ментативна системи травлення яких ще недостатньо розвинута. Біосинтез і активність травних ферментів в організмі тварин зазнають значних змін за віком, , ритмом росту, складом раціону, через що по-різному використовуються поживні речовини. Введення до комбікормів ферментних препаратів забезпечує стабільні умови травлення та кращу трансформацію корму у продукцію тваринництва. Сьогодні спостерігається стрімке зростання вартості мінеральних добавок. Для вирішення проблеми оптимізації енергетичних і мінеральних компонентів, підвищення доступності фосфору та інших мінеральних елементів, які присутні в комбікормах, використовувати фермент фітазу. У зернових кормах значна частина фосфору хімічно зв'язана фітатами. Основа фітатів – інозитол, одна молекула якого ефірним зв'язком приєднує шість молекул фосфорної кислоти. Розщеплювати фітати здатна лише фітаза – фермент рослинного або мікробного походження, при додаванні якого в раціон сільськогосподарських тварин, в тому числі курей-несучок, покращується засвоюваність фосфору та вирівнюється кальцієво-фосфорне співвідношення. Проаналізовано сучасний стан зернопереробної галузі та обґрунтувано доцільність використання побічних продуктів переробки зерна в годівлі сільськогосподарської птиці. Скринінг показав, що фітаза підвищує біодоступність поживних речовин, які містяться в кормах рослинного походження, а також дозволяє суттєво зменшити рівень введення неорганічних фосфатів. Застосування у годівлі ферментів різного спектру дії – дієвий механізм регулювання мінеральної поживності раціону завдяки підвищенню доступності протеїну та енергії, також дає змогу замінити дорогі компоненти кормів на дешевші та зменшити собівартість тваринницької продукції.

Ключові слова: ферментні препарати, біодоступність, поживні речовини, рослинна сировина, побічні продукти переробки зерна, фосфор, фітиновий фосфор, фітаза, дослідження, сільськогосподарські тварини.

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A SYSTEMATIC APPROACH TO OPTIMIZING POULTRY FEED FORMULATIONS USING AMARANTH: TECHNOLOGICAL AND QUALITY ASPECTS

Abstract

The article presents the results of a systematic approach to optimizing poultry feed formulations using amaranth—a high-protein, nutritious, and promising crop. In the face of challenges brought about by military actions affecting Ukraine's agricultural sector, the efficient use of resources and reduction of livestock production costs have become particularly relevant. One possible way to improve the feed base is to incorporate alternative protein components into compound feeds, particularly amaranth press cake, which possesses antimicrobial properties and high digestibility. The aim of the study was to develop balanced starter compound feeds for different types of poultry (broilers, ducks, and laying hens) using amaranth press cake. To achieve this goal, the physicochemical properties of the main ingredients (amaranth, soybean, sunflower, and amaranth press cakes) were determined, optimized feed formulations were developed using specialized software, and laboratory samples of the compound feeds were produced. Their physical properties (moisture content, bulk density, flowability, angle of repose) and chemical composition (protein, fat, fiber, macroelements, and amino acid content) were assessed. The results indicate that amaranth press cake has suitable physicochemical properties for use in compound feed production and contains a significant amount of lysine, arginine, threonine, and other essential amino acids. Compared to soybean and sunflower press cakes, amaranth has a lower protein content but offers advantages in terms of cost, availability, and environmental sustainability of cultivation. The developed formulations comply with feeding standards for the respective poultry groups, ensure balanced nutrition, and can serve as an effective alternative to traditional protein sources. Thus, the use of amaranth press cake as a component of poultry feed not only enhances the economic efficiency of production but

also contributes to the greening of livestock farming and the improvement of product quality under conditions of reduced or complete elimination of antibiotics in feeding.

Key words: amaranth, amaranth meal, optimization, feed formulations, poultry, chemical composition, physical properties.

Introduction

The compound feed industry is one of the key components of Ukraine's agro-industrial complex, ensuring the efficiency of livestock and poultry farming, which in turn contribute to the country's food security. In the context of full-scale war and economic crisis, this sector plays an especially important role, as the stable provision of animals with high-quality feed enables the continued production of meat, milk, and eggs—products that are essential for the population.

