UDC 636.085.55:665.347.8-027.33

PROSPECTS OF USING BY-PRODUCTS OF SUNFLOWER OIL PRODUCTION IN COMPOUND FEED INDUSTRY

B. Yegorov, Doctor of Engineering Science, Professor, *E-mail*: bogdanegoroff58@gmail.com
T. Turpurova, Candidate of Engineering Science, Associate Professor, *E-mail*: turpurova.tatyana@gmail.com
E. Sharabaeva, Postgraduate, *E-mail*: sharabaieva@gmail.com
Y. Bondar, Master, *E-mail*: bulia6094@gmail.com
Department of mixed feeds and biofuel technology
Odessa National Academy of Food Technologies, Kanatna str., 112, Odessa, Ukraine, 65039

Abstract. The article considers the possibility of obtaining a protein-rich feed additive from by-products of sunflower oil production. From literary sources it is known that in the global food market, Ukraine ranks first in cultivating the sunflower and in production and export of sunflower oil. Correspondingly, there are more by-products, such as press cakes and oil meal, which are high-protein feeds for farm animals. Recently, oil press factories have been producing high fat press cakes for farm animals and poultry's energy needs. The shelf-life of high fat press cakes is very short, and besides, their physical properties are poor. So, it has been suggested to produce a protein-rich feed additive based on sunflower oil meal, sunflower press cake and limestone flour. The quality parameters of sunflower seeds and by-products of their processing have been determined. Five samples of the additive with different ratios of sunflower oil meal, sunflower press cakes, and limestone flour have been studied. The coefficient of variation characterizing the even distribution of the components in the additive has been determined. Besides the distribution of limestone flour in the additive, the distribution of sunflower press cake matter has been investigated, because it contains a lot of fat and has poor physical properties. The determination of the coefficients of variation by the distribution of limestone flour and by the distribution of sunflower press cake matter has shown that the mixing is the most effective when the recipe includes 75% of sunflower oil meal, 10 % of sunflower press cake, and 15% of limestone flour. A protein-rich feed additive based on by-products of the sunflower oil production has been developed. The additive can be used to feed animals and poultry.

Key words: sunflower oil, sunflower press cake, sunflower oil meal, quality, coefficient of variation.

ПЕРСПЕКТИВИ ВИКОРИСТАННЯ ПОБІЧНИХ ПРОДУКТІВ ВИРОБНИЦТВА СОНЯШНИКОВОЇ ОЛІЇ В КОМБІКОРМОВІЙ ГАЛУЗІ

Б.В. Єгоров, доктор технічних наук, професор, *E-mail*: bogdanegoroff58@gmail.com
Т.М. Турпурова, кандидат технічних наук, доцент, *E-mail*: turpurova.tatyana@gmail.com
К.М. Шарабаєва, аспірант, *E-mail*: sharabaieva@gmail.com
Ю.І. Бондар, магістр, *E-mail*: bulia6094@gmail.com
Кафедра технології комбікормів і біопалива
Одеська національна академія харчових технологій, вул. Канатна,112, м. Одеса, Україна, 65039

Анотація. Розглянуто можливість отримання високобілкової кормової добавки з побічних продуктів виробництва соняшникової олії. Україна займає перше місце на світовому ринку продовольства за виробництвом соняшника, соняшникової олії та експорту соняшникової олії. Відповідно, постає питання щодо використання та переробки побічних продуктів – макухи та шроту, які є високобілковими кормами для годівлі сільськогосподарських тварин. Останнім часом, олійно-пресові підприємства одержують макуху з підвищеним вмістом жиру для забезпечення енергетичних потреб сільськогосподарських тварин та птиці, проте слід зважити, що термін зберігання макухи з підвищеним вмістом жиру досить короткий. Запропоновано виробництво високобілкової кормової добавки на основі шроту соняшникового, макухи соняшникової та вапнякової муки. Визначено показники якості насіння соняшника та побічних продуктів його переробки. Досліджено п'ять зразків добавки з різним співвідношенням шроту соняшникового, макухи соняшникової та вапнякової муки. Визначено коефіцієнт варіації, який характеризує рівномірність розподілення компонентів у складі добавки. Крім розподілення вапнякової муки в добавці, досліджено розподілення соняшникової макухи. Визначення коефіцієнта варіації по розподіленню вапнякової муки і коефіцієнта варіації по розподіленню макухи соняшникової показало, що найбільш ефективно відбувається змішування рецепту, до складу якого входить 75% соняшникового шроту, 10% макухи соняшникової та 15% вапнякової муки. Розроблено високобілкову кормову добавку на основі побічних продуктів виробництва соняшникової олії, яку можна використовувати для годівлі сільськоподарських тварин і птиці.

