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DEVELOPMENT OF EXTRUDED ANIMAL FEED BASED ON FAT AND OIL INDUSTRY WASTE

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The paper considers the way to solve the problem of processing waste from the oil and fat industry, namely sunflower and soybean meals, which are a source of many valuable substances. The peculiarity of the work lies in determining the rational ratio of the base components of extruded animal feed, which is an important aspect of obtaining high-quality competitive products.

The research object is the use of oil and fat industry waste in extruded animal feed technology. The rational ratio of the components of extruded animal feed has been determined. The rational ratio of animal feed components is: sunflower meal – 0.40 parts by weight; soybean meal – 0.25 parts by weight; oatmeal – 0.35 parts by weight. The animal feed sample with justified composition corresponds to the commercial analogue in terms of porosity (72 % and 76 %, respectively) and cost ($285/t and $285/t, respectively). In addition, the extruded feed with the developed composition exceeds the commercial analogue in terms of protein content by 3.2 times and essential amino acids content by 2.9 times. The obtained data are explained by the use of a complex of components, namely oil and fat waste and starch-containing grain raw materials with various limiting amino acids and various technological features of the extruded mass of their mixture. The feature of the obtained results is the possibility to control the technological characteristic (porosity) of the finished product depending on the components ratio, which allows changing product characteristics according to consumer requirements. The research results make it possible to efficiently process secondary products of oilseed processing into a new competitive marketable product. From a practical point of view, the technology makes it possible to reduce the cost of storage/utilization of industry waste, get additional income from new products sales and improve environmental conditions. The applied aspect of using the scientific result is the possibility to create a range of animal feed with different technological indicators depending on the components ratio

Keywords: extruded feed, sunflower meal, soybean meal, oatmeal, amino acid score, technological indicators

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1. Introduction

The volumes of oilseed processing in the world are constantly growing. The results of world production of sunflower as the main oilseed crop showed all-time record results of 57.2 million tons in the 2021/22 marketing year. According to the State Statistics Service, even under conditions of armed aggression by russia, Ukrainian farmers harvested a record crop of oilseeds in the 2021/22 season: sunflower – 16.4 million tons, soybeans – 3.4 million tons, and rapeseed – 2.96 million tons. Thus, sunflower production in Ukraine accounted for 31% of world production [1].

In addition to the target product (oil), secondary oil- and protein-containing processed products (in particular, meal) are formed in oilseed processing. In the absence of effective industrial processing, these secondary products are sent for storage or disposal [2, 3]. Effective processing of secondary products of oil and fat production makes it possible to reduce the costs of storage/disposal of such waste, obtain additional income from new products sales and also improve environmental conditions. The constant growth of global volumes of oilseed processing only exacerbates the existing problem of production waste accumulation [4].

Meal is a waste of oil and fat production, a by-product obtained during oil crops processing by the extraction method. Meal is mostly used as an additive to the diet of farm animals, as well as a component of compound feed. Meal has a high hygroscopicity, so it cannot be stored for a long time. Storage at high humidity leads to microbiological deterioration of the waste with unpleasant smell release and mold formation. Utilization of meal requires large energy and financial costs. One of the ways to effectively use oilseed meal is to make protein products from it with specified structural and mechanical properties for animal nutrition. It is worth noting that oilseed proteins have a high biological value, which is negatively affected by the presence of anti-alimentary factors in the composition, in particular, inhibitors of proteolytic enzymes [5, 6].

Thus, in order to optimize oil and fat production, reduce waste amount and develop new feed products, it is advisable to improve the technology of oilseed processing into a protein product for animal nutrition. The scientific results of the outlined direction are important, because there is a need to reduce the amount of irrationally used production waste while expanding the raw material base for protein feed products.

2. Literature review and problem statement

The health and life expectancy of any creature, both human and domestic animal, largely depends on the quality, quantity, composition and balance of nutrition. The diet of animals mainly consists of proteins and fats of vegetable and animal origin with a relatively small amount of vegetable carbohydrates. A number of additives are introduced into rations, in particular, trace elements, protein-vitamin supplements and others to improve animals' nutrition [7]. Improvement and creation of new animal feed types with high nutritional and biological value are urgent tasks.

