

Organization of fodder production based on sunflower seed waste

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Abstract—For the implementation of Russia's State policy in animal husbandry, it is essential to seek reserves for fodder base. One of the largest producers of ingredients for high quality fodder is oil and fat industry manufacturing pomace and oil seed cakes as well as fats for food, feed and technical purposes. Sunflower is the main crop covering about 80% of cropland. Its gross harvest increased from 8,5 million tons in 2014 to 10,4 million tons in 2016. Nowadays, there are over 200 enterprises of oil and fat industry processing sunflower seeds. An effective method to support their development is to recycle waste of oil and fat production for feed purposes, which is in line with the set objective to strengthen the livestock fodder base. The most widespread and voluminous type of waste of oil and fat industry is sunflower seed waste. A rough estimate shows that when processing sunflower seeds the total amount of waste generated per year exceeds 1 million tons. Meanwhile, the mass fraction of crude protein in seeds can reach 19 %, whereas the mass fraction of crude fat is 21 %, which makes them valuable raw materials for fodder production. Attempts were made to recycle sunflower seed waste by pressing, granulation, grinding and adding them into pomace and oil seed cakes, but they did not find applications in the oil and fat industry. Therefore, commercial disposal of sunflower seed waste and its storage at industrial waste landfills is the most common method used in the Russian Federation, which may increase the hazard of fire and make environmental problems worse.

On the base of the carried out research, a universal technology of recycling sunflower seed waste has been developed which includes the separation of raw materials from small impurities and overall debris which is no longer fit for subsequent processing such as metals, mineral and organic impurities, husk; burning of seed husk and large organic impurities resulting in steam generation; the production of inedible technical fat and feed protein-lipid products by extrusion and pressing of remaining secondary oily raw materials. For implementation of this universal technology in oil and fat industry, a new production line with capacity 7.2 tons a day recycling sunflower seed waste has been developed which is able to process secondary oily raw materials. Standard equipment is used for above mentioned technological operations with the exception of the operation where husk and oil bearing dust are separated from the mixture of waste implemented by pneumatic gravitational method on a new pneumatic separator designed by the authors of this article.

An experimental production line has been assembled at OOO "Giaginsky Vegetable oil refining complex", which has been working steadily for three years recycling sunflower seed waste and producing inedible (technical) sunflower oil and feed protein-lipid products (pomace) for feed and technical purposes. At present preparations are being made to assemble a similar production line recycling sunflower seed waste at OOO "Kurganinsky vegetable oil refining factory".

Key words—sunflower seed waste, overall debris, large impurities, small impurities, extrusion, pressing, technical oil, feed protein-lipid product.

I. INTRODUCTION

As a result of the Governmental policy, Russia is to reach the compliance with recommended rational norms of per capita consumption of livestock products by 2020. Meat production is to increase 1,7 times, milk production – 27 % [6, 7, 8]. It is essential to find ways and means of fodder base to develop animal production.

Nowadays one of the largest producers of ingredients for high quality fodder is oil and fat industry. Apart from animal feedstuffs, enterprises processing oil-bearing seeds also produce vegetable oils for food and non-food (technical purposes). Pomace and oil seed cakes from sunflower seeds, soy, and rapeseeds are used for fodder production since there are a lot of components in their composition necessary for animal nutrition [3]. Vegetable oil for non-food purposes also can be used as an ingredient for fodder.

The area planted with oil-bearing crops and their gross harvest have grown gradually in the last years [5, 4], but sunflower is the main crop covering about 80% of cropland [4].

For the last three years the gross harvest of sunflower seeds increased from 8,5 million tons in 2014 to 10,4 million tons in 2016[9], while in order to provide 100 % loading of available refining capacities the total number of processing sunflower seeds in the Russian Federation must be no less than 17 million tons [2, 9, 12, 13]. That means that production capacities of oil and fat enterprises far outstrip the available amount of gross harvest of sunflower seeds and can be used to recycle other raw materials.