Ключові слова: соняшникова олія, макуха, шрот, змішування, якість, коефіцієнт варіації.

DOI: http://dx.doi.org/ 10.15673/fst.v13i1.1337

Introduction. Formulation of the problem

In the agro-industrial complex of Ukraine, the fat-and-oil branch of food industry occupies a leading place. The oil seed processing enterprises produce oil and fatty products to be used as food, fodder, or for technical purposes, including strategic ones. The main raw materials for the production of vegetable oils are oilseeds (sunflower, soybean, rapeseed, flax, etc.). Vegetable oil is not only a concentrated source of energy: it contains a number of nutrients that are vital for humans, in particular unsaturated fatty acids [1-6].

Sunflower oil has become an important component of the human diet. It contains many high-calorie nutrients. Today, the composition of sunflower oil is well studied. Researchers point out that, due to the polyunsaturated fatty acids ω-6 and ω-9, sunflower oil protects us from atherosclerosis, improves the activity of the main organs (the liver, the kidney, the gall bladder). The presence of vitamin F in the oil does not only prevent the "overgrowth" of the vessels, but also contributes to the dissolution of existing atherosclerotic plaques [4,7-10].

In some countries, the consumption of the vegetable oils is growing because vegetable fats have several advantages for the human health over animal fats. Only in the period from 2000 to 2015, the consumption of vegetable oils as food increased by 1.75 times. The use of vegetable oils for biodiesel and bioethanol production increased, too, which leads to a growing demand for sunflower seeds [3,11-13].

Analysis of recent research and publications

The sunflower is one of the three most cultivated oil crops. According to the data of the US Department of Agriculture, in 2016–2017, its global production was 24 million tons, which is 1% less than in the previous season. The decrease in production was due to a reduction in areas under cultivation, but the yield remained the same – 1.7 t/ha [11].

In the global food market, Ukraine ranks first in cultivating the sunflower and in production and export of sunflower oil [11]. The dynamics of sunflower production in Ukraine are given in Table 1.

Table 1 – Dynamics of sunflower production in Ukraine in 2010–2017 [14]

Parameters	Years							
	2010	2011	2012	2013	2014	2015	2016	2017
The area where the sunflower was harvested, thousand hectares								
All categories of farms	4572	4739	5194	5051	5257	5105	6073	6034
Production, thousand tons								
All categories of farms	6772	8671	8387	11051	10134	11181	13627	12236
Yield, centners/ha								
All categories of farms	15.0	18.4	16.5	21.7	19.4	21.6	22.4	20.2

Sunflower production has always been quite profitable; the products of its processing are competitive in the domestic and global markets, and are an important component of protein resources contained in food and fodder.

In the production of sunflower oil, by-products, such as press cake and oil meal, constitute up to 36% of the mass of the processed seeds [2]. From the literature, it has been established that by-products of sunflower oil production contain all components of the nutritional value of seeds, except for crude fat, which decreases to 8–17% in press cakes and to 2% in oil meal [15]. Press cake and oil meal are protein-rich animal feed. Its high nutritional value is due to the content of essential amino acids such as lysine, methionine, cystine, tryptophan, as well as of calcium, phosphorus, and B group vitamins [16]. Sunflower oil meal is a good source of vitamin E [7, 17].

