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SCIENTIFIC AND PRACTICAL BASIS OF USING PROTEIN PLANT CONCENTRATES FOR THE PRODUCTION OF COMPOUND FEEDS

B. Yegorov, Doctor of Engineering Science, Professor, *E-mail*: bogdanegoroff58@gmail.com
A. Makarynska, Candidate of Engineering Science, Associate Professor, *E-mail*: allavm2015@gmail.com
I. Cherneha, Candidate of Engineering Science, Associate Professor, *E-mail*: ilonamalaki@gmail.com
A. Oganesian, Master, *E-mail*: asia.oghaniesian.2013@ gmail.com
Department of mixed feeds and biofuel technology
Odessa National Academy of Food Technologies, Kanatna str., 112, Odessa, Ukraine, 65039

Abstract. In the article the advantages of using grain legumes as protein plant concentrates are analysed, and a comparative analysis of the chemical composition of the pea and the soybean meal is carried out. Besides, the official parameters for different protein products for pig feeding are presented. To determine whether it is possible to introduce protein plant concentrates into compound feed, it is necessary to know their physical properties. So, the physical properties of the protein plant concentrates have been investigated for the following parameters: moisture content, bulk density, angle of repose, and flowability. Methods of introducing protein plant concentrates into compound feeds have been developed and presented. Taking into account the physical properties and norms of introducing protein plant concentrates for farm animals and poultry, a scheme has been developed for a technological line preparing a portion of grain, powdery, mineral raw materials and meals. One of the methods of introducing protein plant concentrates into compound feeds is extrusion. That is why, a technological scheme of an extrusion line for grain legumes has been developed. The technological scheme provides for the extrusion of a soybeans and peas mixture in the ratio 1:1. Also, the physical properties of the extruded feed additive have been studied. With the software package "Korm Optima Expert," recipes for feeding piglets aged 43–60 days have been calculated (with protein plant concentrates used in the recipes), and some feeds of animal origin have been replaced with extruded feed additives. According to the calculated recipes, an experimental batch of mixed feeds with the use of protein plant concentrates has been manufactured, and its physical properties have been determined.

Key Words: protein plant concentrates, soybean, peas, extruding, additive, compound feed.

НАУКОВО-ПРАКТИЧНІ ОСНОВИ ВИКОРИСТАННЯ БІЛКОВИХ РОСЛИННИХ КОНЦЕНТРАТІВ ПРИ ВИРОБНИЦТВІ КОМБІКОРМІВ

Б.В. Єгоров, доктор технічних наук, професор, *E-mail*: bogdanegoroff58@gmail.com
А.В. Макаринська, кандидат технічних наук, доцент, *E-mail*: allavm2015@gmail.com
І.С. Чернега, кандидат технічних наук, доцент, *E-mail*: ilonamalaki@gmail.com
А.А. Оганесян, магістр, *E-mail*: asia.oghaniesian.2013@gmail.com
Кафедра технології комбікормів і біопалива
Одеська національна академія харчових технологій, вул. Канатна, 112, м. Одеса, Україна, 65039

Анотація. У статті проаналізовано переваги використання зернобобових культур в якості білкових рослинних концентратів та проведено порівняльний аналіз хімічного складу кормового гороху та соєвого шроту. Представлено офіційні показники поживності для свиней по різним білковим продуктам. Для визначення можливості введення білкових рослинних концентратів до складу комбікормів, необхідно знати їхні фізичні властивості. Тому досліджено фізичні властивості білкових рослинних концентратів за такими показниками як: масова частка вологи, об'ємна маса, кут природного укосу та сипкість. Розроблено та представлено способи введення білкових рослинних концентратів до складу комбікормів. Враховуючи фізичні властивості та норми введення білкових рослинних концентратів до раціону сільськогосподарських тварин та птиці, розроблено схему технологічної лінії підготування порції зернової, мучнистої, мінеральної сировини та шротів. За одним із способів введення білкових рослинних концентратів до складу комбікормів передбачено використання процесу екструдування. Тому розроблено технологічну схему лінії екструдування зернобобових культур. За технологічною схемою передбачено екструдування суміші зерна сої та гороху у співвідношенні 1:1. Досліджено фізичні властивості отриманої екструдованої кормової добавки. За допомогою програмного комплексу «Корм Оптіма Експерт» розраховано рецепти комбікормів для поросят віком 43–60 днів, в яких використовували білкові рослинні концентрати, крім того, частину кормів тваринного походження було замінено екструдованою кормовою добавкою. Згідно розрахованим рецептам було виготовлено дослідну партію комбікорму з використанням білкових рослинних концентратів та визначено його фізичні властивості.