Nowadays there are over 200 enterprises of oil and fat industry on the territory of Russia processing sunflower seeds.

It is necessary to increase profitability and to improve competitiveness of production at vegetable oil refining factories. In this regard, one of the most effective methods is to introduce innovations in the field of waste disposal in fat and oil production [5, 9]. This development path comes in compliance with the objective set to improve the fodder base for animal husbandary.

The most widespread and voluminous type of waste in oil and fat industry is sunflower seed waste. A rough estimate shows that when processing sunflower seeds the total amount of waste generated per year exceeds 1 million tons [9]. The research on chemical composition of sunflower seed waste carried out in 1980-1990s showed that the mass fraction of crude protein in them can reach 19 %, while the mass fraction of crude fat is 21 % which makes them valuable raw materials for the production of animal feedstuffs [10, 11]. Attempts were made to recycle sunflower seed waste by pressing, granulation, grinding and adding them into pomace and oil seed cakes, but they did not find applications in the oil and fat industry. Therefore, commercial disposal of sunflower seed waste and its storage in solid waste disposal facilities is the most common method used in the Russian Federation. Decomposition of this type of waste stored at industrial waste landfills is accompanied by the absence of oxygen resulting in the formation of biogas containing 70 % methane, which is highly combustible, increases fire hazards and makes ecological environment even worse [6].

From our point of view, the lack of the developed universal technology and the steady working production line recycling waste of oil bearing seeds into fodder products is connected with the large amount of components of waste diverse in composition and properties, and substantial variability of their qualitative characteristics. A different quality level of sunflower seeds depends on the region where they grow, methods of their harvesting and cleaning [14].

A new approach was suggested for organization of production of fodder based on recycled sunflower seeds waste which includes the study of component and granular composition of sunflower seed waste; their division into components having more uniform composition and various feeding value; the search of recycling method for each component; the development of a technological operation of processing, and the selection of equipment for each operation.

II. METHOD

In order to determine component composition of samples under examination a method for recycling sunflower seed waste was applied [11]. Granular composition of sunflower seed waste was studied using an upgraded technology to determine the granulometric composition of pomace and oil seed cakes [16]. Sieves with aperture size from 1,0 to 5,0 mm in diameter and the distance between openings 0,5 mm were used.

The acid value of oil produced from sunflower seed waste was determined in accordance with GOST 1933. The peroxid value was determined in accordance with GOST 26593. Color of oil was determined in accordance with GOST 5477. Fatty

acid composition was determined in accordance with GOST 30418.

The fiber content of the feed protein-lipid product obtained from sunflower seed waste was determined on the system Fibretherm FT 12, which meets the requirements of GOST 31675. The protein content was calculated on the Automatic Steam Distillation Unit VELPUDK 149 in accordance with GOST 13496.4. Exhaustive extraction of oil from sunflower seed waste and feed protein-lipid products was carried out on Automatic System for solid-lipid extraction SoxthermSox414a. Mass fraction of crude ash was determined by its burning in accordance with GOST 13979.6.

The research results of statistical processing were obtained using generally accepted methods by performing a range of parallel measurements [15].

III. RESULTS AND DISCUSSION

Sunflower seed waste in oil and fat industry are produced when seeds are passed through aspirator-sieve separators in a Raw Material Preparation Workshop (primary cleaning) and before processing. (industrial cleaning) [4]. When cleaning sunflower seeds on separators, large foreign impurities are separated (sieve oversize) and small foreign impurities which are passed through bottom sieve (sieve undersize) and tail aspirations which are impurities separated on cyclone collectors [2]. This mass of wasting is referred to as debris. According to reference data [14] 70-95 % of tail aspirations of primary cleaning are particles of upper layer of soil. It is generally accepted that the upper layer of soil consists of mineral inorganic fraction (93 %) and organic fraction (7 %) [14]. Mineral fraction is represented by natural oxides, silicates, calcium aluminosilicates, magnesium aluminium silicates, and sodium aluminum silicates. Organic fraction is represented by dead organic matter (95 %) and contains up to 5 % of living organisms. That means that tail aspirations after primary cleaning are no longer fit for further processing and can only be disposed at industrial waste landfills.

