Наведено результати досліджень щодо обґрунтування доцільності збагачення зернової сировини у складі комбікормів некондиційною яєчною масою. Розроблено технологічний спосіб використання некондиційних яєць в годівлі сільськогосподарської птиці шляхом виробництва екструдованої кормової добавки. Вивчено вплив процесу екструдування на показники якості та поживної цінності екструдованої кормової добавки, удосконалена принципова технологічна схема її виробництва

Ключові слова: екструдована кормова добавка, технологія збагачення зернової сировини, некондиційні курячі яйця

Приведены результаты исследований по обоснованию целесообразности обогащения зернового сырья в составе комбикормов некондиционной яичной массой. Разработан технологический способ использования некондиционных яиц в кормлении сельскохозяйственной птицы путем производства экструдированной кормовой добавки. Изучено влияние процесса экструдирования на показатели качества и питательной ценности экструдированной кормовой добавки, усовершенствована принципиальная технологическая схема ее производства

Ключевые слова: экструдированная кормовая добавка, технология обогащения зернового сырья, некондиционные куриные яйца

UDC 636.5:[636.087:637.4]

DOI: 10.15587/1729-4061.2016.76106

DEVELOPMENT OF TECHNOLOGY OF USING SUBSTANDARD EGGS IN FARM POULTRY FEEDING

B. Iegorov
Doctor of Technical Sciences, Professor,
Member-Correspondent of NAAS of Ukraine,
Honored Worker of Science and Technique of Ukraine,
Rector, Head of Department*
E-mail: bogdan_egoroff@list.ru

N. Vorona
PhD, Assistant*
E-mail: tarnin@te.net.ua

A. Makarynska
PhD, Associate Professor*
E-mail: alla.makarinskaya@yandex.ru

O. Voietska
PhD, Associate Professor*
E-mail: vecombi@yandex.ua

T. Bordun
PhD, Associate Professor*
E-mail: borduntv@yandex.ua

*Department of Technology of Nixed Feed and Biofuel
Odessa National Academy of Food Technologies
Kanatnaya str., 112, Odessa, Ukraine, 65039

1. Introduction

In all developed countries, the feed mill industry is the most important branch of the economy, as livestock rearing cannot develop intensively without the use of the feed. Along with the increase in the volume of production of feed products, their quality is constantly improving and the assortment is expanding. The modern stage of the development of the feed mill industry is characterized by intensification of technological processes, aimed primarily at improving the quality of the final product, creating a highly productive and highly effective machines and technologies, providing scientific-technical progress in the field of [1–3]. The experience of development of the world agriculture in the sector of poultry breeding suggests that this industry is efficient and sustainable. It is also known that poultry breeding is a waste-free industry, the products of which are used not only in the food industry, but also in medicine (embryos of poultry eggs are used in the production of children's vaccines), consumer industry (feather garments, pillows, mattresses, shoes, wrist watch straps), agronomy (composts from bird droppings are used to support the content of humus in soil), livestock breeding (production of fodder additives from dried worms – wormiculture) [4]. The peculiarities of digestion and a high genetic potential of productivity of farm poultry imply the need for using high-quality readily assimilable combined fodder with a high content of protein to feed it.

At the same time, the nutritious value of raw materials for feed production, primarily of grain components, has significantly deteriorated. Thus, because of the decrease in soil fertility, the intense and sometimes the suboptimal crop rotation, violations of agrotechnology and insufficient organic and mineral fertilization, the contents of crude protein in the grain of wheat and corn decreased by 1...2 absolute per cent, which complicates balancing the feed [1, 5–7]. This problem can be solved by enriching grain raw materials with animal proteins, which are easily assimilated; however, their use leads to an increase in the cost of feed. In addition, the resolution of the EU N 2002/32 and No. 1831/2003 prohibited the use of by-products of processing of animal raw material, fish, shellfish and marine animals in the composition of feed [8, 9].

At present, scientists and practitioners around the world are looking for the possibility of applying the new feed means, which will lead to reduction in the cost of feed and livestock production.

2. Literature review and problem statement

Grain cereals fodders, whole and ground, are the basis of the poultry feeding birds as a source of energy and the group B vitamins. In the ration of poultry, cereals account for 60...75 % depending on the form and the age [10, 11]. Corn, wheat, millet, sorghum, oats, barley, rye and triticale are used in poultry feeding. However, the effective use of grains of such crops as rye and triticale by poultry is limited due to the presence of anti-nutritious substances and special features of their chemical composition [12, 13].

Corn is the most valuable feed for young poultry, especially broilers. It has good technological properties, is ground to the grainy structure and makes the feed look attractive. Organic substances of corn are digested by 86...93 %. Corn contains 69...75 % of carbohydrates, 4...4,2 % of fat and has metabolic energy of 1.382 mJ, i. e., higher than other kinds of grains (except soy, canola and flax), however it has less protein (8...10 %). In addition, the protein of corn has a small amount of such essential amino acids as lysine (0,27...0,29 %), methionine+cystine (0,28 %) and tryptophan (0,06 %). In this regard, the introduction of corn to the composition of the feed requires an additional amount of synthetic preparations of amino acids. The corn grain contains only 2,2 % of cellulose, which makes it possible to feed it even to young poultry from the first days of life [14, 15].

Yellow sorts of corn contain zeaxanthin and cryptoxanthin that promote the pigmentation of eggs yolks and subcutaneous fat of broilers. With adding 20 % of grain of yellow corn to the feed for laying hens, the eggs with bright colored yolks and with an increased content of vitamin A are obtained in 5 days' time [10]. It should be noted that after 6 months of the storage of corn, the level of non-starch polysaccharides in its composition increases dramatically, the content of the metabolic energy decreases and so does digestibility [16].

The special attention of the world's researchers is paid to exploring the potential of the fodder base, as well as finding new fodders and additives that provide a valuable nutrition of poultry. For the last 5 years, the non-traditional feed has become more widely used in order to reduce the cost of production and to use the traditional feed more rationally. Among the various directions of the elimination of deficit of protein feed, it is promising to use non-traditional feeds, including the wastes of poultry farming (substandard meat, feather, egg shells). Eggs and poultry are the main products of poultry breeding. In 2011, the industrial production of eggs in the world accounted for 1,1 trillion pcs., and every year this figure is growing. The world's ten largest countries make up 65 % of the production. The giants of the egg production are 2 countries – the United States and China, the role of other countries in the global production of eggs is relatively small. However, from 2010, Ukraine is among the leaders in the eggs production, the volume of which approaches 1 million tons per year [17]. However, due to deterioration of the conditions of the technological production process, up to 10 % of the obtained eggs are considered substandard [18].

In the process of storing, especially under inappropriate conditions, during the transportation and for a variety of other reasons (for example, incorrect handling), some defects appear in eggs. The eggs that have drawbacks are referred to substandard food, or to technical waste depending on the type of defect and an extent of its development [19–21]. As a result, the above-mentioned products are often disposed of by poultry farms, which is economically impractical. The plans based on the concept of the development of poultry farming [18, 22] include the extension of the assortment of poultry products by deep processing and the full use of manufactured products with the minimization of wastes and substandard products, especially by the method of utilization.

The introduction of technology of eggs processing allows poultry farms to increase economic efficiency due to the following factors:

– reduction of economic losses from seasonal fluctuations in demand;

– possibility of using substandard eggs (nonmarket egg, eggs with a slash, etc.);

– increase in the storage life of products;

– geographical expansion of the market of a company's products.