Since the onset of military actions, the compound feed sector has faced significant challenges: destroyed infrastructure, blocked logistics routes, reduced grain exports, and a shortage of energy resources. Despite these difficulties, domestic feed producers are adapting to the new realities, seeking alternative raw material supplies and optimizing technological processes. One of the key tasks has become increasing production efficiency through innovative developments, alternative protein sources (such as amaranth, soy, and rapeseed), and the digitalization of production processes.

In addition to internal challenges, the compound feed industry remains important for exports and international cooperation. Ukrainian feed products are in demand in many countries, and their production contributes not only to economic stability but also to maintaining Ukraine's position in the global agricultural market.

The main goal of the compound feed industry is to create balanced feed that meets the physiological needs of animals, promotes their growth, increases productivity, and strengthens their health.

One of the most important aspects in developing effective feed mixtures is the optimization of compound feed formulations. The correct balance of proteins, fats, carbohydrates, macro- and microelements, vitamins, and biologically active substances directly affects feed digestibility, animal growth and reproductive function, as well as the economic efficiency of production.

In modern livestock farming, the optimization of compound feed formulations is carried out using advanced technologies and mathematical models. The use of software for calculating feed rations allows producers to minimize feed production costs while ensuring high animal productivity. In addition, balanced nutrition contributes to improved environmental safety, as it reduces the excessive release of nitrogen and phosphorus into the environment [1–3].

Thus, research in the field of compound feed optimization and nutritional balance is highly relevant for the development of agricultural production. This article will examine modern approaches to ration formulation, their importance for animal productivity, and the economic and environmental aspects of compound feed optimization.

Literary review

Amaranth (Amaranthus spp.) is a valuable feed crop due to its high protein content (14–18% in the grain and up to 25% in the leaves), essential amino acids (especially lysine), unsaturated fatty acids, calcium, phosphorus, and B-group vitamins. Amaranth protein is highly digestible—up to 90%—which exceeds the digestibility rates of soybean, wheat, and even dairy products.

Amaranth meal and cake contain about 20% protein and have a balanced amino acid profile, making them effective components of compound feeds for various types of livestock [4–7].

Studies show that including amaranth in the diets of broilers and laying hens can improve performance without negatively affecting bird health. In particular, the addition of 5–15% amaranth flour to broiler feeds ensures high survival rates and live weights comparable to those of control groups.

In laying hen diets, extruded amaranth can be included at levels up to 40% without negatively affecting productivity, although pigment supplements are recommended to enhance yolk color [8, 9].

To use amaranth effectively in compound feeds, pre-treatment of the grain (such as extrusion or steaming) is recommended to reduce the content of anti-nutritional factors. The use of enzymatic additives can also improve nutrient digestibility.

Fresh green amaranth biomass can be used in the form of grass meal, pellets, or mixed silage. The optimal amaranth-to-corn ratio in silage is 1:1, which ensures high levels of digestible protein and lysine [8, 10].

Poultry, especially modern high-performance crosses, have specific and elevated nutritional requirements. This is due to their intensive productivity, rapid growth, and sensitivity to housing conditions.

Key nutritional requirements:

1.**Protein and energy balance:**

o Diets must be balanced in terms of energy, protein, and essential amino acids such as lysine, methionine, and threonine.

o High-protein ingredients are used in compound feeds (soybean meal, sunflower cake, amaranth, etc.).

2.**Vitamins and minerals:**

o The diet should provide adequate amounts of vitamins (A, D, E, B group) and trace elements (calcium, phosphorus, magnesium, selenium) to ensure optimal growth and productivity.

o Special attention is given to the calcium-to-phosphorus ratio for proper bone development and eggshell formation.

3.**Energy sources:**

o Corn, wheat, and barley are used as carbohydrate sources.

o Fats are added to meet high energy demands.

4.**Enzymes and probiotics:**

o Enzymes (such as xylanase and phytase) improve feed digestibility.

o Probiotics and prebiotics support a healthy gut microbiota.

