − 1.20±0.10; sodium − 0.46 ± 0.05; calcium − 3.10± 0.15; phosphorus − 1.18± 0.20; iron − 0.06± 0.01; zinc − 0.04± 0.01; copper − 0.02± 0.01; manganese − 0.008±0.002. The chemical composition and nutritional value of the product from the black lion is presented in tables 2 and 3.

Table 2. Chemical composition of PVMM "Innovation−BAC" from the larva of the black lion fly Hermetia illucens, %.

Chemical composition	Quantity
	PVMM* "Innovation BAC" Zazimko, 2024
Mass fraction of moisture	36.70±1.22
Mass fraction of crude protein	46.55±1.13
Mass fraction of crude fat, including fatty acids:	10.10±1.06
pentadecane	13.6±1.12
octadecadiene	8.03±1.09
cis-oleic	10.8 ±1.11
palmitic	8.1±1.07
Palmitoleic	2.14±0.14
lauric	61.15±1.34
myristic	14.4±1.16
Mass fraction of crude fiber (chitin)	0.06±0.02
Mass fraction of chitosan	0.50±0.05
Mass fraction of ash	6.09±1.12
Mass fraction of calcium	3.10±0.15
Mass fraction of total phosphorus	1.18±0.20
Mass fraction of iron	0.06±0.01
Mass fraction of zinc	0.04±0.01
Mass fraction of copper	0.02±0.01
Mass fraction of manganese	0.008±0.002

Mass fraction of sodium	0.46±0.05
Mass fraction of potassium	1.20±0.10

Note: * − our own data.

Table 3. Amino acid composition* PVMM "Innovation BAC" from hydrolyzed larva of the black lion fly Hermetia illucens, % of dry matter.

The amino acid	PVMM "Innovation BAC"
Essential Amino Acids:	14.6±0.1
Lysine	2.3±0.2
Tryptophan	0.3±0.1
Methionine + Cystine	0.7±0.2+0.3±0.1
Valine	2.3±0.1
Threonine	1.8±0.1
Leucine	2.7±0.3
Isoleucine	1.5±0.1
Phenylalanine+ tyrosine	2.0±0.3+0.7±0.2
Amine nitrogen of hydrolyzed crude protein (amino acids)	35.40±0.2
Non-protein fraction of crude protein (glucosides, nitrates, ammonium salts and others)	11.15±0.1

Note: * − our own data for 2024.

According to the conclusion of Tyshko N.V., et al. (2021, p. 50): "Comprehensive studies of the biological value of the protein of the larva of the black lion have demonstrated a high protein content in the biomass of the larva, its balanced amino acid composition and high biological value, which makes it possible to consider Hermetia illucens as a potential source of high-grade dietary protein" [3; 4]. The best growth rates were noted in the 2 experimental groups (Table 4).

Table 4. Change in live weight of broiler chickens selected in production testing from each group - section (n=8000) by random sampling method (n=100) by growing periods.

Group	Live weight of chickens by growing period, g, week						
	initial live weight	1	2	3	4	5	6
1, control	45.3 ±4.5	148.4 ±1.8	330.7 ±2.4	699.5 ±5.8	1097.3 ±7.4	1954.8 ±19.3	2512.7 ±26.8
2	44.8 ±4.8	177.7 ±2.1**	423.9 ±2.7**	875.1 ±3.6**	1496.0 ±11.5**	2548.5 ±23.5**	3025.5 ±29.5**

Note: The difference with the control is significant ** − p <0.01.

In the experimental group − section, compared with the control group, the live weight of broilers at the end of the experiment was 20.4% higher, respectively, and amounted to 3025.5 ± 39.5 g. The daily increase in live weight of broilers in the experimental group was significantly higher than the control (Table 5).

Table 5. Average daily live weight gain of broilers for 6 weeks of fattening, n=100.

Group	initial live weight (1 day). g	Final live weight (42 day). g	Average daily body weight gain. g
1. control	45.3±1.5	2512.7±26.8	60.2±1.5
2	44.8±1.8	3025.5±29.5**	72.7±1.2*

Note: the difference with the control is significant * − p <0.05; ** − p <0.01.