Meal is a by-product of the oilseed pressing stage. The properties of meal significantly depend on a number of factors: crop type, variety, place of growth, oil extraction technologies, storage and transportation conditions. Meal contains 34–46 % proteins, up to 2 % lipids, 8–10 % moisture and up to 20 % fiber. Proteins contained in seeds are transformed during processing into a protein group, which includes such important amino acids as methionine, tryptophan, cystine and others [4, 8]. The disadvantages of meal as a raw source of plant proteins include [9]:

– unstable chemical composition;

– short storage period, which can lead to raw materials rotting and oil oxidation;

– sunflower meal has a low lysine content;

– incomplete inactivation of anti-alimentary factors in meal can lead to animal poisoning;

– long-term meal presence in the animal diet can lead to poisoning by hexane used during oil extraction.

The limitation for sunflower meal usage is the presence of chlorogenic (about 1.5 %) and quinic (about 0.5 %) acids in it, which can act as trypsin and lipase inhibitors. Soybean meal contains trypsin inhibitors. Soybean meal has a low fiber content, which is only 72 g in 1 kg of product (in sunflower meal, this figure reaches 152 g, and in flax meal – 145 g). Soybean meal is characterized by a high content of easily digestible protein (up to 42 %) and its completeness. Soy fodder contains all nonessential amino acids necessary for animals. In the case of complete inactivation of anti-alimentary factors, soybean meal is comparable to meat and fish meal in its nutritional value and protein content [9, 10].

One method to make dry animal feed is extrusion. In a short period of time, raw materials manage to undergo several types of processing: heat treatment, grinding and mixing, partial dehydration, stabilization, texturization, sterilization and disinfection. After such processing, the sanitary indicators and palatability of feed can be improved, macromolecules are broken down, which leads to an increase in the feed nutritional value. An extrudate with a pleasant bready taste and smell is obtained as a result of such complex processing [11, 12].

Extrusion consists in the crushing and mixing of raw materials. Raw materials are exposed to high temperature (120–190 °C) and pressure (25–50 atm.) in a short period of time (5–7 s), which allows them to be completely decontaminated. As a result, porous granules are formed, which in the final stage are dried and coated with fats of animal and vegetable origin, stabilized with antioxidants with the addition of the necessary set of vitamins. As the effect of these processing parameters on raw materials is short-term, nutrients, including vitamins, are preserved, while pathogenic microflora and mold fungi are destroyed. The taste qualities of the finished product are improved as a result of such processing. The shelf life of dry extruded feed is 10–12 months, of some low-fat types – 12–18 months [12].

Raw materials in extruded form were included in the experimental compound feed in [13]. Grass flour was replaced with grass meal, sunflower meal – with fodder beans. Peas were used in parallel to enrich the compound feed with protein. Fodder beans and peas were used in extruded form. Wheat content in the compound feed was compensated by rye (triticale) and corn, which, in turn, enriches the compound feed with starch. In order to regulate the protein level and compensate for the lack of phosphorus, diammonium phosphate was added to the experimental feed, and Glauber's salt was added to eliminate the sodium and sulfur deficiency. A slightly larger amount of molasses was included in the experimental compound feed to adjust the sugar-protein ratio in the diet of the experimental group. This feed is optimized in terms of phosphorus, sulfur and sodium, copper, zinc, manganese, cobalt, iodine, selenium, vitamins A, D, E. An unresolved issue in the proposed method is a lack of data on the effect of the selected components on the technological parameters of the obtained extruded product, in particular porosity.

The impact of extrusion processing on cereal and leguminous fodder digestibility was considered in [11], it increased to 85–90 %. A 5–8-fold increase in soluble substances of raw materials was noted. Replacement of non-extruded soybean meal in animal feeding rations with extruded compound feed made it possible to increase their weight indicators. Feed consumption per 1 kg of live weight gain decreased by 100 g. The cereal-legume mixtures produced by this extrusion method contained all essential amino acids and were an animal protein analogue. The disadvantage of this development is a low amount of lysine and methionine in the feed recipe.

There is a known method [14] for obtaining protein feed in the form of sunflower meal based on ozone treatment, which increases the storage duration from three to six months while preserving the original quality. The obtained protein feed after ozone-air mixture disinfection is harmless and can be fed to animals, which leads to increased productivity, feed conversion and body resistance. Among the shortcomings of this study, it is possible to point out the preservation of essential anti-alimentary factors in their native form under the specified processing conditions. This leads to a decrease in feed nutritional value.