Ключові слова: білкові рослинні концентрати, соя, горох, екструдування, добавка, комбікорм.

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Introduction. Formulation of the problem

Currently, in Ukraine and abroad, in order to increase pork production, various broad spectrum feed additives are used, which differ in their origin, biologically active components, and production technology. Introducing them into animal diets helps to maximize the use of nutrients, positively effects on their digestion and assimilation. And this leads to rational and economical use of forages, raising the productivity of animals, and improving the quality of products. Livestock farming in these conditions becomes economically feasible. In modern economic conditions, the pork, especially in small and individual farms, is produced with the use of but few grain ingredients. That is why, providing the animals with the nutrients specified in the norms is quite difficult without using additional ingredients in the grain mix – usually these are protein plant concentrates [1].

If the diet of livestock is strictly rationed and well balanced, it is possible to use no feed of animal origin without any adverse consequences for the health and productivity of animals. For some pig farms, an approach like this can turn out to be the best, as is shown by the analysis of problems of feeding and feed supply [2].

Regardless of the accepted technology of pork production, the system for growing piglets is one of the most important technological processes. The results of this process directly influence the final animal-raising and economic indicators of the whole industry. The main criterion for the growth and development of piglets is their live weight. It depends primarily on whether they are provided with easily digestible quality feeds [3]. The use of extruded grains helps at this stage. Such feeds are better digested and stimulate the health of the intestine [4-7].

Analysis of recent research and publications

In our country, the rate of soybean production tends to increase. In recent years, the cultivating areas of soy crops have been increasingly growing. Soybean consumption in the world and in Ukraine is increasing. Prices of soybeans make this product highly profitable, that is why there is great demand for soy all year round.

Soybeans require a lot of moisture to grow rapidly, so its main cultivating areas are located in the central regions: in Poltava, Kirovograd, Vinnytsya, Khmelnytsky, and Kyiv regions. This reduces the cost of transportation between regions. Also, the constant use of the same regions for cultivating soybeans results in soil exhaustion. This is a negative factor for the agricultural sector [8-10].

Benefits of soybeans:

– considerable growing volumes in Ukraine;

– soy is the most cost-effective source of protein;

– balanced amino acid profile.

But at the same time, soy contains anti-nutrients and tends to constantly increase in price [10].

Describing the anti-nutrients of soybean grains, it should be noted: these compounds are mainly of a protein nature, which makes it possible to neutralize them with a high temperature. These soy substances include: inhibitors of proteases – trypsin and chymotrypsin inhibitors; antivitamins A, D, E, B_{12}; compounds that reduce the availability of such trace elements as zinc, manganese, copper, and iron; alkaloids; allergens; goitre-causing antihormones; estrogenic isoflavones – genistein and daidzein; oligosaccharides – stachyose, raffinose, and verbascose that cause flatulence; enzymes – urease, lipase, and lipoxygenase [11].

Anti-nutrients inhibit animals' growth, reduce the effectiveness of feeds, cause thyroid gland diseases, hyperfunction and hypertrophy of the pancreas, loss of fertility, allergy, rickets, osteoporosis, anaemia, and parakeratosis. The maximum permissible activity of trypsin inhibitors, which is safe for young animals, is 3 mg/g – in other words, every 10% of protein should not contain more than 1 mg/g of trypsin inhibitors [10-12].

High prices of soybean meal and the constant rise in the prices make many farmers look for an alternative to it. Field beans, peas, and lupin are protein feed materials that can be used to feed cattle and pigs. Fodder beans and peas contain only about 50–60% of crude protein in comparison with soybean meal [13].

All legumes differ depending on the sort. Besides, the impact of the environment, soil, and climate is decisive. Therefore, when one feeds one's own leguminous crops (which is true for field peas as well), one should carry out laboratory studies of their nutritious value. Unlike soybean meal, pea grains contain only half the crude protein, but much more energy, due to a high proportion of starch (Table 1) [14].