A sunflower press cake contains an average of 39.6% of protein, 1.6% of fat, 12.3% of crude fibre, 23.5% of nitrogen-free extractives, 6.0% of ash. There are slightly more essential amino acids in it than in sunflower oil meal. Both press cake and oil meal can be used as such or as components of compound feeds and feed mixtures. The feed conversion rate is 3–5 kg/kg [9,16].

However, there are factors that negatively affect the nutritional value and availability of nutrients of sunflower oil meal when feeding farm animals and poultry [17]:

– A high content of crude fibre (12–18%), which can be a problem for young farm animals and poultry, as it leads to the swelling of the feed inhibiting its transit along the intestine intestine;

– It contains a lot of non-starch polysaccharides (up to 40%) that animals cannot digest due to lack of appropriate enzymes;

– It contains chlorogenic and quinic acids, the levels of which are 1.56 and 0.48 %, respectively. The negative effect of high doses of these acids consists in paralyzing the action of the digestive enzymes of the gastrointestinal tract. This affects, first of all, the digestibility of protein and the absorption of the amino acids lysine and methionine. The level of chlorogenic acid should not exceed 1%;

– It is deficient in such an important amino acid as lysine, which requires the additional inclusion of a synthetic drug;

– It has low oxidation resistance.

One of the most important problems in the long-term storage of oil meal and press cake is the deterioration of their quality. Press cake and oil meal quickly turn rancid because they contain residual amounts of fatty acids, and with increasing humidity, the destruction of the nutrients increases, too. The critical moisture content for press cake and oil meal is 8–10% [18]. The low oxidative stability of lipids, especially of those containing unsaturated fatty acids, results in the accumulation of peroxides, hydroxy acids, ketones, aldehydes, which have a negative toxic effect on farm animals and poultry.

To make press cakes more storable, it is necessary to reduce the fat content. However, now there is a tendency to manufacture fattier sunflower press cakes to satisfy farm animals' and poultry's need for energy and to avoid the additional introduction of fats while producing compound feed.

The purpose of our work was to obtain a high-protein feed additive from by-products of sunflower oil production.

For this purpose, it is necessary to attain the following **objectives**:

– to determine the physico-chemical parameters of by-products from the production of sunflower oil;

– to select the optimum ratio of the components that make up the high-protein feed additive;

– to determine the physical properties and quality characteristics of the high-protein feed additive.

Research materials and methods

The main research materials were industrial samples of by-products of sunflower oil production (press cake and oil meal). The research was conducted at the Department of technology of feed and biofuels of the Odessa National Academy of Food Technologies. The sunflower oil by-products were estimated by such physical properties as moisture content, bulk density, flowability, and angle of repose [19].

The method of determining the coefficient of variation of the mixture by Kravchyna P.N. [20]. The method is based on the change in the intensity of the colour of vitamin B2 (riboflavin), depending on its concentration in the solution. To apply this technique, it is necessary to make a calibration graph.

To do this, 100 mg of vitamin B2 is put into a volumetric flask (1000 cm^3) and dissolved – first, in a small amount of water, and then the water is added to the solution up to the measuring mark. 1 cm^3 of the solution contains 0.1 mg of vitamin B2. This solution is then used to prepare standard solutions by pouring 1 to 10 cm^3 of the standard solution into a volumetric flask (100 cm^3) and adding distilled water to it up to the measuring mark. Then, the mixture is colourized in a 5 cm^3 cuvette with a No. 4 blue optical filter.