The efficient deep processing of eggs at poultry farms requires modernization of production, introduction of modern technologies and high-yielding crosses [23]. The essence of producing melange is the pasteurization of the egg mass, and the essence of producing egg powder is drying the egg mass. However, these technologies are very energy consuming and require the use of expensive equipment, which prevents using these technologies everywhere. Poultry farms that do not have their own melange production line face the problem of selling substandard eggs daily, and therefore suffer losses and lose valuable protein raw materials (Table 1) [21, 24, 25].

Table 1

Chemical composition of egg mass without shell of substandard eggs

Indicators	Content
Mass fraction: moisture, %	74,00
crude protein, %	12,70
crude fat, %	11,50
AES, %	0,70
vitamin A, mkg %	250,00
valine, %	0,86
isoleucine, %	0,67
leucine, %	1,13
lysine, %	0,91
metionine + cystine, %	0,65
threonine, %	0,56
tryptophan,%	0,17
phenylalanine,%	0,68

While enriching the grains with animal proteins, they are used in dry or liquid state.

The method of enriching the grain with animal proteins in liquid state causes certain technological difficulties. Due to the difference in physical properties of the grain and the liquid component, and the need for their even distribution in a mixture, the mixing process is getting more complicated. In addition, the liquid components, pathogenic microflora develops much faster, and the storage and transportation of such components require special packaging and stable environmental conditions. In this regard, the most wide spread way of enriching grain is the introduction of the by-products of processing agricultural products of animal origin in a dry condition (fish flour, meat, meat-bone, feather, blood) to the grain raw material [26].

Despite the possibility of introduction and even distribution of dry feed flour of different types, this method has certain technological difficulties, such as:

– because of high concentration of protein and other nutrients, the sanitary quality of feed flour significantly worsens with storing;

– with high content of crude fat, the friability of feed flour worsens. In addition, with its storage, the fodder fats are oxidized rapidly, especially at the increased ambient temperature;

– while drying the by-products of processing agricultural production of animal origin, there may be a possible decrease in bioavailability of crude protein and other nutrients and biologically active substances, and even the destruction of thermolabial vitamins, amino acids, etc. In addition, exacerbating the energy crisis led to a significant rise in energy prices, which makes the process of drying the feed with high mass fraction of moisture unprofitable.

In this regard, there is a need to use energy-saving technological ways of enriching grain raw material as the main component of the feed, with animal proteins.

3. The aim and the tasks of the study

The conducted studies set the aim to increase the feed value of the grain raw materials due to its processing in an extruder in the mixture with substandard chicken eggs.

To achieve the set goal, it was necessary to solve the following tasks:

– to choose the sources of raw materials for the production of extruded feed additive (EFA) for farm poultry;

– to develop a technological way of producing the EFA and to substantiate the rational parameters;

– to define the parameters of quality and nutritional value of the feed additive before and after the extrusion;

– to improve the fundamental technological scheme of the EFA production;

– to define biological efficiency of the EFA for farm poultry, manufactured by the improved technology.

4. Materials and methods of studying the modes of production and the quality indicators of the extruded feed additives

The experimental research was carried out according to the standard methods using the set of laboratory and technological equipment [27].

For the analysis, the average samples of raw materials and of the finished products were selected according to ISO 6497:2002 "Feed for animals. Sample selection".

In the process of conducting the experiments, a range of common and standard methods was used for determining physical-chemical and functional indicators of feed raw materials (corn, egg masses without shell, extruded corn) and the EFA, as well as microbiological indicators of the EFA, which together ensured the fulfillment of the assigned tasks and are given in Table 2.

Table 2

Indicators and methods of research used when conducting experiments

Indicators	Principle, essence and specificity of the method	ISO	Literature source
Technological parameters			
Mass fraction of moisture, %	Drying a weighed portion to the constant mass at (130±2) °C	ISO 6496:1999	[28]
Volume mass, kg/m^3	Using one-liter purka	–	[29]
Module of size, mm	Sifting a weighed portion of the product through a set of sieves with holes of different diameters	–	[29]
Friability, cm/s	The ratio of the measured volume of material that passed through the hole of a certain diameter to the time of flowing	–	[29]
The angle of natural slope, degrees	With the equipment of R. L. Zenkov by free-flowing from a funnel	–	[29]
Index of expansion	The ratio of the diameter of the extrudate to the diameter of the matrix hole	–	[29]
Heterogeneity coefficient	Colorimetric method	–	[29]
Chemical and biochemical indicators			
Crude protein, %	By the Kjeldahl method	ISO 5983-1:2005	[30]
Crude fat, %	The method based on fat extraction by petroleum ether	ISO 6492:1999	[30]
Crude fiber, %	Processing a weighed portion of the tested product with a mixture of concentrated nitric and acetic acids	ISO 6865:2000	[30]
Crude ash, %	Burning a weighed portion with further frying of mineral remnant at 500...600 °C	ISO 5984:2002	[28, 30]
Water soluble carbohydrates, %	The method is based on the ability of reducing sugars to reduce the alkaline solution of copper oxide to protoxide	–	[30]
Starch, %	Polarmetric method	ISO 6493:2000	[28]
Phosphorus, %	Spectrometric method	ISO 6491:1998	[30]
Calcium, %	Titrometric method	ISO 6490-1:1985	[30]
Folic acid, mg	Colorimetric method	–	[28]
Vitamin B_1, mg	Fluorescent method	–	[28]
Vitamin B_2, mg	Fluorescent method	–	[28]
Tocopherine, mg	Colorimetric method	–	[28]
Digestibility of protein (in vitro)	Splitting a weighed portion of product with the mass of 1g in the thermostat by enzymes at the temperature of 37 °C with subsequent drying to constant weight	–	[30]

The study of the microflora of the finished products is an important stage of its production, since the development of microorganisms can cause not only the deterioration of the product quality, but also do harm to the health of animals. The development of microflora in feed production runs much more intensively than in grain, due to the presence of the significant amount of nutrients and biologically active substances, which create a favorable environment for the life of fungi and bacteria.

Changes in the quantitative and qualitative composition of microflora during the storage of the EFA were estimated by the following microbiological indicators:

– the total number of mesofilic aerobic bacteria and optional-anaerobic microorganisms, CFU in 1 g of the product;

– the presence of moulds, CFU in 1 g of the product;

– the presence of pathogenic microorganisms of Salmonella genus, in 25 g of product;

– the presence and the titre of the bacteria of the group of Escherichia coli (coli form) in 0,1 g of the product.

The determination was carried out by the method of planting on a dense environment: general semination (beef-extract agar), the bacteria of paratyphoid group (salmonella) and entero-pathogenic strains of Escherichia coli on the Endo environment [7, 31].

The resulting food additive for farm poultry with 10,7 % mass fraction of moisture was stored in plastic bags for 3 months under uncontrolled conditions (at room temperature and uncontrolled humidity). In the process of storing, the studies were conducted on a monthly basis.

The overall nutritional value of the EFA for farm poultry and the efficiency of its use were determined by using a biological assessment that is characterized by the final result of feeding, i. e. valuable productive action – the constant body mass (an gain in the body mass), appearance and satisfactory state of health. The biological experiment was conducted on laboratory animals. To conduct the experiment, on the basis of the vivarium of the laboratory of Biochemistry of the Institute of Dentistry of AMS of Ukraine, there were formed three tested groups of white laboratory rats Wister, males, aged 45 days, with 7 animals per each group.