Table 1 – The content of nutrients in field peas compared with soybean meal (g/kg in 88% of dry material)

Parameters	Field peas	Soybean meal
Exchange energy, MJ/kg	13.6	13.1
Crude protein, g	221	449
Lysine, g	15.5	27.8
Methionine/Cystine, g	5.3	13.0
Threonine, g	8.2	17.5
Tryptophan, g	2.0	5.8
Calcium, g	0.8	3.0
Phosphorus, g	4.2	6.4

As for providing pigs with protein, the decisive factor is not its absolute content, but the quantitative composition of essential amino acids. It is especially important with pigs to monitor the five essential amino acids (lysine, methionine + cystine, threonine, and tryptophan). The total content of these amino acids is very different for soybean meal and peas. Peas contain only half the amino acids of soybean meal. But if you count them in terms of the total content of crude protein, the ratios are almost the same, so the quality of the protein, in comparison with soybean meal, is even slightly better. Summing up, it can be noted that in pigs' diet, about half of soybean meal can be replaced with double the amount of peas [13-18].

Table 2 shows the official nutritional parameters for pigs in Denmark. According to them, a good source of protein is not only soybeans but also peas that contain up to 535 easy-digestible carbohydrates. However, they contain anti-nutrients, too.

The above data show that using peas to feed pigs can help save part of soybean meal, without reducing the quality of the compound feed [15].

Thus, the necessary condition for using soybeans and peas is the development of a method that will reduce the anti-nutrients content.

Using the extrusion process will be a remedy. Extrusion has many advantages, among them, the most important is the reduction of the anti-nutrients content.

Table 2 – Official nutrition parameters for pigs in Denmark [19]

Product	Crude protein content, %	Protein digestibility, % (standard)	Easy-digestible carbohydrates, g/kg of dry material	Hard-digestible carbohydrates, g/kg of dry material
Soybean concentrate	70.1	93	79	140
Soybean meal	48.7	88	188	168
Full fat soybean	41.1	75	162	142
Potato protein	85.9	89	84	0
Peas	24.0	82	535	87
Dry skim milk	36.9	94	531	–
Dried sweet whey	12.9	85	729	18
Fishmeal	77.5	91	0	0

In this regard, **the aim of the work is**: to increase the effect of compound feed products through the use of protein plant concentrates (PPC) and extruded feed additives (EFA).

Objectives of the study:

– to investigate the physical properties of protein plant concentrates;

– to develop a technological scheme for the introduction of PPC in compound feed production ;

– to give reasons for choosing protein raw material for the production of extruded feed additives;

– to develop a technological scheme of a line of leguminous crops extrusion;

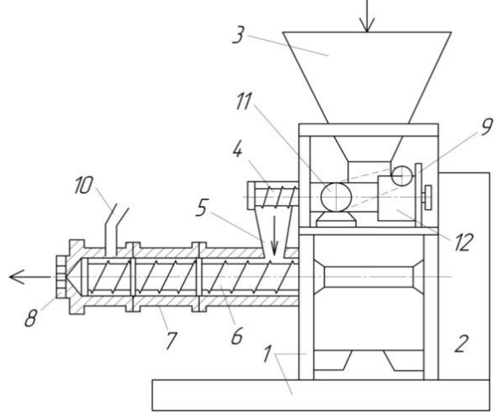
– to investigate the physical properties of extruded feed additives;

– to calculate formulations of a PPC-containing complete compound feed;

– determine the physical properties of the PPC-containing compound feed.

Research materials and methods

To manufacture feed additives, soybeans of the "Tanais" variety and peas of the "N. S. Moroz" variety were used as the raw materials. The additive was extruded with a grain extruder EZ-150 (Figure 1) at a temperature of 110–120°C and a pressure of 2–3 MPa.



1 – base (frame), 2 – main drive, 3 – bin, 4 – feed screw dispenser, 5 – receiving chamber, 6 – forcing screw, 7 – prefabricated housing, 8 – matrix, 9 – secondary drive, 10 – thermometer, 11 – DC motor, 12 – reducer.

Figure 1. Extruder EZ-150 (Bronto, CherkasyElevatorMash)

Feed additives were assessed by physical parameters such as moisture content, bulk density, size modulus, flowability, angle of repose, extrudate expansion index.