The daily increase in live weight of the experimental bird, compared with the control (60.2±4.5 g), was 20.8% higher in the experimental group (72.7±4.2 g). The results obtained allowed us to conclude that the highest daily gains in body weight were in the group where PVMM "Innovation−BAC" was injected into drinking water for 5.0 ml/10 l up to 21 days and 10.0 ml/10 l from 22 to 37 days of cultivation.

Thus, the optimal dose of PVMM "Innovation−BAC", introduced into drinking water for broilers of the "COBB 500" cross in production testing on eight thousand livestock of the experimental group, in the amount for 5.0 ml / 10 l − up to 21 days and 10.0 ml / 10 l − from 22 to 37 days of cultivation, allowed to increase the daily increase live weight of broilers of the "COBB 500" cross by 20.8%.

The control slaughter of broilers on the 42nd day of production tests, 100 heads from each group-section, allowed us to assess the meat productivity of carcasses of the control and experimental groups of broiler poultry of the "COBB-500" cross. It was found that all the slaughter indicators in the experimental group were significantly higher than the control ones (Table 6)

Table 6. Indicators of meat productivity of broilers, n= (50).

Indicator	Group	
	1 control	2
Pre-slaughter live weight, g	2508.7±35.5	3020.5±38.2**
Mass of a half-gutted carcass (exsanguinated, without feather, fluff, intestines, goiter and oviduct), g	2089.7±10.6	2597.6±31.6**
Slaughter yield of a half-gutted carcass, %	83.3	86.0*
Mass of a gutted carcass, g	1751.1±27.5	1930.0±30.2**
Slaughter yield of a gutted carcass, %	69.8	74.3*
The mass of edible parts (pectoral muscles, leg and trunk muscles, liver without gallbladder, heart, muscular stomach without contents and cuticles, kidneys, lungs, skin with subcutaneous fat and internal fat), g	1317.1±8.2	1685.4±9.4**
The yield of edible parts to the Pre-slaughter mass %	52.5	55.8
including pectoral muscles, g	523.2±8.5	612.5±5.8*
shins, g	154.3±4.7	163.7±5.5
hips, g	327.5±9.3	348.5±7.2*
Mass of inedible parts, g	1191.6±7.0	1335.1±6.4*
The yield of inedible parts from the Pre-slaughter mass, %	47.5	44.2
including the yield of bones and tendons, %	12.7	12.3
Meat and bone index (ratio of pulp to bones and tendons)	4.1	4.5
European Poultry Production Efficiency Index, units	274.6	429.7

Note: the difference with the control is significant * − p <0.05; ** − p <0.01.

Drinking PVMM "Innovation−BAC" to broilers of the experimental group contributed to an increase in the proportion of gutted carcass from the Pre-slaughter live weight compared with the control by 4.5% and the yield of edible parts, in relation to the Pre-slaughter live weight, was higher in the experimental group by 3.3%.

Based on the results of anatomical cutting of carcasses, significantly higher indicators were established in the experimental group compared with the control. The pectoral muscles were particularly distinguished, which had a mass of more than 600.0 g, exceeding the control by 17.0%. Total minced meat from the muscles of the thigh, shin and pectoral muscles was used to determine the chemical composition of boneless poultry meat (Table 7).

Table 7. Chemical composition of broiler carcasses at 42 days, %, n=100.

Indicator	Group (M±m)	
	1	2
Mass fraction of moisture	74.2±0.1	73.0±0.2*
Mass fraction of crude protein	21.8±0.1	22.7±0.1*
Mass fraction of crude fat	2.87±0.3	2.92±0.4
Mass fraction of ash	0.9±0.1	1.0±0.1

Note: the difference with the control is significant * − p <0.05

Compared with the broilers of the control group, the chickens of the experimental group showed a decrease in moisture content by 1.6% in the total minced meat (from the thigh, shin and pectoral muscles). The crude protein content in the experimental group was 4.1% higher than in the control group (p <0.05). The amino acid composition of the protein and the protein quality index of the total minced meat significantly differed from the control in the experimental group of broilers. The protein qualitative indicator, which is a criterion for the biological usefulness of broiler muscles, characterizing the content of full-fledged and defective proteins, is determined by the ratio of tryptophan and oxyproline. In the experimental group, the protein quality index was significantly higher than the control indicator by 11.5% (Table 8).