A portion of the mixture is placed in a thin layer, and 10 test samples, with a mass of 2 g, are taken. Each of them is put into a 100 cm^3 volumetric flask and topped to the measuring mark with distilled water. After mixing thoroughly and settling for 5 minutes, the mixture is filtered, and the resulting clear filtrate is colourized and compared with the standard solution. The content of vitamin B2 is determined by the calibration graph. The coefficient of variation is determined by the formula:

$$V_c = \frac{100}{\overline{X}} \sqrt{\frac{\sum_{i=1}^{n} (X_i - \overline{X})^2}{n-1}}, \%$$

where X_i – the content of the key component in the i-th sample, %;

$\overline{X}$ – the average content of the key component in the mixture, %;

n – the number of analyzed samples.

Moisture, fat, protein, and fibre were determined by spectroscopy on a feed and fodder analyser NIRS™ DS2500 F (State Standard of Ukraine 7491:2013).

The NIRS DS2500 F is designed to be used in laboratories or feed mills for the following purposes:

– Initial control for the optimum use of raw materials;

– In-process control for the efficiency and economy;

– Monitoring the final product by different control parameters.

The NIRS™ DS2500 F uses highly accurate optical NIR technology to provide the best-in-class performance in the whole wavelength range of 850 to 2500 nm. Regardless of whether you are checking the content of moisture, fat, and protein, or more demanding parameters such as amino acids, ash, or fibres, the NIRS DS2500 F delivers accurate results in about a minute. The spectrometer is equipped with internal standards to control light intensity, spectral range, and wavelength. Its stability can be validated to make sure that data are transferred continuously and correctly, even over time. Designed to demonstrate exceptional performance, the monochromator NIRS DS2500 F, normally, needs no recalibration. However, internal as well as external standards can be used for automatic recalibration and quality control of the spectrometer.

FOSS NIRS DS2500 F is operated with the user-friendly ISIscan Nova software that supports the latest calibration technologies, as well as networking options. Its many features include:

– Databasing the results automatically;

– Supported regression methods: predicting according to PLS, MPLS, LOCAL, FOSS-ANN;

– Real-time detection of substandard samples for each component;

– Data plotting and trend analysis;

– Product control, with tolerances, target values, and reports;

– User-defined fields for tracking information about a sample;

– LIMS compatibility (export only);

– Online customer support.

Results of the research and their discussion

Along with improving the quality of press cakes, another big problem for poultry industry is calcium imbalance – calcium deficiency in the laying hens during ovulation. All this proves how necessary it is to include mineral raw materials in the composition of high-protein feed additives. Limestone flour is cheap and high in calcium, that is why it has gained such popularity among other mineral raw materials. Its physical properties make limestone flour adsorptive, thus making it possible to increase the percentage of press cake added and to reduce the cost of raw materials, which is an important factor in calculating compound feed recipes for poultry [21].

To manufacture high-protein feed additives, sunflower oil meal, sunflower press cake, and limestone flour were used. Table 2 shows the quality characteristics of sunflower seeds and by-products of their processing.

Experimentally, physical properties have been determined for each type of feed raw materials (Table 3). The data obtained have allowed concluding that oil meal is characterized by low unit weight and high flowability, and press cake, due to its high fat content, has low flowability.

To determine the optimum ratio of the components that make up the high-protein feed additive, five samples of the additive with different ratios of components have been investigated.

Table 4 shows the composition of a high-protein mineral additive produced according to five recipes.

Table 2 – Quality characteristics of sunflower seeds and by-products of theirs processing

Parameters	Sunflower seeds		Sunflower press cake		Sunflower oil meal	
	experimental	State Standard of Ukraine 7011:2009	experimental	State Standard of Ukraine 8096	experimental	State Standard of Ukraine 11246-96
Moisture content, not more %	6.8	8	4.4	8.5	8.9	10
Crude protein, not less %	14.8	–	–	38	34.7	39
Crude fibre, not more %	–	–	–	20	19.2	23
Crude fat, not more %	45.2	–	19.7	6	0.95	1
Acid number, not more %	1.6	2.2	–	–	–	–
Oleic acid, %	85.7	–	–	–	–	–
Residual hexane, ppm	–	–	–	–	117	–

Table 3 – Physical properties of the components used for the production of high-protein feed additive