The component composition of foreign impurities in seed batches is highly diverse but can be typical for a particular region due to the presence of typical seeds of weeds growing in the given location [14]. Main components of sunflower seed waste are organic impurities, metallic impurities, oil bearing impurities and husk [4].

Organic impurities consist of parts of anthode, broken plant stems, inflorescences and other vegetative parts of a plant. Mineral impurities mainly consist of earth lumps, dust, stones and metallic impurities. Metallic impurities have different size and can occur in seeds during harvesting, in transportation and as a result of equipment breakdown at fat-and-oil plants.

Oil-bearing impurities are hulled seeds of the main crop with seed residues (seeds eroded by pests, broken, mouldy, rotten, germinated, damaged by frost, underdeveloped seeds, and those with changed kernel color).

As far as the content of above-mentioned components concerned, the component composition of sunflower seed

waste has been studied on samples selected at enterprises from various regions of the Russian Federation. The selection of samples was made in accordance with instructions [20].

In the first stage the component composition of large impurities of sunflower seed waste after primary cleaning was studied, the results of the study are shown in Table 1.

TABLE I. COMPONENT COMPOSITION OF LARGE IMPURITIES OF SUNFLOWER SEED WASTE AFTER PRIMARY SEED PROCESSING

The name of the indicator	The value of the indicator			
	The Republic of Adygeya	Krasnodar region	Kurgan area	Voronezh region
Oil bearing impurities, %	10,2±2,2	11,9 ±2,4	12,1±2,5	9,8±2,7
Husk, %	28,0±2,3	27,4±2,1	23,7±2,3	25,2±2,5
Mineral impurities, %	29,0±2,6	29,9±2,3	30,2±1,9	33,1±2,9
Organic impurities, %	31,6±1,9	30,9±2,2	30,2±2,3	30,0±2,5
Metallic impurities, %	1,9±0,04	1,7±0,06	1,8±0,03	1,7±0,06

From the achieved results it is possible to conclude, that the content of oil bearing impurities in the waste under examination, the main valuable component used for feed purposes, is no more than 12,1 %. Apart from oil bearing impurities, there is a lot of husk in the waste under examination, its content is up to 28,0 %. The mass fraction of metallic impurities in the waste under examination is 1,9 %.

The obtained results are fully consistent with the chemical composition of large debris studied before (after separation from metallic and large mineral impurities), which testify to the low feed value of this type of waste [10]. Based on results of our own and previously carried out research of large impurities of sunflower seed waste after primary cleaning, it is possible to draw a conclusion that this type of waste is no longer fit for further processing.

Thereafter, the component composition of small impurities of sunflower seed waste after primary processing was investigated. The results of this study are shown in Table 2.

The data analysis has shown that there is a big amount of seed husk in small impurities of sunflower seed waste after primary cleaning, the maximum quantity (27,2 %) occurs in samples taken from Krasnodar region. Mineral impurities are also present in this type of waste and its content amounts to 28,9 %. The content of oil-bearing impurities is much higher than in large impurities of sunflower seed waste after primary cleaning, its maximum amount is 19,0 % recorded in Kurgan area. The amount of organic impurities reaches 37,9 % in the Republic of Adygeya. There are considerably less metallic impurities than in large impurities of sunflower seed waste

after primary cleaning. However, the amount of latter in small impurities ranges from 0,2- 0,4 %.