The indicators of piglets during rearing when using extruded grain feeds in their rations were evaluated in [15]. It was shown that the extrusion of grain components in rations increases the intensity of piglets live weight gain by 11.5–12.7 % and leads to a decrease in feed consumption per 1 kg of animal growth by 14.5 %. The disadvantage of the study is a lack of data on the influence of extruded oil and fat waste in the diet on the intensity of animal weight gain.

Ready-made formulation of compound feed was used as a basis of compound feed production in [16]:

– ground wheat (58 %);
– soybean meal (18.6 %);
– extruded soy (12 %);
– sunflower oil (6 %);
– limestone (1.2 %);
– monocalcium phosphate (0.7 %);
– premix (3.5 %).

Part of the wheat in the recipe was replaced with alfalfa protein-vitamin coagulate (5.4 %) and subjected to extrusion. The quality of the compound feed was improved due to enrichment with vitamins, essential amino acids and vegetable protein with the addition of alfalfa protein-vitamin coagulate. But the work did not consider the issue of rationalizing technological indicators in the context of expanding the composition of compound feed.

The use of non-traditional types of raw materials in the production of compound feed for valuable fish species, modes of production technology of experimental compound feed by the extrusion method and its storage terms were considered in [17]. It was found that the most promising sources of raw materials for valuable types of fish were soybeans, pea isolates and concentrates, wheat and corn gluten, meal and cake (soybean, flaxseed, rapeseed). A 1.2–1.5 times increase in the nutritional value of the developed compound feed was achieved. Additional vitamins and minerals were added to the composition. The disadvantage of the study is the technology complexity and multicomponent nature of the developed formulations (up to 18 components).

The effect of extruded compound feed with a complex preparation of metal nanoparticles on the fish body was evaluated in [18]. The components of the combined feed were: fish meal (20 %), meat and bone meal (6 %), sunflower meal (25 %), soybean meal (35 %), vegetable oil (5 %), wheat flour (8 %), premix (1 %). The production of compound feed included the mixing of compound feed components with metal nanoparticles by the method of stepwise mixing and actual extrusion. It was found that the use of extruded compound feed with metal nanoparticles in feeding cold-blooded animals was accompanied by an increase in growth intensity. But the research lacks justification of compound feed composition, as well as data on the total protein biological value.

Thus, there is a lack of scientific data on the specifics of processing oil and fat industry waste, namely oilseed meal into protein products for animal nutrition. There are no data on the rational ratio of the base components of extruded animal feed from a physiological point of view, the dependence of technological indicators of the extruded mass, in particular porosity, on its components ratio. In this regard, it is necessary to improve the technology of processing waste from oil extraction production (meal) to obtain raw materials for extruded animal feed. In terms of feed biological value, it is important to determine the content of protein and essential amino acids in the developed product. This development will help solve the problem of waste accumulation, greening of oil extraction industries and optimization of rations of a wide range of farm animals.

3. The aim and objectives of the study

The aim of the study is to justify the development of extruded animal feed based on oil and fat industry waste. This will make it possible to green the oil and fat industries while obtaining high-quality, competitive animal feed.

To achieve the aim, the following objectives were accomplished:

– to determine the chemical composition of raw materials as a base of extruded animal feed;
– to determine the rational ratio of the base components of extruded animal feed;
– to compare the composition and technological indicators of extruded animal feed with a commercial analogue.

4. Research materials and methods

4. 1. Research object and hypothesis

The object of research is the use of oil and fat industry waste in the technology of extruded animal feed. The main hypothesis of the study is the possibility to increase the nutritional value of animal feed by combining oil-fat waste and starch-containing raw materials.

The following assumptions have been made in the study:

– combination of protein-containing waste of the oil and fat industry and starch-containing grain raw materials should provide satisfactory technological properties of the extruded mass, in particular, porosity;
– combination of protein-containing waste of the oil and fat industry with different amino acid composition should increase the amino acid score of the product total protein.

The following simplifications have been adopted in the study:

– oil and fat meal as a raw material component of extruded animal feed has a similar content of fat, moisture and volatile substances as the meal studied in this work. This should provide the repeatability of the determined regularities when combining other similar oil and fat industry waste with starch-containing grain raw materials.