Moisture content was determined by drying a sample of the product in a weighing bottle in the drying oven at a temperature of 130°C for 40 min., and was calculated by the formula 1:

$$W = \frac{q_1 - q_2}{q_1 - q_0} \times 100, \% \qquad (1)$$

where q_0 – mass of the empty weighing bottle, g;

q_1 – mass of the weighing bottle with the sample before drying, g;

q_2 – mass of weighing bottle with the sample after drying, g.

The extrudate expansion index was determined by the ratio of the extrudate diameter to that of the outlet of the extruder matrix.

The bulk density of the additive was determined with a half-litre grain-unit scale consisting of a socket, a filler, a cylinder, a funnel, a knife, a weight, and a measurer. The cylinder was closed with the funnel, put down on the filler with the funnel looking downwards, and after the product was poured into the filler, the cylinder with the funnel was removed. The knife was quickly taken out of the slot, and after the weight and the product fell into the measurer, the knife was gently inserted back into the slot. Then the measurer with the filler was taken out of the socket, upended, with the knife and the filler held from falling out, and poured in the excess that had remained on the knife. Then the knife was removed from the slot, the measurer with the product was weighed, and the nature of the product was determined accurate to within ±0.5 g.

The angle of repose was determined by pouring the product from the filler onto a horizontal surface. The product was being poured through a metal funnel that has a cone angle of 60°, until the top reached the height of the vertical walls of the device. The angle was measured with a protractor. The protractor was applied to the cone generatrix, and angle β was determined with a plumb bob. Then the angle of repose α was calculated as: α=90–β.

The flowability was determined by pouring the product through a hole of a certain size (diameter 4 cm). The product was poured in a box with an outlet closed with a latch. To determine the product's flowability, the latch was opened, and the time of pouring the product through the outlet onto a horizontal surface was noted. The volume of the product poured was measured with the cylinder. The flowability was determined by the formula 2:

$$V = \frac{q}{S \times t}, \text{ cm·s}^{-1} \quad (2)$$

where q – volume of the product that passed through the hopper outlet, cm^3;

t – duration of pouring the product, s;

S – crosssection area of the outlet, cm^2.

The size modulus was determined on a laboratory plansifter. A sample of the product was placed on the top sieve of the plansifter, and, after the lid was closed, sifted for 5 minutes, with 190–210 sieve vibrations per minute. After sifting, the residues on each sieve were weighed.

The size modulus was determined by the formula 3:

$$M = \frac{3.5m_1 + 2.5m_2 + 1.5m_3 + 0.78m_4 + 0.28m_5}{100}, \text{ mm} \quad (3)$$

where m_1, m_2, m_3, m_4 – mass of the residues on the sieves with holes Ø 3, Ø 2, Ø 1, Ø 0.56 mm, g;

m_5 – mass of the throughs on the sieve with holes Ø 0,56 mm, g;

3.5; 2.5; 1.5; 0.78 – the average size of particles remaining on sieves with holes Ø 3, Ø 2, Ø 1, Ø 0.56 mm, respectively, mm;

0.28 – the average size of the particles that passed through the sieve with holes Ø 0.56 mm;

100 – mass of the sample taken for the analysis, g.

All tests were performed with the measurements repeated 3 times, and the experimental results were processed by the software (Mathsoft, Inc., USA; Mathcad Professional) [4].

Results of the research and their discussion

To determine whether it is possible to use protein plant concentrates as a component of compound feeds, the physical properties of the concentrate have been studied (Table 3).

As can be seen from Table 1, a protein plant concentrate has satisfactory physical properties, and it can be introduced on the technological line preparing portions of grain, flour, mineral raw materials, and meals without installing additional technological equipment. And the moisture content indicates a long period of its storage.

In accordance with the rules for protein plant concentrates, they can be used to feed farm animals in an amount of 5–20%.

The nutritional value of finished products can be increased by several methods of introducing PPC into compound feeds (Figure 2):

- on the line preparing portions of grain, powdery, mineral raw materials, and meals;
- through the compositions of protein-vitamin additives and protein-vitamin-mineral additives;
- with the use of a line of extrusion of leguminous crops.

Taking into account physical properties and norms of introduction of protein plant concentrates for farm animals and poultry, a scheme has been developed for a technological line preparing portions of grain, powder, mineral raw materials, and meals (Figure 3). According to the scheme, 5% of protein plant concentrate is supposed to be introduced into sack-off bins for protein raw materials.