5. Results of the study of the method of enriching grain raw materials with proteins of animal origin

To substantiate the composition of the feed additive, the chemical composition of the tested corn was determined (Table 3). The analysis of the results indicates that the sample is different by its nutritional value from the literature sources [25]. Thus, the decrease in the mass fractions of crude protein, anitrogenous extractive substances (AES) and amino acids was observed.

For enrichment of the chemical composition of corn grain, it was proposed to produce the feed additive by mixing and extruding the crushed corn grain and the egg mass of substandard eggs without shell with minimum electricity consumption for the extruding process.

To support the choice of grain crops in the composition of the feed additives for research, five crops were selected: shelled barley, oats, corn and wheat. Before extruding, the tested samples were ground to the size of 3 mm particles and moistened to the mass fraction of moisture of 16 %, which provided satisfactory conditions for the extrusion process and the volumetric expansion of products. During the extrusion process of grain crops, the electricity consumption was fixed (Fig. 1).

As it can be seen in Fig. 1, the electricity consumption maintaining the technological process of extruding corn grain is by 10.2 % less than for extruding wheat, by 14.3 % less compared with the shelled oats and by 24.4 % less compared with shelled barley.

Table 3

Chemical composition of corn grain

Indicators of chemical composition	Corn grain	
	literature data [25]	experimental data (n=3, P ≥ 0,95)
Mass fraction,%: moisture	14,00	11,00
crude protein	10,30	8,37
crude fat	4,90	4,10
AES	67,50	70,50
starch	62,90	65,70
valine	0,42	0,38
isoleucine	0,31	0,28
leucine	1,28	0,91
phenylalanine	0,46	0,37
alanine	0,79	0,63
glutamine acid	1,78	1,51

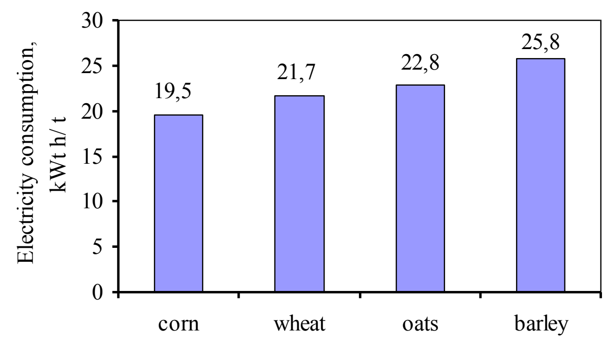

Fig. 1. Electricity consumption for the process of extruding grain crops

The results of the research on determining the effectiveness of mixing ground corn and the egg mass without shell in various ratios are shown in Fig. 2.

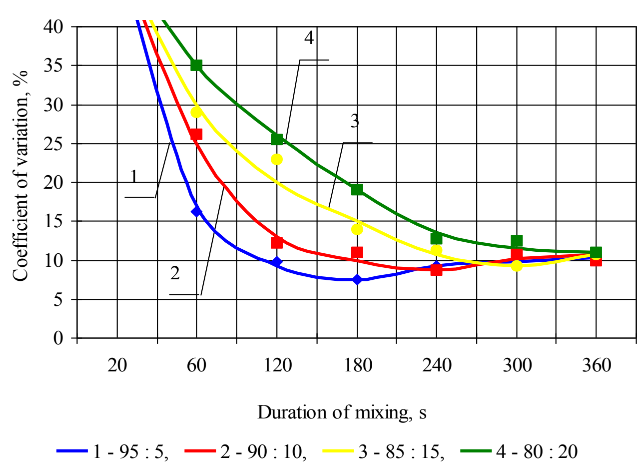

Fig. 2. Dependency of coefficient of variation on the duration of mixing with different ratios of components of mixture (cground corn grain: egg mass without shell)

The analysis of the results of the study indicates that the minimum coefficient of variation 7,5 % is observed in sample No. 1 at 180 s of mixing, in sample No. 2 it is 8.7 % at 240 s of mixing, in sample No. 3 it is 9.2 % at 300 s and in sample No. 4 it is 11 % at 360 s.

For the substantiation of the optimum ratio of ground corn grain and the egg mass without shell in the preceding mix, the studies have been conducted, the results of which are presented in Fig. 3.

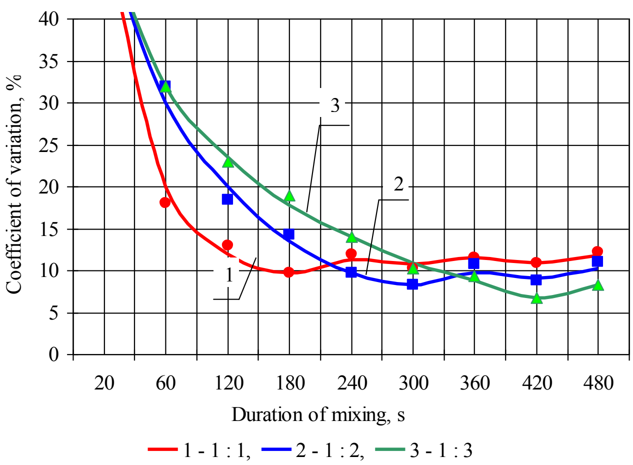

Fig. 3. Dependency of coefficient of variation on duration of mixing in frame mixers at different ratios of components of preceding mixture (crushed corn grain: egg mass without shell)

The analysis of the results of research (Fig. 3) showed that with increasing the mass fraction of egg masses without shell in the preceding mixture, the time of mixing increases considerably, which leads to an increase in electricity consumption. The coefficient of variation with the increase in the concentrations of egg mass without shell in the previous mixture decreases from 9,7 % to 6,7 %, however, in this case, the physical properties worsen which could complicate further production and the problem of even distribution of liquid raw material in a mixture appears once again.

Similar to the one-stage mixing, the studies of the effectiveness of the two-stage process of mixing have been conducted (Fig. 4).

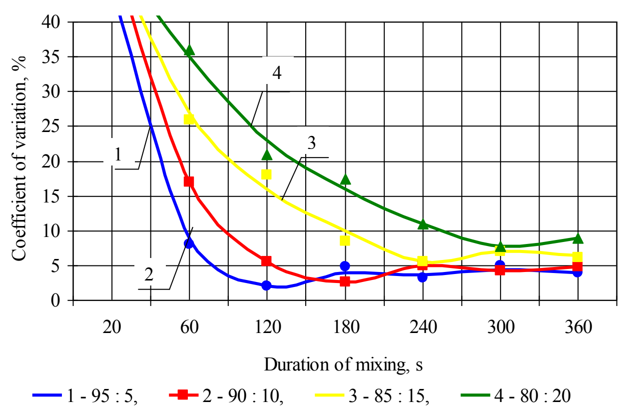

Fig. 4. Dependency of coefficient of variation on duration of mixing at different ratios of components of mixtures (ground corn grain: egg mass without shell) at two-stage mixing

As can be seen in Fig. 4, while using two-stage mixing, its duration significantly shortens, and the coefficient of variation decreases. In samples No. 3 and No. 4 it was above the permissible 3 % norm, due to the low efficiency of distribution of a large quantity (15...20 %) of egg mass without shell in the ground corn. In samples No. 1 and No. 2, the coefficient of variation was within the norm.