4. 2. Researched materials and equipment used in the experiment

The following materials and reagents were used during the research:

– crushed sunflower meal (produced in Ukraine), according to DSTU 4638/CAS 68937-99-5;

– crushed soybean meal (produced in Ukraine), according to DSTU 4230/CAS 68308-36-1;

– crushed oat groats (produced in Ukraine), according to DSTU 7698/CAS 97-56-3.

4. 3. Extrusion method for oil and fat industry waste and grain raw materials

Research of the extrusion process of oilseed meal and grain raw materials mixtures was carried out on a PE-20 press extruder designed for pressing plant materials and producing swollen extrudates. The PE-20 press extruder has a replaceable screw, at the end of which there is a "torpedo" nozzle with four longitudinal grooves of a rectangular cross-section, which serves as a compression shutter. The screw is driven through a V-belt transmission from an asynchronous electric motor. The change in the screw rotation speed is controlled by changing the pulleys of the V-belt transmission. The head of the press extruder allows you to install matrices of various designs. The extrusion material is fed into the feeding funnel, which is connected by the screw body. The screw angular speed is measured using a tachometer. Process temperature control is carried out in the area of the forming head using a mini-multimeter. Weighing of initial components and analyzed samples was carried out on laboratory scales. The temperature of the extruded material in the pre-matrix zone did not exceed 150 °C. The screw rotation speed was 250 rpm.

4. 4. Methods of determining the chemical composition of samples of oil and fat industry waste, starch-containing raw materials and extruded feed

The mass fraction of moisture and volatile substances in samples of oil and fat industry waste, starch-containing raw materials and extruded feed was determined by the gravimetric method according to DSTU 7621. The protein mass fraction in samples of oil and fat waste, starch-containing raw materials and extruded feed was determined by the Kjeldahl method according to DSTU 7169. The mass fraction of lipids and fiber in samples of oil and fat waste, starch-containing raw materials and extruded feed was carried out by the extraction method according to DSTU 7491. The carbohydrates content in samples of oil and fat waste, starch-containing raw materials was determined by the polarimetric method according to DSTU ISO 6493. The ash content in samples of oil and fat waste, starch-containing raw materials was determined by the method of burning with subsequent calcination of the mineral residue at 450...600 °C according to DSTU ISO 5984.

4. 5. Method of determining the amino acid composition of samples of oil and fat industry waste, starch-containing raw materials and extruded feed

Protein amino acid composition of samples of oil and fat waste, starch-containing raw materials and extruded feed was determined by ion-exchange column chromatography according to DSTU ISO 13903. Amino acid analysis was carried out on an LKB 4151 Alfa Plus amino acid analyzer (Sweden). A portion of the studied samples was crushed, protein was hydrolyzed with hydrochloric acid in a thermostat at 110 °C for 24 hours. Hydrochloric acid was evaporated, the resulting sample was neutralized and dried in a desiccator with NaOH presence. The resulting sample was dissolved in a buffer solution (pH 2.2) and filtered. The prepared sample was then injected into the ion exchange resin column. Buffer solutions with different pH values were successively passed through the ion exchange column to separate the amino acids of the test sample. The eluate leaving the ion exchange column entered into a qualitative reaction with ninhydrin. The resulting mixture was sent to a photometer for the quantitative amino acids identification through solutions optical density measurement. The concentration and type of amino acids were recorded automatically.

4. 6. Method of determining the amino acid score of samples of oil and fat industry waste, starch-containing raw materials and extruded feed

The amino acid score is the main indicator of the protein biological value. It is the ratio of the essential amino acid mass fraction in the protein under study to the value of the amino acid fraction in the reference protein (according to the amino acid scale of the Food and Agricultural Organization of the United Nations (FAO) [19]). The amino acid score of the samples is determined by comparing the content of each essential amino acid in the investigated raw material protein with the content of the same amino acid in the "ideal" reference protein. The amino acid score (C) of essential amino acids was calculated by the formula (1):

$$C_j = \left(AA_i / AA_i^{stand} \right) \cdot 100, \quad (1)$$

where C_j – amino acid score of the i-th essential amino acid of the protein, %;

AA_i – content of the essential amino acid of the studied protein, g/100 g of protein;

AA_i^{stand} – essential amino acid content in the reference protein, g/100 g.