Table 3 – Physical properties of PPC

Raw material	Parameters			
	Moisture content, %	Bulk density, kg/m^3	Angle of repose, degree	Flowability, cm/s
Protein Plant Concentrate	10.8	399	48	8.7

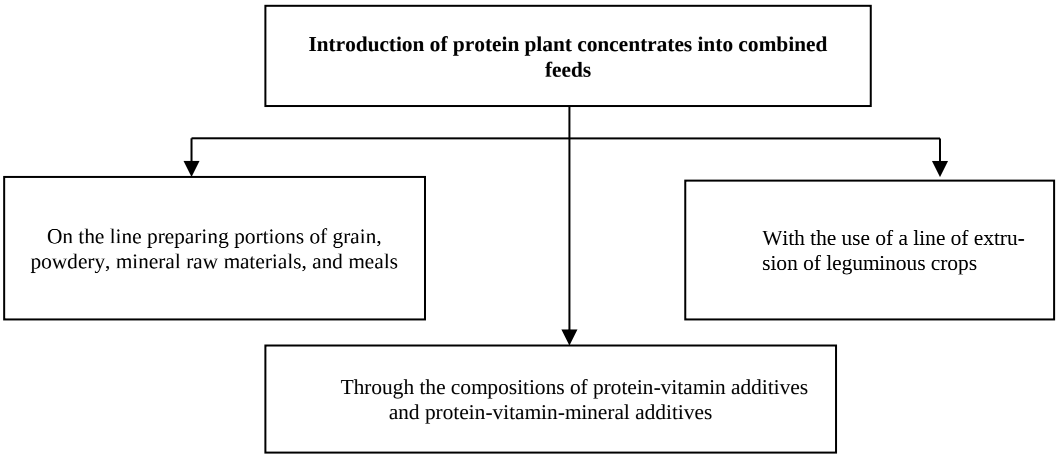


Figure 2. Methods of introducing protein plant concentrates into compound feeds

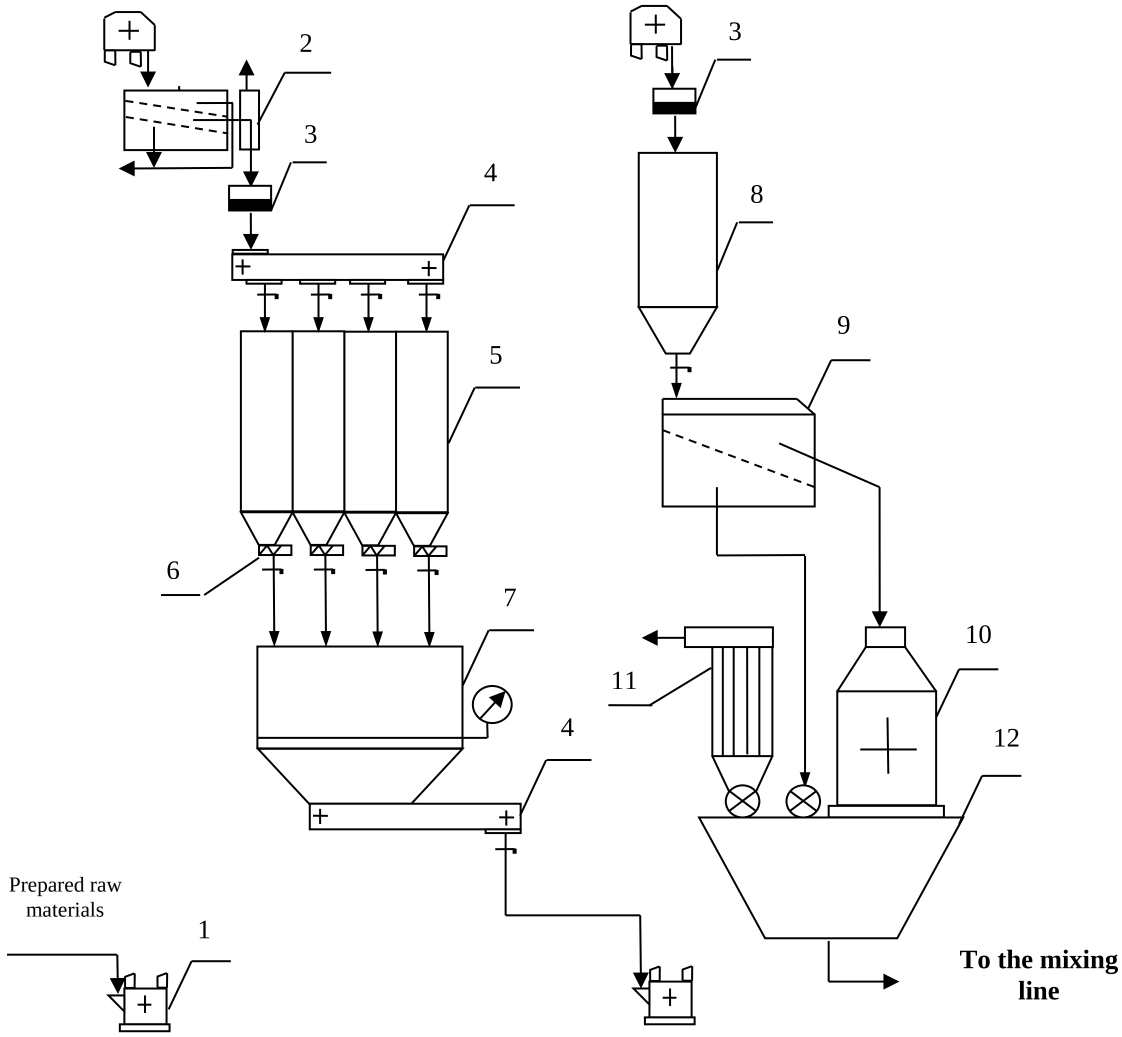


Figure 3. Scheme of the technological line of preparation of a portion of grain, powdery, mineral raw materials, and meals: 1 – elevator; 2 – air-sieve separator; 3 – magnetic column; 4 – conveyor; 5 – sack-off bins; 6 – screw feeder; 7 – multiple weigher; 8 – processing bin; 9 – sifting machine; 10 – hammer crusher; 11 – cyclone filter; 12 – submerged bunker.

The concentrate is to be introduced on the line preparing a portion of grain, powdery, mineral raw materials, and meals. The technological scheme developed provides for the purification of PPC from waste in an air-sieve separator A1-BIS-12 (2), in which two sieve frames are installed: the upper one is a sieve plate No. 100–160, the lower one is a sieve plate No. 10–14. Cleaning from metal-magnetic impurities is carried out on a magnetic column KM-20 (3) (productivity 20 t/h).