TABLE II. COMPONENT COMPOSITION OF SMALL IMPURITIES OF SUNFLOWER SEED WASTE AFTER PRIMARY CLEANING

The name of the indicator	The value of the indicator			
	The Republic of Adygeya	Krasnodar region	Kurgan area	Voronezh region
Oil bearing impurities, %	13,4±2,3	15,9±2,1	19,0±2,7	14,7±2,8
Husk, %	26,3±2,1	27,2±2,2	22,4±2,4	24,8±2,6
Mineral impurities, %	23,4±2,7	25,0±2,3	25,4±2,6	28,9±2,5
Organic impurities, %	37,9±1,9	35,6±2,8	35,0±2,2	34,7±2,9
Metallic impurities, %	0,3±0,05	0,4±0,07	0,3±0,04	0,2±0,03

Generalizing the data obtained and taken into consideration the fact that in previously carried out research the mass fraction of crude protein and crude fat in small impurities of sunflower seed waste after primary cleaning was significantly greater than in large impurities [10], the given type of waste can be used for further processing. However, it is necessary to separate metallic impurities for safety reasons to reduce the content of organic and mineral impurities and husk with the view to improve the feeding value.

Thus, considering all types of waste after primary cleaning it is possible to say only small impurities should be separated for further processing with the objective of producing fodder products; the rest of them should be disposed at industrial waste landfills. It is known that the fraction of small impurities in overall debris after primary cleaning can reach 72 % [10].

Thereafter, the component composition of overall debris of sunflower seed waste after industrial cleaning was studied. The research results are shown in Table 3.

The data analysis has shown that sunflower seed waste after industrial seed cleaning has husk in its composition, the same as after primary cleaning; but its amount in considerably smaller (maximum 23,3 % in samples taken from Krasnodar region). Mineral impurities are also present in this type of waste, but their maximum content is 23 % recorded in samples taken from enterprises of Kurgan area. The content of oversize in overall debris after industrial seed cleaning (when going through the sieve with aperture size 3.0 mm in diameter) ranged from 55,9 % to 81,7 %. The content of oil bearing impurities connected with oversize is higher than in small impurities after primary cleaning, its maximum content is 21,5 % recorded Voronezh region. The amount of organic impurities is also the biggest in Voronezh region, their content reaches 28,0 %. The amount of metallic impurities is less than

in overall debris after primary cleaning, their maximum content is 0,7 %.

TABLE III. COMPONENT COMPOSITION OF OVERALL DEBRIS OF SUNFLOWER SEED WASTE AFTER INDUSTRIAL SEED CLEANING

The name of the indicator	The value of the indicator			
	The Republic of Adygeya	Krasnodar region	Kurgan area	Voronezh region
Oil bearing impurities, %	19,9±1,1	20,3±1,3	20,6±1,0	21,5±1,4
Husk, %	21,1±2,6	23,2±2,3	18,6±2,1	19,7±2,7
Mineral impurities, %	20,2±1,3	21,0±1,6	22,3±1,1	21,4±1,5
Organic impurities, %	26,8±0,6	27,0±0,7	26,9±0,3	28,0±0,8
metallic impurities, %	0,3±0,01	0,5±0,03	0,3±0,01	0,7±0,02

Summing up the component composition of overall debris of sunflower seed waste after industrial seed cleaning, it is possible to draw a conclusion that in terms of feeding value, this type of waste outstrips small impurities after primary cleaning and it can be used for subsequent processing for feed purposes.

Thus, large impurities and tail aspirations after primary cleaning of sunflower seeds should be disposed at industrial waste landfills. The rest of sunflower seed waste after primary cleaning and overall debris after industrial cleaning can be recycled by fat and vegetable oil refining factory with the objective to produce feedstuffs. In order to avoid heterogeneity and to increase the feeding value of the remaining part of sunflower seeds waste it is necessary to separate metallic, mineral, organic impurities, and husk from them. Taking into consideration the fact that in fat and oil industry husk after dehulling and separating dehulled sunflower seeds is usually burned in boilers for steam generation for technological and household needs [19], it is expedient to unite the husk separated from seed waste with overall flow for further burning in a boiler room of fat vegetable oil refining factory. It is obvious that prepared in this way small impurities after primary cleaning of sunflower seeds and overall debris after industrial cleaning of sunflower seeds contains a large part of crushed seeds and kernels, and is less heterogeneous, than initial waste. Therefore, the remained part of waste can be classified as a secondary oily raw material.