Parameters	Sunflower oil meal	Sunflower press cake	Limestone flour
Unit weight, kg/м^3	458	1028	1416
Flowability, sm/s	12.9	2.2	0.9
Angle of repose, g.	37	42	45
Moisture content, %	8.9	4.4	0.4

Table 4 – The composition of high-protein feed additives

Ingredient	Recipe № 1	Recipe № 2	Recipe № 3	Recipe № 4	Recipe № 5
Sunflower oil meal, %	90	80	70	60	50
Sunflower press cake, %	5	10	15	20	25
Limestone flour, %	5	10	15	20	25
Total, %	100	100	100	100	100

Samples of the high-protein feed additive were studied by the qualities that characterize best the physical properties of the finished product: the moisture content, the angle of repose, the flowability, and the bulk density (Fig. 1-4).

As sunflower press cakes and limestone flour are characterized by low flowability, a higher percentage of these components reduces the flowability (Fig. 2) of the high protein feed additive, whereas the angle of repose (Fig. 3) and the bulk density (Fig. 4) increase.

The quality of any feed additive depends on the uniform distribution of its components, i. e. on the technological process of mixing.

From a zootechnical point of view, it is important not only to develop a highly effective recipe, select high-quality feed raw materials for its implementation, ensure its proper preparation, and measure out the doses of the prepared components with high precision, but also to ensure their uniform distribution in all the microvolumes of the mixture so that in each consumed portion of the feed, there is the ratio of components that is indicated in the recipe. So, it is important to carry out mixing effectively.

Mixing is the process of forced redistribution of particles of individual components until a homogeneous mixture is formed. The homogeneity of the mixture can be considered to be almost perfect, when in each microvolume, which approaches the minimum, there are particles of separate components in the ratio provided by the recipe. At the same time, it is important that the microvolume be smaller than a portion of one-time consumption of the feed by animals [19].

For the mixing process, the qualitative indicator showing how much the goal is achieved is the degree of variation.

To assess the effectiveness of mixing, the mixture is conventionally considered to be two-component. Usually, one component (the key one) is selected; all the rest are viewed as the other one (conditional). Thus, in a two-component mixture, the random variable is the content of the key component in a certain microvolume. Limestone flour was selected as the key component (Fig. 5).

The data in Fig. 5 show that the more sunflower press cake and limestone flour is introduced, the higher is the coefficient of variation. Considering that mixing is effective when the coefficient of variation of a loose high-protein feed additive is not more than 2.5%, the smallest is the coefficient of variation for mixing recipe No 2 (sunflower oil meal – 80%, sunflower press cake – 10%, limestone flour – 10%). That is why the next step was studying the changes in the limestone flour content in the second recipe. Compositions of the high-protein feed additive have been suggested, with mineral raw materials introduced in different ratios (Table 5).