To determine the optimum ratio of the components in the composition of the feed additive, five samples were produced of the feed additive containing ground corn and 10 %, 12,5 %, 15 %, 17,5 % and 20 % of egg mass without shell, respectively. The efficiency of the extrusion process was determined by the extension index, electricity consumption and technological properties of feed additives (Fig. 5, 6).

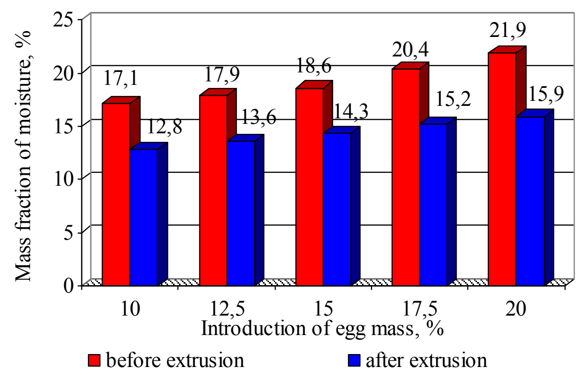

Fig. 5. Changes of content of mass fraction of moisture during processing depending on the amount of egg mass in the mixture

As can be seen in Fig. 5, with the increase in mass fraction of the egg mass without shell in the mixture, the mass fraction of moisture increases.

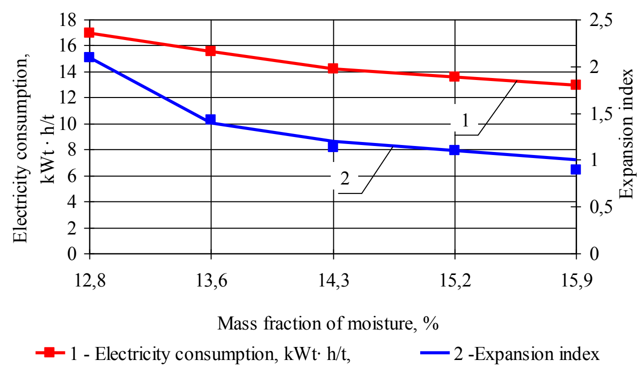

Fig. 6. Dependency of electricity consumption (1) and expansion index of extrudate (2) on the mass fraction of moisture in the EFA

An increase in the mass fraction of moisture in the tested samples (Fig. 6) leads to the decrease in specific electricity consumption during the extrusion from 17 to 13 kW×h/t and to the decrease in the index of expansion from 2,1 to 1 [31, 32]. For extruded products, the characteristic index of expansion is not less than 2 [33, 34].

The process of extruding a mixture of ground corn grain and egg masses without shell was conducted at the press-extruder EZ-150, on which the matrix with a hole of 10 mm diameter was installed. In the process of extruding, we kept records of the pressure in the working zone of the extruder, the power consumption of the motor, the product temperature at the outlet of the extruder, which accounted for 2…3 MPa, 4.0…4.5 kW, 110…120 °C, respectively. The duration of the process was 60…120 s.

As a result of the research, it was defined that with the introduction of 10 % of egg mass without shell into the composition of the feed additive, the extrusion process takes place with minimum energy consumption and the quality indicators of the feed additive are the best.

On the basis of experimental research, the method of enriching ground corn grain with proteins of substandard eggs [30] was proposed, which can be implemented with using the following scheme of the technological process (Fig. 7).

The technological scheme is based on the variant of construction of the technological process with formation of the preceding mixture of components. The implementation of the accepted variant of design of the technological process of producing the EFA for farm poultry involves the following technical lines that include such operations:

– cleaning from impurities of the grain component;
– grinding the grain component;
– controlling the size of the ground product;
– batching grain raw material;
– cleaning the egg mass of substandard eggs from the remains of the shell;
– homogenization of the egg mass;
– batching the egg mass;
– mixing the egg mass and corn grit to obtain the preceding mixture;
– mixing the preceding mixture and corn grit;
– treatment of the mixture of components in the extruder;
– cooling and grinding the extruded feed additive to the required size.

The developed technology implies the feed of grain corn for cleaning from impurities to A1-BZO sculperator (1) and A1-BIS-12 sieve-air separator (2), in which two sieve frames are installed: the upper frame – lattice blade (PR) No. 100… 160, the lower one – PR No. 10…14. Cleaning from metal magnetic impurities is conducted in a stream in the P-100 magnetic separator (3).

The cleaned corn grains are fed to the over-crusher bunkers (4), crushed in A1-DM2R-22 hammer crusher (5), in which a sieve with holes of ∅3 mm is set. The ground product, for the size control, is sent to the A1-SMC-10 sifter (6), where the sieves PR No. 30 and No. 20 are installed. Pass of the sieve No. 30 is sent to repeated grinding, pass of the sieve PR No. 20 is used for the production of feed for other species and age groups of farm animals and poultry.

Corn grit (pass of the sieve PR No. 30 and pass of the sieve PR No. 20) is sent for batching to AD-50-RCC one-component batcher (7).

The egg mass without shell of substandard chicken eggs is fed to the production facility in a plastic container (8). With the help of the pump (9) and the valve (21), it is sent to the bunker-mixer (11) through the pre-filter (10), in which a grid filter of rough cleaning with holes ∅3…4 mm is installed, to get homogeneous mass. To ensure continuous operation of the line in case of contamination of one of the filters, it is proposed to establish two coarse cleaning filters.