In order to further develop the technology of secondary oily raw materials from selected types of sunflower seed waste the granulometric composition has been studied and technological operations for recycling or processing of components have been selected. It was established that the

most part of waste under examination (over 50 %) is the oversize on a sieve with a 3 mm mesh size and the undersize on a sieve with a 1 mm mesh size. The main part of this fraction consists of kernel fragments, crushed sunflower seeds, and crushed husk. It is this part of waste, which can be processed as secondary raw materials, while the separation of crushed husks can increase its feeding value.

The undersize on a sieve with a 1 mm mesh size does not exceed 6.2 % and is referred to as oil bearing dust.

When the composition of undersize on sieves with aperture size 3,0-5,0 mm in diameter was examined, it was found out that this fraction mainly consists of particles of husk and organic impurities which are, in fact, fragments of stems and leaves which size exceed the diameter of sieve openings.

The research of granulometric composition has shown that, apart from previously fully justified technological operations, it is expedient to apply separation using sieves with aperture size in the studied range to produce secondary oily raw materials from small impurities after primary cleaning and overall debris after industrial cleaning. Since the component composition depends on the region where seeds grow, a particular size of a sieve aperture must be specified when equipment for the production line of the enterprise is selected.

The fraction of oversize with a sieve mesh 3,0-5,0 mm in diameter does not have any feeding value but can be used to generate technological steam when burned in boilers together with husk fraction.

Based on scientific and practical experience of authors of this article, it is more efficient to use a pneumatic gravitational method and an appropriate pneumatic separator to separate husk from the oversize fraction on the sieve with aperture size 3,0 mm in diameter and undersize fraction on the sieve with aperture size 1,0 mm in diameter [1].

For processing secondary oily raw materials a well known method used for processing low-oil-yielding raw materials has been suggested which includes the combination of technological operations of extrusion and pressing. This method allows carrying out the full decontamination of the received oil seed cake and to increase starch assimilability, digestibility of fiber and protein in its composition without breaking down amino acids [17,18]. A laboratory extruder and oil press produced by Farmet with capacity 20 kg per hour were used to adjust technological modes of the given method for production of secondary oily raw materials resulting in full stability of the process and production of inedible (technical) sunflower oil and a feed protein-lipid product.

On the base of the carried our research, the general structural scheme of the universal technology of recycling sunflower seed waste was developed which is presented in Figure 1.