The PPC is supplied into a multiple weigher HWBA-2000 (7) with a capacity of 2000 kg with the help of the elevator NM-50 (1) and the conveyor K4-UTF-200 (4) from the sack-off bins (5) with the screw feeders PS-320 (6). After the weighing, the PPC, along with the first portion, with the help of a scraper conveyor K4-UTF-200 (4) of the passport capacity 50 t/h, and with the help of the elevator NM-50 (1) of the passport capacity 50 t/h, is fed into the magnetic column KM-20 (3) (productivity 20 t/h) to be cleaned from metal-magnetic impurities. After the purification, the grain enters the processing bin (8), then the sifting machine VZ 800x2000 (9) of the passport capacity 20 t/h. For the purification, a sieve plate No. 30–40 is installed. One side of the sieve is directed to the submerged bunker (12), and the other – to the hammer crusher NM 650-500 (10), with the passport capacity 20 t/h.

The portion of crushed components is directed to the mixing line.

To increase the nutritional value of finished products, a line of extrusion of leguminous crops is supposed to be installed. It is to process a 1:1 mixture of soybeans and peas (Figure 4).

The technological scheme developed provides for the purification of grain raw materials from waste in an air-sieve separator A1-BIS-12 (2), in which two sieve frames are installed: the upper one is a sieve plate No. 100–160, the lower one is a sieve plate No. 10–14. Cleaning from metal-magnetic impurities is carried out on a magnetic column KM-20 (3) (productivity 20 t/h).