5.**Water:**

o Access to clean water is critically important, as

productive poultry consumes a large amount of fluids.

Each type of poultry has specific nutritional needs. Broiler chicks require diets high in protein and energy to support rapid weight gain, along with additives possessing antioxidant properties to reduce stress. Laying hens need elevated levels of calcium and vitamin D to ensure proper eggshell quality. Turkeys and ducks require compound feeds rich in energy, with the mandatory inclusion of fats and feed additives to strengthen the skeletal system.

At the early stages of poultry feeding, antibiotics are used to address several important challenges that arise due to the physiological characteristics of young birds and their living conditions. During the first days of life, the immune system of poultry is not yet fully developed, making chicks highly susceptible to pathogenic microorganisms (bacteria, viruses, fungi). Antibiotics help protect the birds from bacterial infections until their own immune defense matures. The initial feeding phase is accompanied by significant stress due to environmental changes, transportation, and transition to compound feed. Stress lowers the body's resistance, increasing the risk of disease outbreaks. Antibiotics help prevent these risks. In young poultry, the gut is not yet populated by beneficial microflora that could suppress pathogenic organisms. Antibiotics help prevent coccidiosis, salmonellosis, colibacillosis, and other bacterial infections. At the start of feeding, antibiotics are also used to prevent diseases that can spread rapidly in intensive production systems (Newcastle disease, bacterial enteritis). Previously, antibiotics were widely used as growth promoters, helping to increase weight gain and improve feed conversion efficiency.

However, the excessive use of antibiotics in animal husbandry contributes to the emergence of drug-resistant bacteria, as microorganisms gradually adapt and mutate, rendering the medications ineffective (Fig. 1). Antimicrobial resistance is one of the major threats to human and animal health, and the spread of such bacteria increases the risk of infectious disease outbreaks.

Consumption of poultry, pork, beef, turkey, or fish meat containing antibiotic residues can lead to the development of antibiotic resistance. This is also associated with negative consequences such as weakened immunity, metabolic disorders, allergies, swelling, dermatitis, and dysbiosis.

The absence of effective antibiotics will significantly impact the quality of life in modern society. According to research, approximately 700,000 people die each year worldwide from infections caused by resistant bacteria. If effective measures are not taken, this number could rise to 10 million deaths per year by 2051 [11, 12].

Formulation of the problem

Due to the risk of developing resistance and the accumulation of antibiotics in animal products, many countries have reduced or prohibited their use. Since 2006, the EU has enforced a strict ban on the use of antibiotics in livestock for prophylactic purposes. In Ukraine, a similar ban was introduced in 2023, although the level of control is still not fully effective. To replace antibiotics, probiotics and prebiotics, phytobiotics, organic acids, and immunomodulators are used. Additionally, amaranth and amaranth cake, which possess antimicrobial properties, can be applied.

Amaranth is a promising raw material for feed production, as its inclusion helps improve animal and poultry productivity, reduce feed costs, and enhance the quality of the resulting products. Its use is particularly relevant in cases of protein-deficient diets and the prohibition of antibiotics in animal feeding. Modern poultry feeding strategies involve an integrated approach using natural additives and the exclusion of antibiotics as growth promoters, ensuring both high productivity and product safety.

The aim of the study was to develop poultry complete feed formulations using amaranth and determine their physical properties and chemical composition. To achieve this goal, the following research objectives were set:

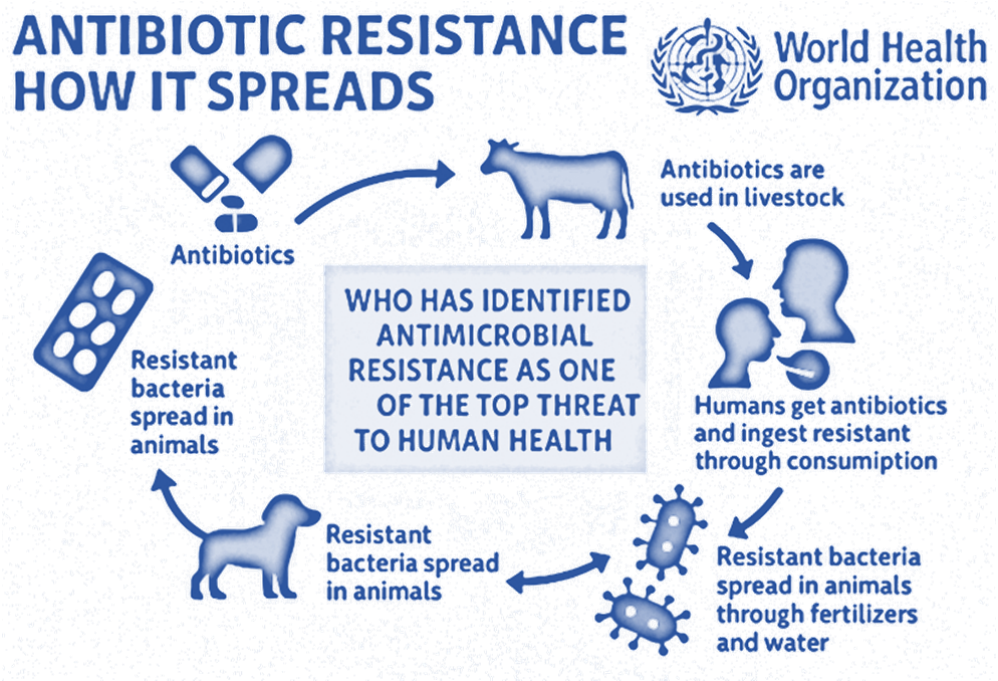

Fig. 1. The spread of antibiotic resistance

– to summarize the characteristics of amaranth grain and its processed products, technological methods of its use in compound feeds, and the nutritional features of poultry diets based on the analysis of literature and patent sources;

– to study the qualitative parameters of amaranth and its by-products;

– to develop complete feed formulations for poultry using amaranth cake;

– to produce experimental samples of poultry compound feeds with amaranth

cake in the laboratory of the Department of Grain and Feed Technology and to determine their physical properties and chemical composition.

Materials and methods

According to the stated objective, the subject of the study was selected as feed raw materials included in complete feed formulations for poultry, as well as the compound feeds themselves.

During the experiments, a set of commonly accepted and standardized methods was used to determine the physicochemical and functional characteristics of amaranth, soybean, and sunflower cakes, amaranth grain, and complete poultry compound feeds.

In assessing the physical properties of the compound feeds, the main parameters influencing the selection of processing conditions and the efficiency of technological processes (physicotechnological properties) were evaluated. These parameters included moisture content, bulk density, flowability, and angle of repose.

Chemical composition indicators included the content of crude protein, crude fat, crude fiber, macroelements, and amino acids. Conclusions regarding the effectiveness of the produced compound feeds were based on these chemical and biochemical characteristics of the study object.

Results of the study and their discussion

Based on the selected research methods, the quality indicators of amaranth, soybean, sunflower cakes, and amaranth grain were determined. Optimized formulations of compound feeds for poultry using amaranth cake were developed, experimental samples were produced, and their quality characteristics were evaluated.

The study focused on comparing the chemical composition of amaranth, soybean, sunflower cakes, and amaranth grain, which is highly relevant and important for researchers, agricultural producers, and the food industry. It supports the advancement of agricultural technologies, promotes environmentally friendly alternatives, and enhances resource efficiency.

Oilseed cake is a valuable by-product obtained after oil extraction and is widely used in both feed and food industries. Among different crops, the content of protein, essential amino acids, fats, and fiber varies significantly.

The nutritional value of the experimental samples was assessed based on the content of moisture, crude protein, crude fat, crude fiber, calcium, phosphorus, sodium, and amino acids.

Table 1 presents the data on the chemical and amino acid composition of amaranth, soybean, and sunflower cakes, as well as amaranth grain.

