Optimization of the protein product formulation based on safflower production waste

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Abstract. The global volume of feed production is growing annually, for example, in 2021 it increased by 2.3%, to about 1.2 billion tons against 1.19 billion tons in 2020. The production of compound feeds is a complex technological process that allows you to obtain a final feed product with the required characteristics from several types of raw materials. The effectiveness of the finished feed depends on its chemical composition, nutritional value, form of release, etc. Each type of feed mixture is made according to a certain recipe, taking into account the type of animal or bird, breed, direction, age and contributes to the maximum disclosure of the genetic potential of an individual. The main indicator of the high quality of compound feeds is their balance in accordance with the needs of animals in irreplaceable nutrition factors. Compliance with this provision ensures a high conversion of compound feeds into livestock products. Therefore, along with the expansion of the feed base at the expense of traditional types of feed, it becomes obvious that there is a need to expand the possibilities of using non-traditional feed products, especially of plant origin. However, there is currently no effective and simple technology for recycling waste after processing oilseeds, which is an effective and simple method with significant innovative potential in the feed industry. One of the promising directions in the development of waste management technology for processing oilseeds is the use of extrusion after rational preparation of this process, which includes an even distribution of waste and valuable components.

1 Introduction

The feed industry is designed to solve one of the most important tasks of the national economy: increasing the productivity of animal husbandry. The production of compound feeds is growing annually [1,2,3]. Thus, the global volume of feed production in 2021 increased by 2.3%, to about 1.2 billion tons against 1.19 billion tons in 2020. Their output grew most actively in the countries of the Asia-Pacific region: by 5.7%, to 458.12 million tons. African producers produced 44.22 million tons of compound feeds — 2.4% more than

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a year earlier. In Europe, feed production decreased from 270.2 million tons to 266.8 million tons [4]. The production of compound feeds is a complex technological process that allows you to obtain a final feed product with the required characteristics from several types of raw materials. The effectiveness of the finished feed depends on its chemical composition, nutritional value, form of release, etc. [5,6]. Each type of feed mixture is made according to a certain recipe, taking into account the type of animal or bird, breed, direction, age and contributes to the maximum disclosure of the genetic potential of an individual [7,8].

More than 100 types of components are used for the production of compound feeds [9]. The composition of a specific feed mixture is determined by the required nutritional and energy value, as well as the type, direction and age of the animals for which it was developed. The raw materials for the manufacture of compound feeds are: hay, straw, cake; grain raw materials (barley, oats, corn, beans, etc.); flour (herbal, fish, meat, bone, blood); starches (hydrol, molasses); mineral components (salt, chalk, shells); synthetic minerals, vitamins, antibiotics [10]. The basis for compound feeds is feed grain, as well as legumes, oilseeds, hay and haylage [11,12,13,14]. To enrich the product with fiber, herbal flour is added [15]. A search is underway for the possibility of reducing the amount of grain raw materials in the compound feed [16,17,18,19].

The main indicator of the high quality of compound feeds is their balance in accordance with the needs of animals in irreplaceable nutrition factors [20]. Compliance with this provision ensures a high conversion of compound feeds into livestock products. Therefore, along with the expansion of the feed base due to traditional types of feed, it becomes obvious that there is a need to expand the possibilities of using non-traditional feed products, especially of plant origin [21].

The use of unconventional raw materials in the technology of compound feeds solves a number of important tasks. Firstly, a decrease in the share of valuable grain raw materials in the composition of compound feeds, consequently, a decrease in their cost, an increase in biological value [22,23,24]. Secondly, the improvement of the ecological situation [25]. Therefore, the development of new types of compound feeds and concentrated products containing high dosages of various nutrients based on non-traditional plant raw materials, including secondary, is an urgent task.

Oilseeds are introduced into compound feeds in the form of their waste (cake, meal). For example, in the production of compound feed, grain raw materials in the structure of the feed balance in Kazakhstan 60....80% is grain. In this regard, the experience of a number of foreign countries deserves great attention, where the share of grain in the composition of compound feeds is from 30 to 60%, and the remaining 40...70% are raw materials of non—grain origin [26].

The production and processing of oilseeds such as safflower, as well as the further processing of oilseeds, in turn, lead to the formation of a significant amount of waste. Safflower is used as a feed for farm animals with a high protein content (15-40%) [27].

After the processing of oilseeds, the processing waste mainly contains a low-quality part of the main product - small hollow damaged seeds. But in general, this mass is oilseeds with a fat content of 20 to 63%, a well-balanced protein content, which includes arginine (2 times more than in corn and wheat), histidine, lysine and other essential amino acids [28]. Thus, oilseed proteins are an important additional source of dietary protein, which is of great importance in solving the protein problem.

To solve these problems, the most effective are developments in the field of waste processing of fat and oil production. This is due to the fact that they give a triple effect – a significant reduction in the cost of removal of production waste, additional revenue from sales of new products, improvement of the environmental situation [29]. Safflower is characterized by a low fiber content as a source of protein. It contains both protein and fiber. Despite the fact that it contains fewer minerals than soy meal, it is a good source of calcium, phosphorus and iron. In terms of vitamin content, safflower is somewhat superior to soy, although it contains very little vitamin B6 and is poor in vitamin E. It can be used as a vegetable additive in compound feed [30]. The chemical composition of safflower field waste for feed flour collected from Zhambyl region has been studied [31]. It is shown that field waste has feed value and contains a large amount of raw fat. Physico-chemical indicators of field waste safflower production are presented in Table 1.

Table 1. Physico-chemical indicators of field waste safflower production.