4. 7. Method of determining extruded feed porosity

Samples of extruded material were covered with waterproof varnish and placed after drying in a measuring cylinder with water. Taking into account the mass of water displaced from the cylinder, the volume of the sample of extruded material with pores was determined. The extrudate sample was then pressed, after which its volume was measured. The porosity of extruded feed (%) was determined by the formula:

$$P = (1 - V_p / V_w) \cdot 100, \quad (2)$$

where V_p – volume of extrudate with pores, mm^3;

V_w – volume of extrudate after pressing, mm^3.

4. 8. Research planning and results processing

Scheffe's simplex lattice design was used in the work to plan the experiment. Each experiment was repeated three times. Processing of the obtained data and construction of graphical dependencies were performed using the Stat Soft Statistica v 6.0 package (USA). The statistical model of dependence was determined by approximating the experimental data by constructing a trend line.

The significance test of the coefficients of approximation dependence equation (3) was determined using the least squares method. The significance of the equation coefficients was determined using the Student's test by testing the hypothesis that the corresponding parameter of the equation was equal to zero. The calculated absolute value of the Student's criterion when evaluating individual coefficients of the approximation dependence equation was compared with its critical table value at the significance level p=0.05 and the number of degrees of freedom for the approximation dependence df=9. If the calculated value of the Student's criterion was greater than its critical table value, then the null hypothesis was rejected and the value of the corresponding coefficient of the approximation dependence equation was recognized as significant with a probability of 95 %. If the calculated value of the Student's criterion was less than its critical table value, such a coefficient was considered insignificant and excluded from the dependence equation.

The quality of the approximation dependence equation (3) and completeness of the selected factors influence were assessed using the coefficient of determination R^2. The obtained value of R^2=0.952 allows us to conclude about the influence, greater than 95 %, of variations in the component ratio of extruded mass on variations in its porosity. The significance of the approximation dependence equation (3) was determined by calculating the Fisher's test (F) based on the assumption (null hypothesis) that the equation is statistically insignificant. The calculated value of the Fisher's test was F(3, 6)=39.916 and was greater than its critical table value F_{table}(3, 6)=4.76 at the significance level p=0.05. This result allows us to reject the null hypothesis and with a probability of 95 % recognize the value of the determination coefficient R^2=0.952 as significant, and the approximation dependence equation as significant.

5. Results of studies on the use of fat and oil industry waste as a base for extruded animal feed

5. 1. Determination of the chemical composition of raw materials as a base of extruded animal feed

The chemical composition of experimental samples of oil and fat industry waste, as well as starch-containing raw materials, selected as a base of extruded animal feed, was determined. The obtained data are given in Table 1.

Table 1

Chemical composition of samples of oil and fat waste and starch-containing raw materials selected as a base of extruded animal feed

Raw materials	Content, %					
	moisture and volatile substances	protein	lipids	carbohydrates	cellulose	ash
Sunflower meal	10.1	39.8	1.7	24.2	15.1	7.8
Soybean meal	9.5	43.1	1.2	34.7	5.4	4.6
Oat groats	12.0	12.6	6.1	59.0	8.0	1.8

According to the research results, experimental samples of fat and oil waste, as well as starch-containing raw materials, meet the requirements established in the relevant regulatory documentation – DSTU 4638/CAS 68937-99-5, DSTU 4230/CAS 68308-36-1, DSTU 7698/CAS 97-56-3.

The content of essential acids and quality assessment (according to the amino acid rate (C_a, %) of protein from fat and oil waste and starch-containing raw materials are given in Table 2.