Analysis of Table 1 shows that soybean cake has the highest nutritional value due to its high protein content and is the most widely used protein source. However, concerns remain about its content of anti-nutritional factors and high cost. Moreover, it is increasingly subject to adulteration. Sunflower cake typically contains more fiber but less protein, which may limit its use in high-protein diets. Both soybean and sunflower production have a considerable environmental impact due to intensive cultivation and processing.

Amaranth cake, although having lower nutrient content, is more cost-effective. It is notable for its high squalene content, which makes it unique compared to other protein sources. Additionally, its use in poultry feed, especially for young birds, may help reduce antibiotic use due to the antibacterial and antiparasitic activity of amaranth cake.

Amaranth, as a crop, is still underutilized on an industrial scale compared to soybeans and sunflower. Analyzing its chemical composition in comparison with more widespread crops may help promote the use of amaranth among farmers and feed producers.

Due to its drought resistance and low soil requirements, amaranth can serve as an environmentally beneficial alternative. Its practical significance in the feed industry enables the development of efficient feed rations for various types of livestock, helping optimize feed production costs by utilizing press cake with the best nutritional characteristics. However, the high cost of amaranth seeds (UAH 30,000 per ton) limits its use in compound feed formulations. It is more reasonable to apply this crop in human nutrition, pharmaceuticals, and cosmetics.

Table 1 – Quality indicators of amaranth, soybean, sunflower press cakes and amaranth

Indicators	Amaranth	Amaranth cake	Soybean cake	Sunflower cake
Moisture content, %	10,00	10,00	6,60	8,00
Crude protein, %	18,50	16,50	44,00	32,00
Crude fat, %	5,50	4,91	6,48	9,00
Crude fiber, %	4,80	4,28	6,47	19,00
Calcium, %	0,17	0,15	0,20	0,43
Phosphorus, %	0,48	0,43	0,60	0,80
Sodium, %	0,03	0,03	0,05	0,09
Lysine, %	0,87	0,78	2,67	1,10
Methionine + cystine, %	0,62	0,55	1,22	1,23
Threonine, %	0,64	0,57	1,70	1,17
Tryptophan, %	0,21	0,19	0,60	0,42
Arginine, %	1,64	1,46	3,23	2,54

In the cost structure of poultry production, compound feed accounts for about 70%, making the reduction of feed costs a key objective under conditions of intense competition. This issue can be addressed through the optimization of feed composition, ensuring nutritional and biologically active balance, and lowering production costs.

On the poultry feed market, domestic producers must compete with foreign suppliers who have earned a reputation for high-quality products. Ukrainian compound feeds often face skepticism regarding their compliance with modern feeding standards. The leading producers of poultry feed include countries such as the Netherlands, Belgium, and the USA. The use of imported products increases the cost of compound feed and, consequently, the final product.

Therefore, the development of high-quality compound feeds for poultry with an emphasis on the use of local raw materials is a relevant task. This will not only reduce feed costs but also improve the competitiveness of domestic producers in both domestic and international markets.

For the development of complete feed formulations for poultry, the following components were selected: wheat, corn, barley, wheat feed flour, barley feed flour, corn gluten meal (CGM), sunflower meal, sun flower press cake, soybean press cake, amaranth press cake, meat and feather meal, feed yeast, table salt, feed chalk, limestone flour, lysine monohydrochloride, DL-methionine, L-threonine, monocalcium phosphate, baking soda, vitamin B4, phytase, antioxidant, sorbent, antibiotic, acidifier, coccidiostat, flavoring agent, 2% and 3% premixes, vitamin blend, and trace element blend.

Using an optimization software package, we developed formulations for complete compound feeds:

1. For Loman White cross laying hens (starter), aged 1–8 weeks, with the inclusion of amaranth press cake;
2. For Loman White cross laying hens (starter), aged 1–8 weeks, without amaranth press cake;
3. For Cobb 500 broiler chicks (starter), aged 1–10 days, with the inclusion of amaranth press cake;
4. For Cobb 500 broiler chicks (starter), aged 1–10 days, without amaranth press cake;
5. For Pekin breeding ducks (starter), aged 1–3 weeks, with the inclusion of amaranth press cake;
6. For Pekin breeding ducks (starter), aged 1–3 weeks, without amaranth press cake.