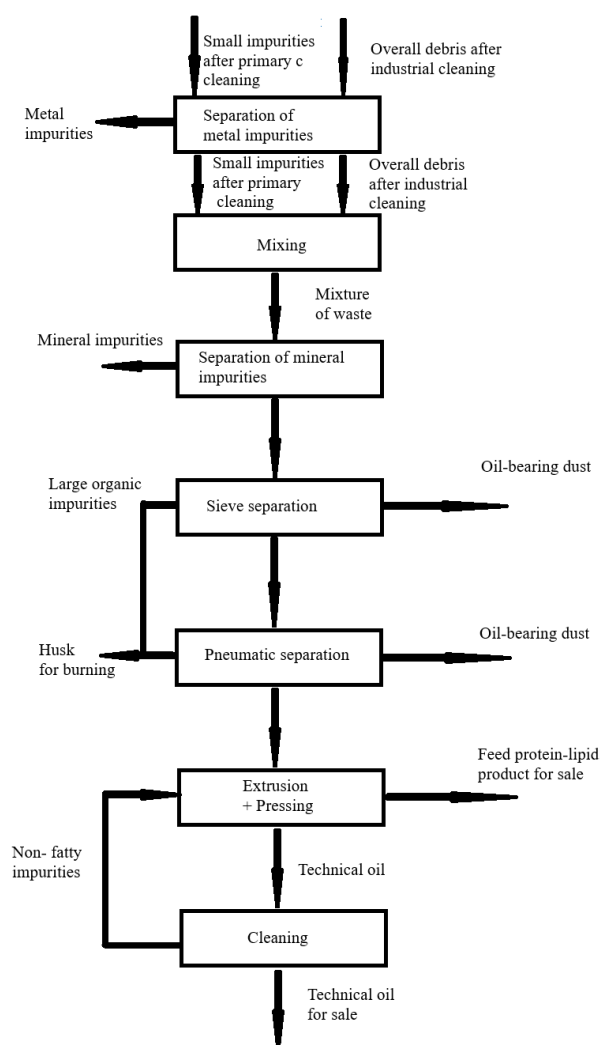


Fig. 1. Structural scheme of the universal technology of recycling sunflower seed waste

The given scheme reflects the developed universal technology of recycling sunflower seed waste; however, some minor adjustments on technological operations and technological modes are possible in dependence on the location of fat and oil plant, initial quality of sunflower seed waste, commercial and ecological tasks to be solved.

Then a new production line processing secondary oily raw materials with capacity 7.2 tons per day has been developed using standard equipment for the above mentioned operations [2], except for separation of husks and oil bearing dust from the mixture of waste performed by pneumatic gravitational method on a new pneumatic separator [1].

The presented experimental production line has been assembled at OOO "Giaginsky Vegetable oil refining complex" and has been working steadily for three years recycling sunflower seed waste and producing inedible (technical) sunflower oil and feed protein-lipid products (pomace) used for feed and technical purposes. Generalization of quality indicators of the produced oil made it possible to establish that, as for fatty acid composition is concerned, the

given oil complies fully with sunflower oil. Meanwhile, it has acid value ranged from 20-50 mgKOH/g, its peroxid value is over 10 mmol of active oxygen per kilo, color value is 35-40 mg of iodine. This oil is sold in a crude form for feeding purposes and used for production of fatty acids, which are potential raw materials for biodiesel production [21].

Generalized quality indices of the feed protein-lipid product (pomace) are presented in Table 4.

TABLE IV. QUALITY INDICES OF THE FEED PROTEIN-LIPID PRODUCT

The name of the indicator	Standard values
Mass fraction of crude protein in conversion to absolute dry substance, % no less than	20
Mass fraction of crude fiber in defatted product in conversion to absolute dry substance, %, no more than	32
Overall energy nutrient density in conversion to absolute dry substance, caloric unit, no less than	1,04
Mass fraction of crude fat in conversion to absolute dry substance, %, no more than	15,0
Mass fraction of overall ash in conversion to absolute dry substance, %	7,4-7,6

The feed protein-lipid product was used by the enterprise as an ingredient for feeding livestock. At present moment, preparations are being made to assemble a similar production line recycling sunflower seed waste at OOO "Kurganinsky vegetable oil refining factory".

IV. CONCLUSION

On the base of the carried out research, a universal technology of recycling sunflower seed waste has been developed, which includes separation of sunflower seed waste from impurities which are no longer fit for subsequent processing (metallic, mineral, organic impurities and husk); burning of husk and large organic impurities with steam generation; the production of inedible technical fat and feed protein-lipid products by extrusion and pressing of remaining secondary oily raw materials.

A new production line with capacity 7.2 tons a day recycling sunflower seed waste as secondary oily materials has been developed and still works successfully. The produced sunflower oil and feed protein-lipid product are used for feeding and technical purposes, which makes it possible to increase profitability of the enterprise and to reduce local environmental pressure.

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