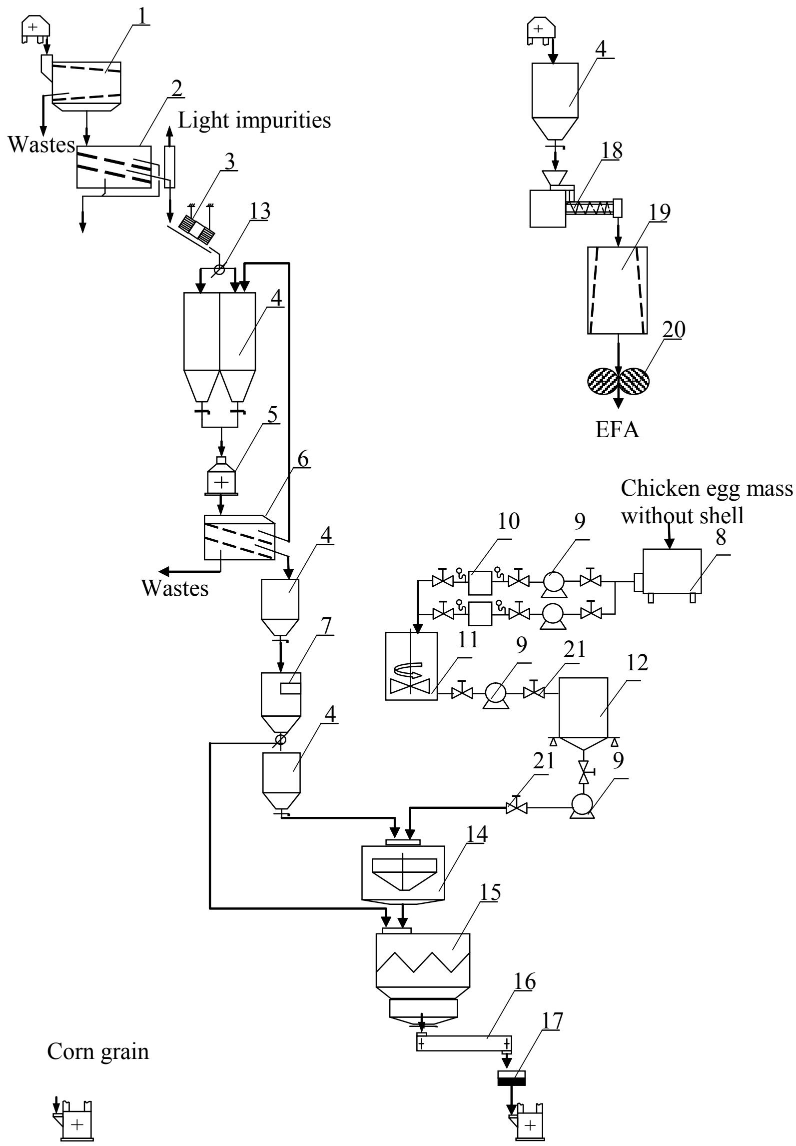

Fig. 7. Fundamental technological scheme of the EFA production:
1 – scalperator A1-BZO, 2 – sieve air separator A1-BIS-12, 3 – magnetic separator P–100, 4 – bunker, 5 – hammer crusher A1-DM2R-22, 6 – sifter A1-SMC-10, 7 – weight batcher D-50-RCC, 8 – container with egg mass without shell, 9 – pump, 10 – filter of coarse cleaning, 11 – bunker-mixer, 12 – bunker on tenzometers, 13 –changeover valve, 14 – frame mixer; 15 – blade mixer SP–500, 16 – transporter TSC-25, 17 – magnetic separator U1-BMZ, 18 – press extruder E–500, 19 – cooling column B6-DHA-II, 20 – roll crusher, 21 – valve

The homogeneous egg mass is sent for batching to the bunker on tenzometers (12) and to the frame mixer (14). To obtain the pre-mixture components, a weighed portion of corn meal is sent to the frame mixer (14) through the changeover valve (13). The mixing is conducted for 180 s at the frequency of rotation of the working body of the mixer of $n=1\ s^{-1}$, and with the 1:1 proportion of corn meal and egg mass without shell for even distribution of liquid raw material in the mixture.

The resulting preceding mixture is sent to the SP-500 mixer of periodic action with the blade mixing device (15), to which, through the changeover valve (13), the remained portion of corn grit arrives. The mixing is conducted for 120...180 s at the frequency of rotation of the working body of the mixer n=1,33 s^{-1}.

Highly homogeneous feed additive is fed to the E-500 extruder (18) with the use of the CSC-25 transporter (16) through the U1-BMZ magnetic separator (17).

Hot extrudate is cooled by means of the B6-DHA-II vertical cooler (19) to the temperature, which does not exceed the ambient temperature by more than 10 °C. The extrudate is crushed on the roller crusher (20). The resulting EFA is sent for packaging or for the production of feed.

In accordance with the developed method of the production of EFA for farm poultry, the samples were produced, in which the physical properties (Table 4), chemical composition (Table 5) and the quantitative and qualitative composition of microflora (Table 6) before and after the extrusion were defined.

Table 4

Influence of extrusion on physical properties of feed additive (n=3, P ≥ 0,95)

Indicators	Feed additive before processing	Feed additive After processing	Feed additive changes
Mass fraction of moisture, %	17,1	12,8	–25,1
Angle of natural slope, degree	35,0	38,0	+8,6
Friability, cm/s	8,6	4,6	–46,0
Volume mass, kg/m³	625,0	480,0	–23,2
Size module, mm	1,8	1,1	–38,9
Degree of starch dextrinization, %	0	58,0	58,0
Index of extrudate expansion	2,1		
Electricity consumption, kWt/h	17,0		

The analysis of the data listed in Table 4 indicates that in the process of extrusion of the feed additive, the mass fraction of moisture decreases by 25,1 %, the angle of slope increases by 8.6 %, friability decreases by 46 % and the volume mass decreases by 23.2 %. With extrusion of the mixture of ground corn and egg mass without shell of sub-standard eggs, the degree of dextrinization of starch makes up 58 % while the recommended value is not lower than 55 %.

The main component of plant raw materials, which affects conditions of processing and quality of the extrudate is starch. In the process of extrusion, the amount of water-soluble carbohydrates (sugars) increased by 6 times, and the starch decreases by 26.8 %. In the process of extrusion of starch-containing raw materials, proteins are simultaneously influenced by a whole range of factors which causes their partial denaturation. The content of crude fat, crude cellulose and ash changes insignificantly. However, the conversion of these elements in the process of hydrothermomechanical treatment, probably, is not crucial in the changes of physical and chemical properties of the main components. As can be seen from Table 5, the content of macroelements and vitamins does not change significantly, but the amount of fat-soluble vitamins decreases by 40...55 %. Vitamins A, C, E are the most labile in this case, and vitamins B are the most stable.

Table 5

Chemical composition of extruded corn and feed additive before and after extrusion (in terms of dry substance) (n=3, P ≥ 0,95)

Indicators	Feed additive before extrusion	Feed additive after extrusion	Extruded corn
Mass fraction of dry substances, %	82,90	87,20	88,30
crude protein	12,90	12,50	9,25
crude fat	7,60	7,50	4,50
water-soluble carbohydrates	3,90	23,70	25,50
Starch	66,40	48,60	53,90
crude cellulose	2,20	2,10	2,25
crude ash	1,90	1,85	1,60
calcium, mg %	53,00	54,00	38,00
phosphorus, mg %	348,00	340,00	302,00
Mass fraction of vitamins: B_1, mg %	0,37	0,35	0,37
B_2, mg %	0,26	0,25	0,11
B_C, mg %	0,20	0,11	0,11
E (tocopherine), mkg %	2,45	1,15	1,60
D, mkg %	0,79	0,40	0
A, mkg %	83,90	50,30	0
Digestibility of protein, %	61,70	85,50	80,60

When comparing chemical composition of the EFA and of the extruded corn (Table 5), it was noted that the content of crude protein, crude fat, crude ash, calcium and phosphorus in the EFA compared with extruded corn is higher by 35,1 %, 66,7 %, 15,6 %, 42 %, 126 %, respectively. However, by the content of starch, water-soluble carbohydrates and raw cellulose, the extruded feed additive is inferior to the extruded corn, as the content of the above mentioned components is 9,8 %, 7,1 %, 6,7 % lower, respectively. The digestibility of protein in extruded feed additive is 6.1 % higher in comparison with extruded corn. In addition, due to the introduction of egg mass without shell of substandard eggs to the composition of the feed additive, the content of fat-soluble vitamins A and D is 50,30 mkg % and 0,40 mkg %, respectively.

To evaluate the quantitative and qualitative composition of microorganisms, the standards for feed were accepted, i. e., the total number of microorganisms must not exceed 5×10^5 CFU/g.

The results of studying the change in the sanitary condition of the feed additive during processing and storing, given in Fig. 8, show that in the mixtures of ground corn and the egg mass without shell, the general bacterial semination is within the norm. A small amount of moulds and yeasts were also detected in this sample. By their morphological features, the detected moulds belong to the fungi of the genus *Mucor,* which due to their continuous cover complicate recording, because they grow faster than fungi of the genus *Aspergillus* and *Penicillium*.