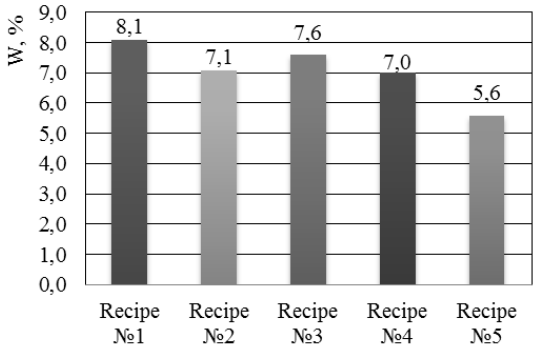


Fig. 1. The moisture content of the tested samples

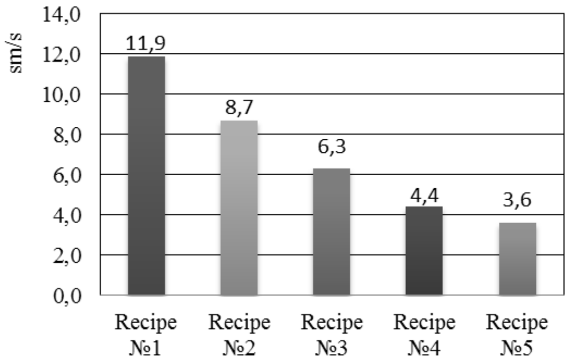


Fig. 2. The flowability of the tested samples

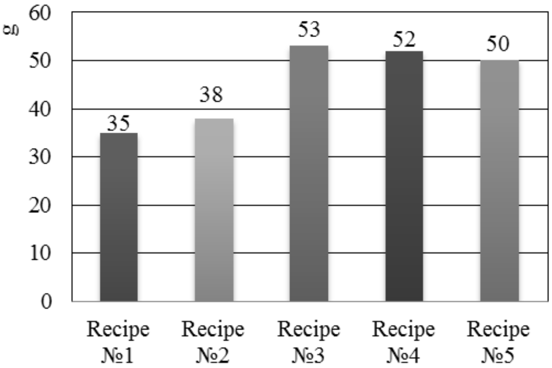


Fig. 3. The angle of response of the tested samples

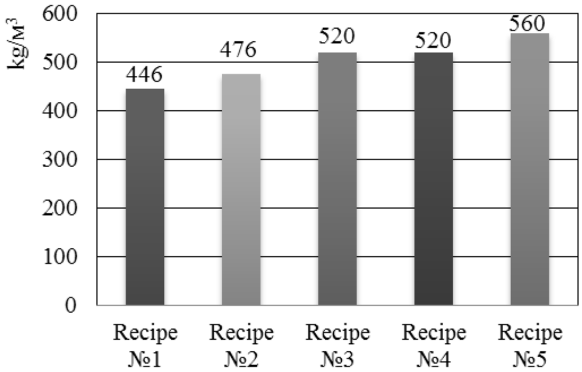


Fig. 4. The bulk density of the tested samples

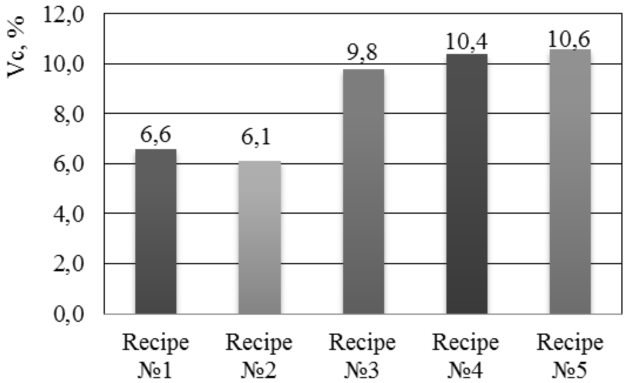


Fig. 5. Evaluation of the effectiveness of mixing

With an increase in the mass fraction of limestone flour, the moisture (Fig. 6) and the flowability (Fig. 7) decrease, and the bulk density (Fig. 9) and the angle of repose (Fig. 8) increase.

Table 5 – Compositions of the high-protein feed additive with a different content of limestone flour

Ingredient	Recipe № 2.1	Recipe № 2.2	Recipe № 2.3
Limestone flour, %	10	15	20
Sunflower oil meal, %	80	75	70
Sunflower press cake, %	10	10	10
Total, %	100	100	100