Table 8. Amino acid composition of protein in% to dry matter* boneless meat and biological value of boneless meat from carcasses of broilers "COBB 500", n=100.

Amino Acid	Group	
	1, control	2
Essential amino acids:	32.5±0.2	35.1±0.1
Lysine	6.4±0.2	6.9±0.2
Tryptophan	1.0±0.2	1.2±0.2
Methionine + Cystine	2.1±0.1+0.7±0.1	2.4±0.1+0.6±0.1
Valine	3.8±0.2	4.7±0.1
Threonine	3.4±0.1	3.3±0.1
Leucine	6.0±0.1	6.8±0.1
Isoleucine	3.5±0.1	3.4±0.2
Phenylalanine+ tyrosine	3.0±0.1+2.6±0.1	3.1±0.1+2.7±0.1
Interchangeable Amino Acids:	42.8±0.2	47.0±0.2
Histidine	4.2±0.2	4.1±0.1
Arginine	4.9±0.2	5.2±0.2
Glycine	3.5±0.2	3.7±0.2
Aspartic acid	6.7±0.2	8.9±0.2
Glutamic acid	12.9±0.2	14.8±0.2
Serin	2.9±0.2	2.8±0.1
Alanin	4.4±0.2	4.5±0.2
Proline	3.3±0.2	3.0±0.1
Amine nitrogen of hydrolyzed crude protein (amino acids)	75.3±0.2	82.10±0.2
Non-protein fraction of crude protein (glucosides, nitrates, ammonia salts, etc.)	9.20±0.3	1.97±0.4
Tryptophan, mg/100 g of raw meat	258.0	324
Oxyproline, mg/100 g of raw meat	49.6	55.8
Protein quality indicator	5.2	5.8

Note: the dry matter content in boneless meat from "COBB 500" broiler carcasses In-group 1: 25.8±0.1percentage; in the second group: 27.0±0.2 percentage.

The technological properties of boneless broiler meat, as a characteristic of structural and mechanical parameters, with the superiority of the experimental group, and nutritional value are presented in Table 9.

Table 9. Technological indicators, nutritional value and safety of boneless broiler meat of the COBB 500 cross, n=100.

Indicator	Acceptable level	The result of the analysis	
Moisture-retaining capacity. %	–	58.8±0.3	59.2±0.5
Scalability during cooking. %	–	34.5	33.8
Culinary and technological indicator	–	1.7	1.8
Energy value of 1 kg of boneless meat. MJ	–	8.5±0.2	8.6±0.3
pH	–	5.9	6.0
Mass fraction of total phosphorus. %	no more than 0.2	0.15	0.14
Lead. mg/kg	no more than 0.1	0.058±0.02	0.053±0.03
Arsenic. mg/kg	no more than 0.1	< 0.0025	
Cadmium. mg/kg	no more than 0.03	< 0.01	
Mercury. mg/kg	no more than 0.01	< 0.005	
Levomycetin. (mg/kg)	< 0.0003	< 0.0003	
Tetracycline group (units/g)	< 0.01	not found	
Hexachlorocyclohexane (α. β. γ isomers). mg/kg	no more than 0.01	< 0.004	
Dust and its metabolites. mg/kg	no more than 0.01	< 0.005	
Other Pesticides	not allowed	not found	
Salmonella in 25.0 g	not allowed	not found	
Listeria in 25 g	not allowed	not found	
Bacteria of the genus Proteus. in 1.0 g	not allowed	not found	
Genetically modified sources	not allowed	not found	

The Mineral composition of the total minced meat sample is shown in Table 10.

Table 10. Mineral composition of boneless meat with natural moisture content of "COBB 500" broilers, n=100.