The name of the indicator	Actual results
Mass fraction of protein, %	6.08
Mass fraction of fat, %	2.49
Mass fraction of carbohydrates, %	18.7
Mass fraction of fiber , %	1.44
Mass fraction of ash, %	4.33
Mineral elements	mg /100g
Potassium	432.9
Magnesium	229.4
Phosphorus	450
Sodium	2.55
Calcium	50.7
Vitamin composition	mg /100g
B1	0.040
B2	0.039
B6	0.063
C	0.35
B3	0.17
B 5	5
B_c	0.021

As a result of research, it was found that safflower waste contains potassium 432.9mg / g, phosphorus 450 mg / g, magnesium 229.4 mg / g, which exceeds corn by 2-3 times. Field waste is inferior in calcium content to sunflower.

However, there is currently no effective and simple technology for recycling waste after processing oilseeds, which is an effective and simple method with significant innovative potential in the feed industry.

One of the promising directions in the development of waste management technology for processing oilseeds is the use of extrusion after rational preparation of this process, which includes an even distribution of waste and valuable components [32].

Extrusion technology is one of the types of deep processing of compound feeds. Also, the extrusion method makes it possible to increase the nutritional value and biological value of the resulting feed [33].

Particular attention should be paid to the higher digestibility of the resulting product (25-30% higher than usual), which makes it possible to increase weight gain during feeding (compared with traditional feed) and dramatically reduce the amount of waste [34].

The purpose and objectives of the study. The aim of the research is to create products containing high dosages of various nutrients from waste oilseeds. To achieve this goal, the following tasks will be solved: analysis of physical and chemical parameters of post-harvest waste and safflower processing waste; optimize the formulation of a protein product based on safflower production waste.

2 Materials and methods of research

The main materials of the study were waste from safflower processing – cake and waste from post-harvest processing of safflower. Well-known methods and equipment were used to analyze the physico-chemical parameters of post-harvest waste and safflower processing waste [35]. To optimize the formulation of an extruded protein product based on safflower production waste, studies were conducted in accordance with the rotatable method of experiment planning [36].

3 The results of the study

As a result of the work carried out, the physicochemical parameters of post-harvest waste and safflower processing waste were analyzed. It has been established that field waste and safflower cake processing waste have the following indicators presented in Table 1.

Table 1. Physico–chemical indicators of field waste and cake.

№	Indicators	Waste of fields	Cake	Indicators of compound feeds according to GOST
1	*Fat,%*	2.4	5 - 7	> 2.5
2	*Protein,%*	6	64 - 72	12 - 18
3	*Fiber, %*	1.44	2.8 – 4.1	< 12 -14
4	*Humidity,%*	2	12	2 - 4

To optimize the formulation of the extruded concentrated protein product based on safflower production waste, extrusion processing was carried out.

To obtain a protein product from safflower production waste, a two-component mixture consisting of safflower cake and waste from safflower cultivation fields was extruded according to GOST parameters. In order to determine the optimal ratio of cake and field waste, the dependences of the effect of the amount of protein (%), fiber (%), moisture content of the final product (%) on the percentage ratio of the components of protein concentrate (%) were studied.

To obtain a mathematical model of the technological process of producing an extruded protein product based on safflower production waste, which is a regression equation, where a rotating plan of the second order was used, in which the number of factors was 3, the number of planned experiments was more than 20, the number of experiments at the zero level was 6, and the number of coefficients of the equation was 10 [36]. The coding of intervals and levels of variation of input factors is presented in Table 1.

Table 1. Coding of intervals and levels of variation of input factors

Factors		Variation levels					Variation intervals
natural	coded	-1,68	-1	0	+1	+1,68	
Protein, %	x_1	6	22	38	60	70	6
Humidity, %	x_2	2	4.5	7	9.5	12	1
Fiber, %	x_3	1.44	2.1	2.8	3.4	4.1	1

The main factors were chosen: X1 — protein content, % by weight of the resulting mixture; X2 — moisture content of the raw material, % by humidity of the resulting mixture; X3 — fiber, % by weight of the resulting mixture.

Based on the processing of the results of mathematical processing of the technological process of obtaining an extruded protein product based on safflower production waste, the following results are obtained, presented in Table 2.

Table 2. Percentage of protein product components

№	Name	Proportion of protein product,%
1	*Cake, %*	17
2	*Waste fields, %*	83

The results of studies of the physico-chemical parameters of the protein product with a percentage of the components of the cake of 17%, and waste fields of 83% are presented in Table 3.

Table 3. Physico-chemical parameters of the protein product

№	Name	Percentage content
1	*Protein, %*	14.5
2	*Fiber, %*	3.2
3	*Humidity, %*	3.1

4 Discussion of the results obtained

Analysis of the physico-chemical indicators of waste fields and cake (Table 1) shows that the protein content in the cake exceeds the permissible norms according to GOST by several times, i.e. 70% at the rate of 18%, and the fiber content is less than the standard indicators (4% at the requirement of 14%).

Processing of the results allowed determine the optimal ratio of the components of the protein product. It was found that with a ratio of cake of 17% and field waste of 83%, the physico-chemical parameters of the protein product are: protein - 14.5%; fiber – 3.2% and moisture – 3.1%.

5 Conclusion

Based on the results obtained, it can be stated that the extrusion treatment of waste fields and safflower cake, allows you to obtain a protein product that meets regulatory requirements. The resulting protein product can be used as a balancing additive to coarse feeds. Also, the use of field waste and safflower cake in the production of compound feeds will reduce the proportion of grain in the composition of compound feeds.

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