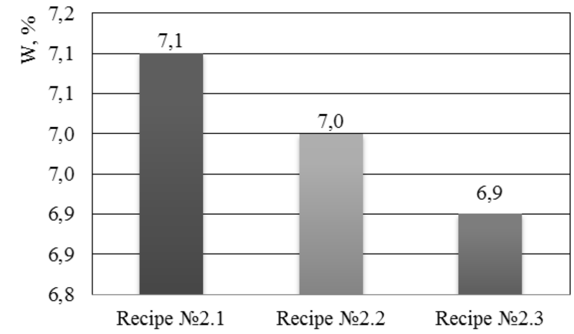


Fig. 6. The moisture content in the test samples

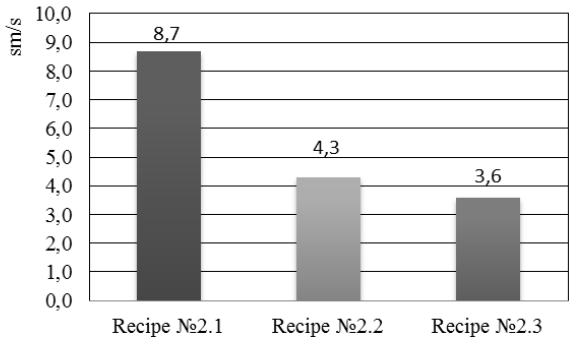


Fig. 7. The flowability of the test samples

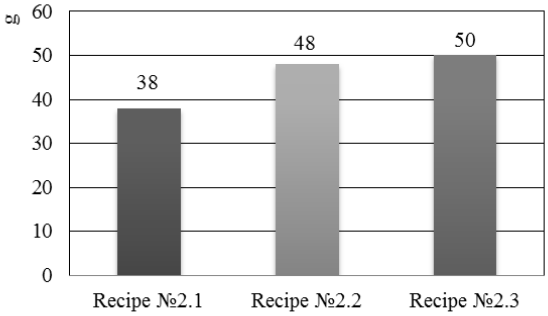


Fig. 8. The angle of repose of the test samples

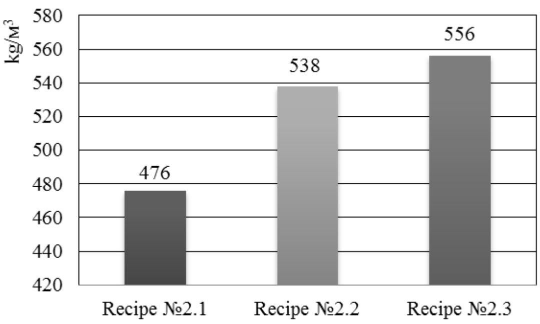
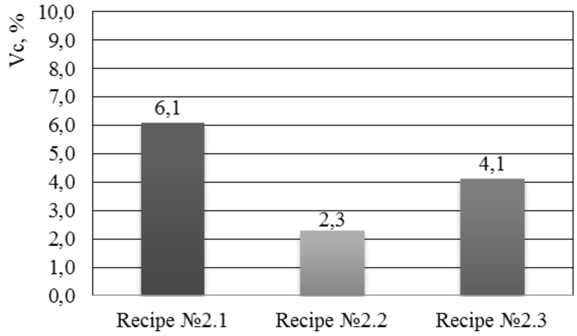
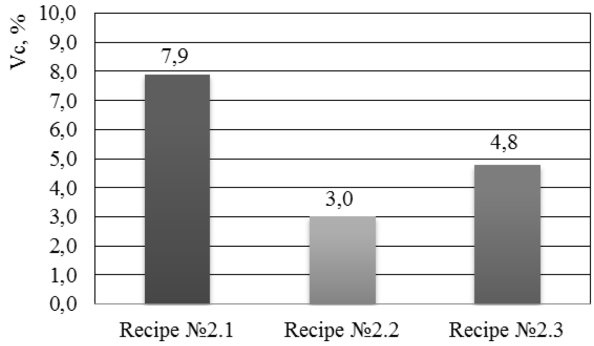


Fig. 9. The bulk density of the test samples

To assess the effectiveness of mixing, the coefficient of variation of all samples has been determined by the key component, limestone flour (Fig. 10a). The data in Fig. 12a show that the coefficient of variation is the lowest for recipe No. 2.2 (sunflower oil meal – 75%, sunflower press cake – 10%, limestone flour – 15%). Besides the distribution of limestone flour in the additive, it is important to study the distribution of sunflower press cake, because it contains a lot of fat and has poor physical properties. We have determined the coefficient of variation by the fat content (Fig. 10b).



a) the key component is limestone flour



b) the key component is sunflower press cake

Fig. 10. Evaluation of the effectiveness of the mixing of samples with different proportions of limestone flour

As a result of the research, we can conclude that the smallest coefficient of variation in both cases has been obtained when mixing recipe No 2.2. The effectiveness of mixing this recipe has been rated as excellent.