Thermal treatment contributes to improving sanitary quality of feed products. After it, the number of microorganisms in the feed additive for farm poultry decreased by almost 200 times, and the amount of moulds of the genus *Mucor* decreased to 10 CFU/g. During the storage of the extruded feed additive for 3 months, the total bacterial semination decreased from 1340 CFU/g to 200 CFU/g, the moulds and yeast were not detected (in ten-time breeding).

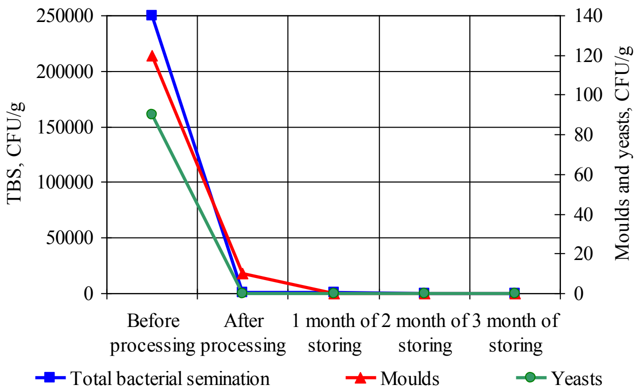

Fig. 8. Change in composition of microflora of feed additive for farm poultry during processing and storing for 3 months under uncontrolled conditions

Biological assessment of the efficiency of the improved technology of the EFA production was conducted on laboratory animals. Within 14 days, the laboratory animals in experimental groups were fed with the rations having the following composition (by the content of dry substances):

– the 1st group received standard fully-rationed feed, balanced according to the physiological needs of animals (100 %);

– the 2nd group (control) received 75 % of standard fully-rationed feed and 25 % of ground extruded corn;

– the 3rd group (experimental) received 75 % of standard fully-rationed feed and 25 % of the EFA for farm poultry.

The productive effect of using feed with the EFA was estimated by the gain in the body weight and by the feed conversion (Fig. 9, 10) [31, 35].

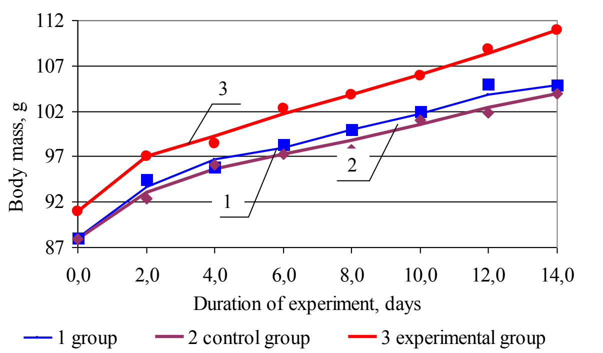

Fig. 9. Changes in average body mass of laboratory animals

During the experiment, the following changes occurred. A daily average gain in mass of lab rats in the 1st group accounted for 1,20 g/day, and the average value in the 2nd (control) group accounted for 1,14 g/day, which is 5,0 % less than in the 1st group. A daily average gain in the mass of lab rats in the 3rd (experimental) group accounted for 1,43 g/day, which is 19,2 % higher than in the 1st group and 25.4 % higher than in the 2nd (control) group.

The feed consumption per unit of gain in live weight of lab rats in the 2nd (control) group were 5,3 % higher than in the 1st group, and in the 3rd (experimental) group the feed conversion was 16.1 % lower than in the 1st group and 20.3 % lower than in the 2nd (control) group.

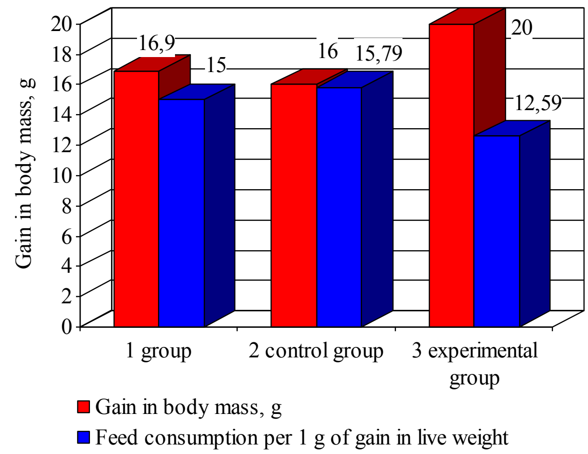

Fig. 10. Relative gain in body mass and feed consumption per 1 g of gain in live weight of laboratory animals

6. Discussion of the results of study of the process of extrusion of the mixture of grain raw materials and the egg mass of substandard chicken eggs

It should be noted that the preliminary crushing of corn grain has a positive effect on the technological extrusion process by reducing the electricity consumption (Fig. 1). In this case, the dense shell of grain is destroyed and the availability of the effects of an increased temperature and pressure on its internal layers increases. However, it is necessary to prevent the over–crushing of grain and formation of a large number of mealy fractions, which is quickly pasted and transfers into a viscous flowing state just in the compression zone of the extruder. The result is caking of grain and deterioration of organoleptic and physical properties of the extrudate [33, 34].

To get a high quality product at the output of the extruder, it is necessary to achieve maximum homogeneity of the original mixture of the component (corn and egg masses without shell). These components significantly differ in physical properties and aggregate state and, as a result, technological difficulties occur. Therefore, it is necessary to experimentally determine the modes of the technological process of mixing, in other words, to set the maximally possible mass fraction of the egg mass without shell of substandard eggs in the mixture, the type of a mixer and the necessary duration of mixing, which can provide the necessary degree of homogeneity of the mixture.

According to the world's scientists and practitioners, to obtain high-quality homogeneous mixtures of feed and premixes, considering technological characteristics of mixtures and the results of experimental research, the use of mixers with the blade mixing device is the most effective [2, 36, 37].

It is a common knowledge that the process of mixing is considered efficient if the coefficient of heterogeneity does not exceed 3 % [36, 37]. On the basis of the received data (Fig. 2), the technological process of mixing was not effective. With the increase in the mass fraction of the egg mass without shell in the mixture, the homogeneity of samples significantly decreased and the duration of mixing increased. In addition, due to the difference in the physical properties, the egg mass and the ground corn grain made up a mixture that was lumped and contained conglomerates.

The conducted studies of the effectiveness of mixing the components (Fig. 3, 4) indicate that in order to achieve even distribution of liquid raw material in the mixture, it is expedient to use two-stage mixing, namely, producing the preceding mixture of crushed corn and egg masses without shell of substandard chicken eggs. For making the preceding mixture, it is expedient for mixing substances of high viscosity to use frame mixers, which are used in the processes where the stagnation of peripheral layers is not allowed. As a result, there was established the expedience of the production of preceding mixture of ground corn grain and egg mass without shell in the 1:1 ratio in a frame mixer at the mixing duration of 180 s.

Making the preceding mixture with the amount of egg mass without shell of less than 50 % in the mix is impractical because the electricity consumption for mixing wet mixtures will increase in frame mixtures, because they are intended for mixing liquid raw materials. It is appropriate to mix wet mixtures in mixers with the blade mixing devices, the research into mixing capacities of which was presented above.

The problem was to determine the maximally possible mass fraction of egg mass without shell in the mixture with crushed corn under optimum conditions of conducting technological mixing process. After the study had been conducted, it was established that to obtain the high-quality homogeneous crushed corn, maximally enriched with egg protein, it is necessary to carry out two-stage mixing:

1) obtaining the preceding mixture of components in the 1:1 ratio in a frame mixer for 180 s;

2) main mixing of the preceding mixture of components and the part of the ground corn, which remained in the batcher with the blade mixing device within 120…180 s with maximum introduction of 10 % egg mass.