The feed composition calculation program operates on the principle of cost minimization, taking into account predefined restrictions for each ingredient, as well as the nutritional characteristics of the final product. This approach is implemented using linear programming methods, which allow for the calculation of optimal formulas based on the given parameters.

As a result of the optimization modeling conducted using specialized software, the most effective starter feed formulas were developed for broiler chicks, laying hens, and breeding ducks. The resulting formulas are characterized by minimal cost, full compliance with poultry feeding standards, adherence to ingredient inclusion limits, and provision of balanced nutrition. These formulas are effective for use in feeding the respective categories of poultry (Table 2).

Analysis of the calculated compound feed formulations for poultry shows that the inclusion of amaranth cake in the composition reduces the cost of the final product due to the decreased amount of soybean cake in the formula and allows for the avoidance of antibiotics thanks to the antibacterial properties of amaranth. The inclusion of 5% amaranth cake in the starter compound feed for broiler chicks results in a cost saving of approximately UAH 250/ton without reducing nutritional value. In starter feeds for laying hens, the saving reaches approximately UAH 200/ton, and for ducks – about UAH 160/ton.

For the study, experimental samples of complete compound feeds were produced for broiler chicks, laying hens, and breeding Peking ducks during the starter period. The feed samples were created based on the developed formulations presented in Table 2, with and without the inclusion of amaranth cake.

The physical properties and chemical composition of the produced samples were analyzed to assess their quality and compliance with established feeding standards. The results of these studies made it possible to compare the effect of amaranth cake on the nutritional characteristics and efficiency of compound feeds.

Study of physical properties. The experimental compound feed samples were analyzed using the following indicators: moisture content, angle of repose, flowability, and bulk density. The research results are presented in Table 3.

As can be seen from the obtained data, the experimental samples of starter compound feeds are characterized by satisfactory physical properties and comply with regulatory and technical documentation requirements.

Chemical composition study. The nutritional value of the starter compound feeds in the experimental samples was assessed using the following key indicators: content of crude protein, linoleic acid, crude fiber, calcium and phosphorus content, as well as lysine, methionine with cystine, threonine, and tryptophan. Table 4 presents the results of the study on the chemical composition and amino acid profile of the compound feeds developed for broiler chickens, laying hens, and breeding ducks during the starter feeding phase.

According to the obtained data, the developed starter compound feeds for different types of poultry are balanced in terms of nutritional and biologically active substances. They fully meet the physiological needs and feeding standards. The addition of amaranth meal to the composition of the compound feeds does not reduce their nutritional value; on the contrary, it helps to lower the overall cost, providing economic benefits without compromising feed quality.

Table 2 – Composition and nutritional value of the calculated poultry feed formulations