Table 2

Content of essential acids of oil and fat waste and starch-containing raw materials

Essential amino acids	FAO nutrient reference values [19]	Sunflower meal		Soybean meal		Oat groats	
		Content, mg/100 g protein	C_a, %	Content, mg/100 g protein	C_a, %	Content, mg/100 g protein	C_a, %
Valine	5,000	1,056	21.1	2,244	44.9	938	18.8
Leucine	7,000	1,292	18.5	3,662	52.3	1,283	18.3
Isoleucine	4,000	794	19.9	2,181	54.5	695	17.4
Lysine	5,500	735	13.4	2,992	54.4	704	12.8
Methionine+cystine	3,500	844	24.1	1,324	37.8	717	20.5
Phenylalanine+Tyrosine	6,000	1,377	23.0	4,046	67.4	1,471	24.5
Tryptophan	1,000	363	36.3	655	65.5	233	23.3
Threonine	4,000	832	20.8	1,950	48.8	577	14.4

According to the research results, the calculated amino acid score of experimental samples of oil and fat waste, as well as starch-containing raw materials, indicates that the selected raw materials are a source of essential amino acids. The discrepancy between the amino acid score of essential amino acids is rather low in the protein of sunflower meal and oatmeal, and somewhat higher in the protein of soybean meal, which affects its biological value. Therefore, it is of interest to create combined extruded products based on the selected components.

5. 2. Determination of the rational ratio of the base components of extruded animal feed

The dependence of extruded mixture mass porosity on the ratio of components, namely sunflower meal (c_{sf}), soybean meal (c_{sb}) and oatmeal (c_{om}), was studied in order to determine the rational ratio of the base components of extruded animal feed.

Approximation dependence of extruded mass porosity on the ratio of sunflower meal (c_{sf}, mass fraction), soybean meal (c_{sb}, mass fraction) and oatmeal (c_{om}, mass fraction) is presented using equation (3).

$$P(c_{sf},c_{sb},c_{om})=59.0571\cdot c_{sf}+ +67.3429\cdot c_{sb}+85.0571\cdot c_{om}+ +11.5714\cdot c_{sf}\cdot c_{sb}-1.2857\cdot c_{sf}\cdot c_{om}+ +2.5714\cdot c_{sb}\cdot c_{om}. \quad (3)$$

Table 3 shows the experiment planning matrix, as well as experimental and calculated porosity values of the extruded mass depending on the components ratio. The calculated values of the response function were obtained using the regression equation (3).

Table 3

Dependence of extruded mass porosity on components ratio

Sample No.	Content of components in the mixture, parts by weight			Extruded mass porosity, P (c_{sf}, c_{sb}, c_{om}), %	
	Sunflower meal, c_{sf}	Soybean meal, c_{sb}	Oat groats, c_{om}	Experimental values	Estimated values
1	1	0	0	60	59.1
2	0	1	0	68	67.3
3	0	0	1	85	85.1
4	0.66	0.33	0	63	63.7
5	0.33	0.66	0	67	66.5
6	0	0.66	0.33	72	72.1
7	0	0.33	0.66	80	78.9
8	0.66	0	0.33	66	66.8
9	0.33	0	0.66	76	75.3
10	0.33	0.33	0.33	73	71.2

The surface of the obtained dependence of extruded mass porosity on the components ratio is shown in Fig. 1.

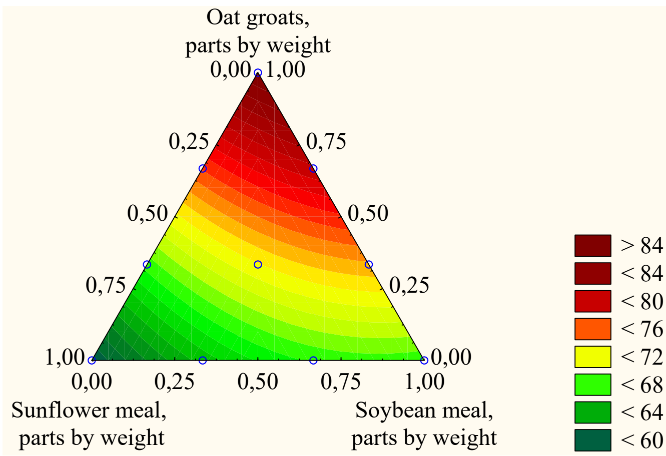

Fig. 1. Dependence of extruded mass porosity on its components ratio

It should be noted that the given approximation dependencies adequately describe the porosity of extruded mass in the 0...100 % components ratio range. Thus, the range of raw components ratios has been outlined, in which the extruded mass porosity is 70...75 %:

– sunflower meal – 0.35 ... 0.50 parts by weight;
– soybean meal – 0.25 ... 0.80 parts by weight;
– oat groats – 0.20 ... 0.45 parts by weight.