Analyzing the dependency of electricity consumption on the mass fraction of moisture in the experimental samples (Fig. 6), it was found that with the introduction of more than 10 % egg mass without shell to the original mixture, electricity consumption decreases. In this case, the process of formation of the product, but not extrusion is observed, due to high mass fraction of moisture of the resulting mixture, and as a result, getting the finished product of high humidity. The introduction of less than 10 % of the egg mass without shell to the composition of the resulting mixture is impractical as the mass fraction of moisture decreases and the process of extrusion becomes complicated. Baking of the product and a decrease in its volume expansion may be observed. On the other hand, it was necessary to get extruded feed additive enriched with protein of animal origin with its maximally possible content.

On the basis of the conducted studies [26], there was developed a technological way of producing extruded feed additives by enriching crushed corn grain with the egg mass of substandard eggs without shell. The resulting feed additive may be used as independent feed on farms for feeding farm animals and poultry, or as a component of the feed in the amount of 15…25 %. The use of the egg mass of substandard eggs in the composition of the feed additive allows using the wastes of poultry breeding efficiently.

Extrusion technology allows changing quantitatively and qualitatively the structure, composition and the feed value of the finished product. The least resilient components of raw materials in the process of extrusion are starch, protein and vitamins. The process of extrusion is accompanied by 3,1 % loss of crude protein (Tables 4, 5) because of partial denaturation of protein and its splitting to amino acids. The violation of order of internal structure of a protein molecule is observed. In this case, nitrogen transfers into gas state (deamination reaction) and reacts with polysaccharides with formation of sparingly soluble compounds, which are not possible to determine by the method of Kjeldahl. As in the process of extrusion, protein-carbohydrate complexes are formed, it affects the degree of dextrinization of starch and the expansion index of the extrudate. During extrusive processing of starchy materials, at the moment of decompression, the total content of starch decreases due to splitting of molecules of amylose and amylopectin; simultaneously, the number of oligosaccharides and dextrines increases. It implies an increase in the content of water-soluble substances and, respectively, feed value of the product due to its better assimilation.

The study of sanitary quality of feed additives for farm poultry (Fig. 8) indicate that after the extrusion and during the process of storing under uncontrolled conditions for 3 months, the level of semination decreases dramatically. An insignificant accumulation of microorganisms in the process of storing is connected with both low humidity of the samples and with the comprehensive effect of high temperatures and pressure during processing in the extruder. During the extrusion, complete inactivation of e.coli, protea, salmonella, staphylococcus occurs, the 98,8…99,8 % decrease in total bacterial semination and 88,7…89,6 % decrease in the toxicity degree, The EFA must be stored in dry, well-ventilated premises, preventing its moistening and packing. In this case, it is possible to ensure consistent quality indicators and satisfactory sanitary condition of the product, which can be used for feeding farm poultry throughout all period of storage.

The obtained results of biological assessment indicate high biological efficiency of using the EFA in feeding laboratory animals in comparison with extruded corn, and the possibility of using it in the composition of feed for young farm poultry.

In the future, it would be expedient to study the use of a whole substandard chicken egg for enriching grain raw materials not only with animal proteins, but also with calcium.

7. Conclusions

1. The composition of raw materials for the production of extruded feed additive, which includes crushed corn grain and egg mass of substandard eggs without shell was substantiated. It was found that the optimum amount of egg mass without shell in a mixture with ground corn grain is 10 % under condition of the minimum specific electricity consumption for production and the best quality indicators of the extruded feed additive.

2. There was proposed a technological way of enriching grain raw materials with the protein of animal origin by mixing crushed corn and egg mass of substandard eggs without shell with the subsequent extrusion of a highly homogeneous mixture of components. There was established the expedience of using a two-stage mixing to achieve even distribution of the liquid egg mass without shell in a mixture with ground corn grain, namely, the preceding mixture of components in the ratio of 1:1 in a frame mixer for 180 s and mixing the

preceding mixture with a part of the remained corn grit in the batcher with a blade mixing device for 120…180 s. The coefficient of variation of the obtained mixture is 2,7 %. The rational parameters of technological process of extrusion of the feed additive were recommended: pressure in the working zone of the extruder is 2…3 MPa, consuming power of the electromotor is 4.0… 4.5 kW, product temperature at the output of the extruder is 110….120 ^{o}C, duration of the extrusion process of the feed additive is 60…120 s, diameter of the outlet of the matrix is 10 mm.

3. The influence of the extrusion process on the physical properties, chemical composition and sanitary quality of the EFA was determined. In the extrusion process, the 3,1 % loss of crude protein content was observed, the starch decreases by 26,8 %, in this case, the content of water– soluble carbohydrates increased by 6 times. During storage of the extruded feed additive for 3 months, the total bacterial semination decreases by 7 times.

4. The fundamental technological scheme of the EFA production was improved. Thanks to using the EFA, such valuable and easily assimilable product as the egg mass of substandard eggs is used for feeding poultry and is not wasted. The additive can be used in the composition of feed in the amount of 15…25 % either by independent households or on farms.

5. Biological evaluation of feeding EFA indicates that daily average gain of live body mass of laboratory animals increases by 25.4 %, and the fodder conversion decreases by 20.3 % in comparison with the control group.