The purified grains are supplied to the overcrusher bins (5), then the soybeans and peas from the sack-off bins are provided into the multiple weigher HWBA-2000 (7) of the capacity 2000 kg, with the help of the screw feeders PS-320 (6). After the weighing, the grain material, by means of the elevator NM-5 (1) and the conveyor K4-UTF-200 (4), is supplied into the magnetic column UZ-DKM-00 (8), with the productivity 5 t/h, to be purified from metal-magnetic impurities. Then, the grain material goes to processing bin No 8, and then, to the conditioner CM 2/5 (9), with the productivity 5 t/h, that moisturizes the product. The softened raw material is fed further into the extruder EZ-150 (10), where the mixture is extruded. The hot extrudate is cooled in the cooler VK 14x14 R (11) with a capacity of 5 t/h, and then enters the roller breaker SRM 855 SS (12), with the passport capacity 10 t/h. Then, the extruded feed additive is sent to the line of preparation of a portion of grain, powdery, mineral raw materials, and meals.

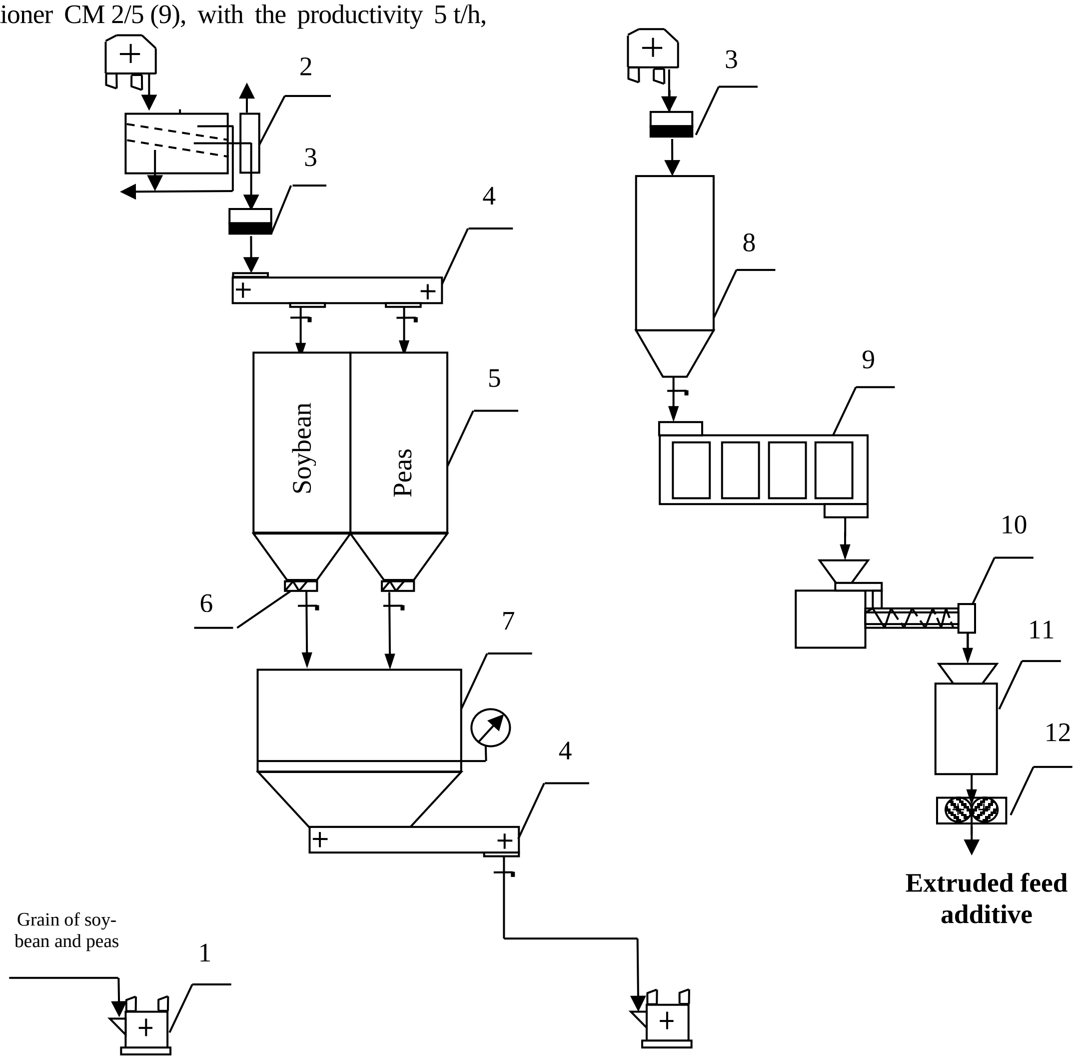


Figure 4. Scheme of the technological line extruding leguminous crops: 1 – elevator; 2 – air-sieve separator; 3 – magnetic column; 4 – conveyor; 5 – sack-off bins; 6 – screw feeder; 7 – multiple weigher; 8 – processing bin; 9 – conditioner; 10 – extruder; 11 – cooler; 12 – roller breaker.