Components and quality indicators	Starter feed for broiler chicks (1–10 days)		Starter feed for laying hens (1-8 weeks)		Starter feed for breeding ducks (1-3 weeks)	
Wheat	30,0	44,4	13,7	7,0	12,3	19,1
Barley	-	-	-	-	5,0	5,0
Corn	20,4	5,0	37,9	37,9	8,0	1,5
Wheat feed flour	10,0	10,0	10,0	10,0	10,0	10,0
Barley feed flour	-	-	6,6	10,0	-	9,6
By-products of groats production	-	-	-	-	20,0	20,0
Soybean cake	23,3	20,3	17,7	13,1	10,5	5,7
Sunflower cake, CP 32%	-	-	7,0	-	7,0	7,0
Sunflower meal, CP 46%	5,2	5,1	-	7,0	7,0	7,0
Amaranth cake	-	**5,0**	-	**5,0**	-	**5,0**
Meat and feather meal	3,0	3,0	3,0	3,0	3,0	3,0
Feed yeast, CP 38%	3,0	3,0	-	3,0	3,0	3,0
Table salt	0,09	0,12	0,09	0,15	0,30	0,30
Feed chalk	1,65	-	-	-	1,10	1,89
Limestone flour	-	0,74	1,20	1,23	1,034	0,20
Monocalcium phosphate	-	-	0,40	0,30	0,87	0,755
Baking soda	0,10	0,10	-	-	0,10	0,10
Lysine monohydrochloride 98%	-	-	0,09	0,08	0,275	0,34
DL-Methionine 98.5%	-	-	-	-	0,166	0,16
L-Threonine 98%	-	-	0,05	-	-	-
VILZIM PHY 10T 0.005%	-	-	-	-	0,005	0,005
Vitamin B4 60%	0,04	0,04	0,04	0,04	0,04	0,04
Loxidan	0,01	0,01	0,01	0,01	0,01	0,01
Medicilat	0,02	0,02	0,03	0,03	-	-
Insorb	0,05	0,05	0,05	0,05	0,05	0,05
Feed Mold	0,1	0,1	0,1	0,1	0,1	0,1
Raycox	0,04	0,04	0,04	0,04	0,04	0,04
Cuxarom (fruit flavor)	-	-	-	-	0,01	0,01
Premix for laying hens, 2%	-	-	2,0	2,0	-	-
Premix for broiler chicks, 3%	3,0	3,0	-	-	-	-
Alfamix Broiler	-	-	-	-	0,02	0,02
Microelement blend for poultry	-	-	-	-	0,08	0,08
Total	100	100	100	100	100	100
Compound feed cost, UAH/ton	**17188**	**16936**	**15330**	**15126**	**13396**	**13230**
Metabolizable energy, kcal/100 g	306	301	275	275	311	306
Mass fraction, %:						
crude protein	21,24	21,01	18,02	18,04	18,08	18,02
c18:2 ω6	1,55	1,34	1,86	1,43	2,05	1,69
crude fiber	4,00	4,00	4,24	4,10	5,30	5,56
lysine	1,26	1,23	1,00	1,00	1,00	1,00
methionine	0,55	0,55	0,50	0,50	0,46	0,45
methionine + cystine	0,92	0,92	0,83	0,83	0,80	0,78
threonine	0,88	0,86	0,70	0,70	0,68	0,66
tryptophan	0,26	0,26	0,21	0,21	0,21	0,22
arginine	1,36	1,36	1,20	1,20	0,88	1,00
calcium	1,18	0,91	1,00	1,00	1,26	1,20
phosphorus	0,70	0,71	0,60	0,62	0,76	0,80
phosphorus available	0,50	0,50	0,45	0,45	0,51	0,50
sodium	0,20	0,20	0,17	0,19	0,21	0,21

Table 3 – Physical properties of compound feeds

Indicators	Starter feed for broiler chicks (1–10 days)		Starter feed for laying hens (1-8 weeks)		Starter feed for breeding ducks (1-3 weeks)	
	without amaranth cake	with amaranth cake	without amaranth cake	with amaranth cake	without amaranth cake	with amaranth cake
Moisture content, %	11,8	12,4	12,1	12,5	12,6	13,0
Angle of repose, degree	39	41	40	41	41,5	42
Flowability, cm/s	7,4	7,0	7,3	6,8	6,9	6,3
Bulk density, kg/m^3	600	635	610	625	630	660

Table 4 – Chemical and amino acid composition of compound feeds for poultry (based on dry matter)

Indicators	Starter feed for broiler chicks (1–10 days)		Starter feed for laying hens (1-8 weeks)		Starter feed for breeding ducks (1-3 weeks)	
	without amaranth cake	with amaranth cake	without amaranth cake	with amaranth cake	without amaranth cake	with amaranth cake
Mass fraction, %: dry matter	88,4	87,6	87,9	87,5	87,4	87,2
crude protein	24,21	23,98	20,5	20,62	20,69	20,67
c18:2 ω6	1,75	1,53	2,12	1,63	2,35	1,94
crude fiber	4,52	4,57	4,82	4,68	5,72	6,38
calcium	1,33	1,04	1,14	1,14	1,44	1,38
phosphorus	0,79	0,81	0,68	0,71	0,87	0,92
lysine	1,43	1,40	1,14	1,14	1,14	1,15
methionine + cystine	1,04	1,05	0,94	0,95	0,92	0,89
threonine	1,00	0,98	0,80	0,80	0,78	0,76
tryptophan	0,29	0,30	0,24	0,24	0,24	0,25