An increase in the oatmeal mass fraction in the mixture leads to an increase in extruded mass porosity. The presence of sunflower meal in the extruded mass negatively affects its porosity compared to soybean meal content (extruded sunflower meal porosity is about 60 %; soybean meal porosity is about 68 %).

The rational ratio of animal feed components was chosen based on the obtained research results, in particular, extruded mass porosity, protein content in raw components and their cost characteristics [20–22]:

– sunflower meal – 0.40 parts by weight;
– soybean meal – 0.25 parts by weight;
– oat groats – 0.35 parts by weight.

The extruded mass based on fat and oil industry waste and starch-containing raw materials of the specified composition contains 31.1 % protein, has 72 % porosity, and the cost characteristics of the initial mixture are about $285/t.

5. 3. Comparison of the composition and technological indicators of extruded animal feed with a commercial analogue

The composition and technological indicators of the developed extruded animal feed with a justified composition have been determined. The results of the study have been compared with the same indicators of a commercial analog (the composition declared by the manufacturer: extruded mixture of corn, barley, wheat), which has been chosen as a control sample of extruded feed. The cost of the commercial analogue was about $273/t [23]. The chemical composition of the developed samples of extruded feed is given in Table 4.

Table 4

Chemical composition of the developed extruded animal feed and its commercial analogue

Content, %	Extruded feed samples	
	Developed	Commercial analogue (control sample)
Moisture and volatile matter	3.9	4.1
Lipids	3.1	1.8
Cellulose	9.8	8.8
Protein	31.1	9.6

The content of essential acids and protein quality assessment (by amino acid ratio (C_a, %) of the developed extruded animal feed and the commercial analogue are shown in Table 5.

According to the obtained research results (Tables 4, 5), the sample of the developed extruded feed with the specified composition does not differ in moisture content from the sample of commercial extruded feed obtained from grain crops (3.9 % vs. 4.1 %, respectively). A similar pattern is observed in lipid content (3.1 % vs. 1.8 %, respectively), as well as in fiber content (9.8 % vs. 8.8 %, respectively). But there is a significant difference between the studied samples in the composition of protein and essential amino acids. In particular, the protein content in the extruded feed with the proposed composition exceeds that in the control sample by 3.2 times (31.1% vs. 9.6 %, respectively). The content of essential amino acids in the developed extruded feed exceeds that in the control sample by 2.9 times (9,971 mg/100 g of protein vs. 3,454 mg/100 g of protein, respectively).

Table 5

Content of essential acids of the developed extruded animal feed and its commercial analogue

Essential amino acids	FAO nutrient reference value [19]	Developed extruded feed		Commercial analogue	
		Content, mg/100 g protein	C_a, %	Content, mg/100 g protein	C_a, %
Valine	5,000	1,307	26.1	409.0	8.2
Leucine	7,000	1,876	26.8	888.0	12.7
Isoleucine	4,000	1,115	27.9	381.0	9.5
Lysine	5,500	1,285	23.4	374.0	6.8
Methionine+cystine	3,500	926	26.5	250.0	7.1
Phenylalanine+Tyrosine	6,000	2,065	34.4	750.0	12.5
Tryptophan	1,000	390	39.0	93.0	9.3
Threonine	4,000	1,007	25.2	309.0	7.7

It should be added that the porosity of extruded feed with the proposed composition is lower than that in the control sample by only 4 % (72 % and 76 %, respectively).

6. Discussion of the results of developing extruded animal feed based on oil and fat industry waste

The use of oil and fat industry waste as raw material for extruded animal feed, namely sunflower and soybean meal (Ukraine), has been studied. In addition, a starch-containing component, namely oat groats (Ukraine) as a component of extruded feed has been investigated. Oil and fat waste, namely sunflower and soybean meal, has been chosen as a raw material for extruded feed for reasons of resource-saving and greening of production.

According to Table 1, sunflower and soybean meal is a significant source of protein (39.8 % and 43.1 %, respectively) and minerals (7.8 % and 4.6 %, respectively). In addition, sunflower meal contains a significant amount of fiber (15.1 %). In turn, oat groats are a source of carbohydrates – starch and pentosans (59.0 % total content), which has been used to regulate the technological characteristics of the extruded mixture, in particular porosity.