References

1. Shevcov, A. A. Povyshenie yeffektivnosti proizvodstva kombikormov [Text] / A. A. Shevcov, A. N. Ostrikov, L. I. Lytkina, A. I. Suharev. – Moscow: DeLi Print, 2005. – 243 p.
2. Iegorov, B. V. Tehnologiya virobnictva kombikormiv [Text] / B. V. Yehorov. – Odesa: Drukars'kij dim, 2011. – 448 p.
3. Svezhencov, A. I. Kombikorma, premiksy, BVMD dlya zhivotnyh i pticy [Text] / A. I. Svezhencov. – Dnepropetrovsk: ART-PRESS, 2008. – 412 p.
4. Luk'yanova, V. D. Promyshlennoe pticevodstvo [Text] / V. D. Luk'yanova, Ye. A. Dugonov, N. F. Kosenko. – Moscow, 1989. – 278.
5. Svezhencov, A. I. Korma i kormlenie sel'skohozyajstvennoj pticy [Text] / A. I. Svezhencov, R. M. Urdzik, I. A. Egorov. – Dnepropetrovsk: ART-PRESS, 2006. – P. 232–361.
6. Podobed, L. I. Kombikormi dlya molodnyaka sil's'kogospodars'kih tvarin [Text] / L. I. Podobed. – Kyiv: Urozhaj, 1994. – 144 p.
7. Pelevin, A. D. Kombikorma i ih komponenty [Text] / A. D. Pelevin, G. A. Pelevina, I. Yu. Vencova. – Moscow: DeLi print, 2008. – 519 p.
8. ES 07.052002. N 2002/32/ES pro nebazhani rechovini u kormah dlya tvarin [Text]. – Direktiva Evropejs'kogo parlamentu ta Radi
9. ES 22.09.2003. N 1831/2003 pro domishki dlya vikoristannya u harchuvanni tvarin [Text]. – Reglament Evropejs'kogo parlamentu ta Radi
10. Mel'nik, V. V. Kormi dlya ptici [Text] / V. V. Mel'nik // Suchasne ptahivnictvo. – 2007. – Vol. 5-6, Issue 54-55. – P. 14–19.
11. Taranu, I. Nutrition, feeding and egg quality [Text] / I. Taranu // Poultry international. – 2006. – Vol. 8. – P. 38–42.
12. Egorov, I. A. Novye podhody v ispol'zovanii netradicionnyh kormov v pticevodstve [Electronic resource] / I. A. Egorov, N. V. Toporkov // VNITIP. – Available at: http://www.webpticeprom.ru/ru/articles-birdseed.html?pageID=1209369752
13. Jackson, M. Improving soya utilization in monogastrics: maize-soya diets with -mannanase [Text] / M. Jackson // Feed international. – 2009. – Vol. 12. – P. 22–26.
14. Gill, C. Poultry nutrition update [Text] / C. Gill // Feed international. – 2007. – Vol. 4. – P. 16–17.
15. Gill, C. Enzymes for broilers: reducing maize energy variability [Text] / C. Gill // Feed international. – 2008. – Vol. 4. – P. 12–14.
16. Semykin, V. A. Vozdelyvanie kukuruzy na zerno bez gerbicidov [Text] / V. A. Semykin, I. Ya. Pigorev, I. A. Oksenenko // Sovremennye naukoemkie tehnologii. – 2008. – Vol. 4. – P. 58–60.
17. Bol'shinstvo yaic v mire proizvodyat 15 stran [Text] // Dajdzhest mirovogo pticevodstva. Prilozhenie k zhurnalu "Ptica i pticeprodukty". – 2012. – Vol. 2, Issue 16. – P. 76.
18. Velyamov, M. T. Ispol'zovanie pitatel'noj sredy iz fermentativnogo gidroliza nekondicionnyh kurinyh yaic dlya kul'tivirovaniya proizvodstvennyh shtammov na predpriyatii [Text] / M. T. Velyamov, Zh. K. Knyazheva, Zh. A. Kashaganova // Mezhdunarodnyj zhurnal yeksperimental'nogo obrazovaniya. – 2015. – Vol. 3. – P. 86–89.
19. Angelovičová, M. The table eggs and their quality in small-scale breeding [Text] / M. Angelovičová, L. Ševčíková, M. Angelovič // Potravinarstvo. – 2015. – Vol. 9, Issue 1. – P. 442–450. doi: 10.5219/515
20. Chukwuka, O. K. Egg Quality Defects in Poultry Management and Food Safety [Text] / O. K. Chukwuka, N. J. Okoli, A. Okeudo, B. I. Udedibie, I. P. Ogbuewu, N. O. Aladi et. al. // Asian Journal of Agricultural Research. – 2011. – Vol. 5, Issue 1. – P. 1–16. doi: 10.3923/ajar.2011.1.16
21. Iegorov, B. V. Ispol'zovanie nekondicionnyh kurinyh yaic pri proizvodstve kormovyh dobavok i Iegorov[Text] / B. V. Yehorov, N. V. Vorona // Zernovi produkti i kombikormi. – 2010. – Vol. 3. – P. 43–45.
22. Ryabokon', Yu. A. Sostoyanie i nauchnoe obespechenie otrasli pticevodstva [Text] / Yu. A. Ryabokon' // Ptahivnictvo. – 2006. – Vol. 58. – P. 10.
23. Taranov, P. M. Povyshenie yekonomicheskoj yeffektivnosti rossijskogo pticeproduktovogo podkompleksa cherez glubokuyu pererabotku yajca [Text] / P. M. Taranov, V. Yu. Gadaeva // Yekonomicheskie nauki. – 2013. – Available at: http://

cyberleninka.ru/article/n/povyshenie-ekonomicheskoy-effektivnosti-rossiyskogo-ptitseproduktovogo-podkompleksa-cherez-glubokuyu-pererabotku-yaytsa
24. Narabari, D. Nutritionally enriched eggs [Text] / D. Narabari // Poultry international. – 2008. – Vol. 10. – P. 22–30.
25. Skurihin, I. M. Tablicy himicheskogo sostava i kalorijnosti rossijskih produktov pitaniya [Text] / I. M. Skurihin, V. A. Tutel'yan. – Moscow: DeLi print, 2007. – 276 p.
26. Iegorov, B. V. Tehnologiya virobnictva ekstrudovanoi kormovoi dobavki dlya sil's'kogospodars'koi ptici [Text] / B. V. Iegorov, N. V. Vorona // Zernovi produkti i kombikormi. – 2011. – Vol. 4. – P. 31–36.
27. Iegorov, B. The study of production regimes and quality parameters of extruded feed additive based of corn seed and substandard egg mass [Text] / B. Iegorov, N. Vorona, A. Makarynska, O. Voietska, T. Bordun // Eureka: Life Sciences. – 2016. – Vol. 3 (3). – P. 26–35. doi: 10.21303/2504-5695.2016.00144
28. Braterskij, F. D. Ocenka kachestva syr'ya i kombikormov [Text] / F. D. Braterskij. – Moscow: Kolos, 1983. – 320 p.
29. Tehnologiya kombikormovogo virobnictva [Text] / B. V. Egorov (Ed.). – Odesa: ONAHT, 2010. – 60 p.
30. Organizaciya tehnohimichnogo i tehnologichnogo kontrolyu na pidpriemstvah galuzi [Text] / B. V. Egorov (Ed.). – Odesa: ONAHT, 2011. – 82 p.
31. Iegorov, B. V. Issledovanie biologicheskoj yeffektivnosti i sanitarnogo kachestva yekstrudirovannoj kormovoj dobavki dlya molodnyaka sel'skohozyajstvennoj pticy v processe hraneniya [Text] / B. V. Iegorov, N. V. Vorona // Zernovi produkti i kombikormi. – 2011. – Vol. 2. – P. 29–33.
32. Afanas'ev, V. A. Teoriya i praktika special'noj obrabotki zernovyh komponentov v tehnologii kombikormov [Text] / V. A. Afanas'ev. – Voronezh: Voronezhskij gosudarstvennyj universitet, 2002. – 296 p.
33. Pat. 64221 Ukraina, MPK A23K 1/10. Dobavka do kombikormu dlya sil's'kogospodars'koj ptici [Text] / Yehorov B. V., Vorona N. V. – № u201108847. Declareted: 14.07.2011, published: 25.10.2011, Byul. № 2.
34. Ostrikov, A. N. Ekstruziya v pishhevoj tehnologii [Text] / A. N. Ostrikov, O. V. Abramov, A. S. Rudometkin. – SPb.: GIORD, 2004. – 288 p.
35. Iegorov, B. V. Vivchennya kormovoi cinnosti ekstrudovanoi dobavki dlya sil's'kogospodars'koi ptici [Text] / B. V. Iegorov, A. P. Levic'kij, N. V. Vorona // Hranenie i pererabotka zerna. – 2014. – Vol. 9, Issue 186. – P. 43–45.
36. Fairfield, D. Back to basics: mixing system efficiency [Text] / D. Fairfield, C. Gill // Feed international. – 2010. – Vol. 8. – P. 24–26.
37. Behnke, K. C. From ingredient uniformity to animal performance [Text] / K. C. Behnke. – Roche Technical Seminar, Lafferson GA, 2006. – P. 43–51.