Conclusions

Thus, the development of the compound feed industry during wartime is not only a matter for the agricultural sector but also a strategic component of national security. The conducted research confirmed the feasibility of using amaranth press cake in poultry feed formulations as an alternative protein source, allowing for partial or complete replacement of more expensive ingredients, particularly soybean and sunflower meal. The inclusion of amaranth has a positive effect on feed quality due to its high content of protein, lysine, arginine, and other valuable amino acids, which are critically important for fast-growing poultry species. The developed rations for broilers, laying hens, and ducks are well-balanced, meet the nutritional requirements at early stages of development, and demonstrate optimal technological characteristics — including indicators of moisture content, flowability, bulk density, and angle of repose.

The use of software for optimizing feed composition based on the principles of linear programming enabled the minimization of the final feed cost without compromising its nutritional value. The obtained results have practical value for feed producers, farms, and poultry enterprises, as they contribute to reducing production costs while improving product quality and safety.

In the context of restrictions or bans on the use of antibiotics in livestock farming, amaranth serves as a promising component with antimicrobial properties. Further research should focus on improving the processing technology of amaranth to reduce the content of antinutritional substances and enhance its digestibility, as well as on studying the effects of amaranth-based feeds on growth performance, immunity, and product quality of poultry under production conditions.

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СИСТЕМНИЙ ПІДХІД ДО ОПТИМІЗАЦІЇ РЕЦЕПТІВ КОМБІКОРМІВ ДЛЯ СІЛЬСЬКОГОСПОДАРСЬКОЇ ПТИЦІ З ВИКОРИСТАННЯМ АМАРАНТУ: ТЕХНОЛОГІЧНІ ТА ЯКІСНІ АСПЕКТИ

Анотація

У статті представлено результати системного підходу до оптимізації рецептів комбікормів для птиці із застосуванням амаранту — високобілкової, поживної та перспективної культури. В умовах викликів, що постали перед аграрним сектором України внаслідок військових дій, питання ефективного використання ресурсів та зменшення собівартості тваринницької продукції набуває особливої актуальності. Одним із можливих шляхів удосконалення кормової бази є включення до складу комбікормів альтернативних білкових компонентів, зокрема амарантової макухи, що володіє антимікробними властивостями та високою засвоюваністю. Метою дослідження було створення збалансованих стартових комбікормів для різних видів птиці (бройлери, качки, кури-несучки) з використанням амарантової макухи. Для досягнення мети були визначені фізико-хімічні властивості основних інгредієнтів (амарант, соєва, соняшникова та амарантова макухи), розроблені оптимізовані рецептури комбікормів за допомогою спеціалізованого програмного забезпечення та виготовлені лабораторні зразки комбікормів. Визначено їх фізичні властивості (вологість, об'ємна маса, сипкість, кут природного укосу) та хімічний склад (вміст білка, жиру, клітковини, макроелементів та амінокислот). Результати свідчать про те, що амарантова макуха має прийнятні фізико-хімічні властивості для використання у виробництві комбікормів, містить значну кількість лізину, аргініну, треоніну та інших важливих амінокислот. У порівнянні з соєвою і соняшниковою макухами, амарант демонструє нижчий вміст білка, але має переваги у вартості, доступності та екологічній стійкості вирощування. Розроблені рецептури відповідають нормативам годівлі для відповідних груп птиці, забезпечують збалансовану годівлю та можуть слугувати ефективною альтернативою традиційним білковим джерелам. Таким чином, використання амарантової макухи, як складової комбікормів для птиці, дозволяє не лише підвищити економічну ефективність виробництва, а й сприяє екологізації тваринництва та покращенню якості готової продукції за умов зниження рівня використання або повної відмови від антибіотиків у годівлі.

Ключові слова: амарант, амарантовий шрот, оптимізація, рецепти комбікормів, сільськогосподарська птиця, хімічний склад, фізичні властивості.

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