According to Table 2, the protein complex of the selected oil and fat waste has different first and second limiting amino acids (lysine and leucine for sunflower meal and methionine+cystine for soybean meal). This makes it expedient to use them together in the technology of extruded animal feed to solve the problem of balancing the amino acid composition of the finished product.

As a result of studies of such a technological indicator of extruded mass as porosity, its value has been modeled for a wide range of ratios of raw components (equation (3), Table 3, Fig. 1). This makes it possible to outline the range of ratios of raw components in which extruded mass porosity is within the specified limits (70...75 %), corresponding to the generally accepted requirements for extruded feed.

Having considered a complex of technological (porosity), physiological (content of protein and essential amino acids) and economic (raw materials cost) characteristics, the rational ratio of feed components has been substantiated. The proposed ratio is: sunflower meal:soybean meal:oat groats as 0.4:0.25:0.35, respectively. Based on a comparison of the specified characteristics of extruded feed with the developed composition with the commercial analogue (Table 4), a significant advantage of its physiological characteristics and equality of technological and economic indicators have been proved. Such advantages can be explained by the use of oil and fat waste as raw components in combination with a grain component having positive technological characteristics.

This development has some differences from [16, 17], where the production of high-protein extruded feed based on soybean meal with the addition of soybean isolates and other high-cost additives was proposed. The increase in protein content in the developed feed is 31.1 % (Table 4) due to the addition of sunflower meal, which has a much lower cost. This allows the wide use of the developed feed not only for keeping animals, but also for growing and breeding. The production of competitive protein-containing feed with high biological value becomes possible due to the combination of various raw materials, primarily oil and fat industry waste, taking into account their composition and predicting technological properties after extrusion.

The research results allow more effective use of oil and fat industry waste such as sunflower and soybean meal in the technology of extruded animal feed. The obtained results, in particular Table 2 and approximation dependence (3) are a scientific development that should contribute to a more rational use of sunflower and soybean meal as extruded feed components, as well as their justified combination with starch-containing grain components.

The limitation of the obtained research results is that oil and fat industry waste with fixed composition indicators has been used in the experiment:

– content of water, protein, lipids, carbohydrates (according to the data given in Table 1);

– amino acid composition and biological value (according to the data given in Table 2).

Therefore, in the case of using raw materials with a different composition in extruded animal feed technology, it is necessary to take into account these indicators to correct the given technological and physiological characteristics of the finished product.

The drawback of the study is the lack of data on the effect of changing the extruder technological parameters on the extrusion process. The process has been carried out at a fixed temperature in different areas of the extruder and screw rotation speed.

It is worth noting promising areas of work regarding the use of oil and fat industry waste as raw materials for extruded animal feed. This is primarily a study of the dependence of the technological characteristics of the finished product on the moisture and fat content of extruded raw material.

7. Conclusions

1. The chemical (content of moisture, protein, lipids, carbohydrates, fiber and ash) and amino acid (content of essential amino acids) composition of raw materials as the base of extruded animal feed has been determined. The selected

samples of oil and fat industry waste (sunflower and soybean meal), as well as starch-containing raw materials (oat groats) meet the requirements established in the relevant regulatory documentation – DSTU 4638/CAS 68937-99-5, DSTU 4230/CAS 68308-36-1, DSTU 7698/CAS 97-56-3.

2. The rational ratio of the base components of extruded animal feed has been determined using the analysis of the dependence of extruded mass porosity on its components ratio and relying on information about the protein content of raw components and their cost characteristics. The rational ratio of animal feed components is: sunflower meal – 0.40 parts by weight; soybean meal – 0.25 parts by weight; oat groats – 0.35 parts by weight.

3. The sample of justified composition corresponds to the parameters of the commercial analogue in terms of porosity (72 and 76 %, respectively) and cost ($285/t and $273/t, respectively). But extruded feed with the developed composition exceeds the commercial analogue in protein content by 3.2 times (31.1 % vs. 9.6 %, respectively) and in essential amino acids content by 2.9 times (9,971 mg/100 g of protein versus 3,454 mg/100 g of protein, respectively).

Conflict of interest

The authors declare that they have no conflict of interest regarding this study, whether financial, personal, authorship, or any other that could affect the study and its results presented in this paper.

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Data availability

The manuscript has no associated data.

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