Element	Unit of measurement	Group	
		1. control	2
macro –			
Potassium	g/kg	3.45±0.11	3.43±0.11
Phosphorus	g/kg	1.87±0.09	2.86 ±0.08*
Sulfur	g/kg	1.86±0.09	1.85±0.08
Magnesium	g/kg	0.84±0.02	0.83±0.05
Sodium	g/kg	0.55±0.04	0.57±0.04
Calcium	g/kg	0.08±0.02	0.09±0.03
micro –			
Zinc	mg/kg	36.10±1.20	34.50±1.20
Iron	mg/kg	15.80±0.90	15.60±1.00
Copper	mg/kg	7.80±0.40	7.30±0.50
Manganese	mg/kg	0.34±0.06	0.35±0.04

Selenium	mg/kg	0.32±0.02	0.33±0.01
Iodine	mg/kg	0.60±0.01	0.62±0.01

The reliability of the difference between the control and experimental groups: * – p <0.001

The content of toxic substances in the meat did not exceed the permissible limits, and most of them were "not detected", i.e., below the detection limit of the method. In the economic assessment of poultry farming using PVMM "Innovation−BAC" as part of the drinking water of the broiler diet of the "COBB 500" cross, the expected results of high production efficiency were obtained (Table 11).

Table 11. Economic efficiency of poultry meat cultivation in production conditions when using PVMM "Innovation−BAC" as part of the drinking water ration of broilers of the COBB 500 cross, n=100 (8000).

Indicator	**Group**	
	1 control	**2**
The number of daily broilers. heads	100	100
The number of broilers before slaughter. heads	97	98
Safety. %	97.0	98.0
Live weight of daily broilers. g	45.3±4.5	44.8±4.8
Live weight before slaughter. g	2508.7±35.5	3020.5±38.2
Slaughter yield of meat on bones. %	69.8	74.3
Average daily increase in fat for 42 days. g	60.2±1.5	72.7±1.2
Live weight gain for 42 days. kg	245.254	292.108
Feed costs per 1 kg of body weight gain. RUB.	57.4	46.76
The cost of PVMM "Innovation−BAC" per 1 kg of body weight gain. RUB.	–	0.9
Material production costs. RUB.	14077.58	13921.87
The cost of 1 kg of meat per bone. RUB.	57.4*	47.66
Revenue from the sale of 1 kg of meat per bone. RUB.	130.0	130.0
Revenue of profit for 1 kg of meat per bone. RUB.	72.6	82.34
Proceeds from the sale of meat on the bones of the entire livestock. RUB.	22254.31	28214.68
The revenue of profit for meat on bones from the entire livestock. RUB.	12428.18	17870.74
Revenue of profit for meat on bones from one head. RUB.	128.13	182.35
Economic efficiency based on the number of 8000 broilers. RUB.	1 025 040.00	1 458 800.0
Profitability. %	55.8	63.3

The material costs of feed (57.4 rubles), per 1 kg of live weight gain of broilers, in the control group were significantly higher by 9.74 rubles than the sum of the costs of feed and PVMM "Innovation−BAC" as part of drinking water (47.66 rubles). The profit from material revenue for 1 kg of meat per bones from broilers of the experimental group, amounting to 82.34 rubles, i.e. 13.4% higher than in the control. The material profit from the sale of meat on the bones of eight thousand broiler livestock in the control group amounted to 1 million 25 thousand 40 rubles, and in the experimental group – 1 million 458 thousand 800 rubles, i.e., more by 433 thousand 760 rubles, or – by 42.3%.

3 Conclusion

The optimal doses of PVMM "Innovation−BAC" for the introduction of broiler poultry into the watering system were confirmed: 5.0 ml/10 l − up to 21 days and 10.0 ml/10 l − from 22 to 37 days of cultivation. The economic significance of using PVMM "Innovation−BAC" as part of the drinking water of the "COBB 500" cross broiler diet was realized in production tests, where the cost of poultry meat was reduced by 42.3%, which can free up resources for other production purposes on poultry farms and large complexes supplying environmentally friendly meat raw materials for food.

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