The samples of the feed additive have been studied as for the parameters most characteristic of the physical properties of the finished product and the effectiveness of extrusion (Table 4).

The extruded feed additive has satisfactory physical properties. The extrudate expansion index, which was 2.1, with the diameter of the extruder matrix head 10 mm, indicates deep structural and mechanical changes that occurred during the extrusion.

To manufacture compound feeds for farm animals and poultry, it is important nowadays to develop recipes of high quality feeds using high-protein raw materials that will reduce the cost, but not the nutritional value of feeds – quite the contrary, will provide animals with all essential nutrients and biologically active substances.

The recipes of complete compound feed for pigs (Table 5) have been developed using the software package “Korm Optima Expert” programmed to calculate recipes with the minimum cost, taking into account the constraints of the input of each component and the nutritional value of the finished product, by means of linear programming.

Table 4 – Physical properties of the extruded feed additives

Parameters	EFA
Moisture content, %	10.6
Bulk density, kg/m^3	450.0
Flowability, cm/s	8.5
Angle of repose, degree	39.0
Size modulus, mm	1.2
Extrudate expansion index	2.1

Table 5 – Ingredients and quality characteristics of the recipes of complete compound feeds for piglets aged 43–60 days

Ingredients	Mass percentage, %	
Wheat	16.60	16.60
Barley without films	13.73	13.73
Maize	29.48	29.48
Extruded feed additive	15.00	15.00
Soybean meal 46%	11.79	11.79
Protein plant concentrate	–	5.00
Yeast feed 38 %	7.20	2.20
98% lysine monochlorhydrate	0.26	0.26
Methionine 98.5 %	0.21	0.21
Salt	0.25	0.25
Monocalciphosphate	1.80	1.80
Feed chalk	2.68	2.68
Premix	1.00	1.00
Total	100	100
Quality parameters		
Exchange energy, MJ / Kg	12.8	12.8
Feed units in 100 kg	115	115
Crude protein, %	18.00	18.20
Crude fibre,%	3.72	3.71
Lysine, %	0.90	0.92
Methionine + cystine,%	0.60	0.60
Ca, %	1.00	1.00
P, %	0,80	0.80
NaCl, %	0,34	0.34
Cost		
The price of compound feed, UAH/t	5841.9	5781.9

To determine the cost effectiveness, formulations of compound feeds for piglets aged 43–60 days have been calculated. The feeds contained an extruded feed additive and protein plant concentrate. Thus, minimum cost recipes of complete compound feeds for piglets aged 43–60 days have been developed. They meet the feeding standards and restrictions on the introduction of the components, and can be used for pigs' adequate nutrition on farms. Compound feeds containing an extruded feed additive and protein plant concentrate are cheaper and of high nutritional value. The use of protein plant concentrates can reduce the cost of compound feeds by 60 UAH/t.

Samples of compound feeds have been studied for the following parameters: moisture content, angle of repose, flowability, bulk density, size modulus. The results of the study are given in Table 6.

Table 6 – Physical properties of compound feeds with the use of protein plant concentrates

Parameters	Compound feed
Moisture content, %	11.2
Bulk density, kg/m^3	515
Flowability, cm/s	14.5
Angle of repose, degree	48
Size modulus, mm	1.8

As can be seen from the data obtained, when yeast feed is replaced with a protein plant concentrate in a compound feed for 43–60 days old piglets, it does not significantly affect the physical properties of the compound feed. Thus, the analysis of the research results shows that compound feeds for pigs are characterized by satisfactory physical properties.

Conclusions

– Physical properties of protein plant concentrates have been studied;

– A technological scheme for the introduction of protein plant concentrates in the production of compound feed has been developed;

– The choice of protein raw material for the production of extruded feed additive has been explained;

– The technological scheme of the line of leguminous crops extrusion has been developed;

– The physical properties of the extruded feed additive have been studied;

– The recipes of complete compound feeds with the use of protein plant concentrates have been calculated;

– The physical properties of compound feeds with the use of protein plant concentrates have been determined.

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