Conclusion

1. The quality characteristics of sunflower seeds and by-products of their processing have been determined.
2. Five samples of the additive, with different ratios of sunflower oil meal, sunflower press cake, and limestone flour, have been considered.
3. The coefficient of variation characterizing the uniformity of distribution of the components in the additive has been determined. Besides the distribution of limestone flour, that of sunflower press cake has been studied, too, as it contains a lot of fat and has poor physical properties. Determining the coefficient of variation of limestone flour distribution and that of sunflower press cake distribution has shown that the additive most effectively mixed is the one with 75% of sunflower oil meal, 10% of sunflower press cake, and 15% of limestone flour.
4. A high-protein feed additive has been developed based on by-products of sunflower oil production. The additive can be used to feed farm animals and poultry.

List of references:

1. Левицкий А.П., Гулавский В.Т., Селиванская И.А., Вертикова Е.К. Высокоолеиновый подсолнечник – перспективное сырье для получения ценного подсолнечного масла «Оливка» // Зернові продукти і комбікорми. 2010. № 4. С. 16-17.
2. Мхитарьянц Л.А., Корнена Е.П., Мартовщук Е.В., Мустафаев С.К. Технология отрасли (производство растительных масел). СПб.: ГИОРД, 2009. 352 с.
3. Marmesat S., Velasco L., Ruiz-Méndez M.V., Fernández-Martínez J.M. Thermostability of genetically modified sunflower oils differing in fatty acid and tocopherol compositions // Europ. J. Lipid Science and Technology. 2008. V.110. P. 776-782.
4. Ebrahimi M., Rajion M.A., Jafari S., Faseleh Jahromi M., Oskoueian E., Qurni Sazili A. Effects of dietary *n*-6: *n*-3 polyunsaturated fatty acid ratios on meat quality, carcass characteristics, tissue fatty acid profiles, and expression of lipogenic genes in growing goats // PLoS ONE 13(8): e0188369. DOI: https://doi.org/10.1371/journal.pone.0188369
5. Antonyuk P.O., Lisyuk V.M. The state and progress of oilseeds market and foods of their processing trends are in Ukraine // Economic innovations. 2018. V.20(66). P. 44-52. DOI: https://doi.org/10.31520/ei.2018.20.1(66).44-52
6. Noci F., French P., Monahan F.J., Moloney A.P. The fatty acid composition of muscle fat and sub-cutaneous adipose tissue of grazing heifers supplemented with plant oil-enriched concentrates // Journal of Animal Science. 2007. 85: 1062–1073.
7. Demirel G., Wachira A.M., Sinclair L.A., Wilkinson R.G., Wood J.D., Enser M. Effects of dietary n-3 polyunsaturated fatty acids, breed and dietary vitamin E on the fatty acids of lamb muscle, liver and adipose tissue // The British Journal of Nutrition. 2004. 91: 551–565. DOI: https://doi.org/10.1079/BJN20031079
8. Cardoso C.R., Souza M.A., Ferro E.A., Favoreto S. Jr., Pena J.D. Influence of topical administration of ω-3 and ω-6-essential and ω-9 nonessential fatty acids on the healing of cutaneons wounds // Wound Repair and Regenerat. 2004. V.12, № 2. P. 235–243. DOI: 10.1111/j.1067-1927.2004.012216.x
9. Aguilera C.M., Ramirez-Tortosa M.C., Mesa M.D. Sunflower, virgin-olive and fish oils differentially effect the progression of aortic lesions in rabbits with experimental atherosclerosis // Atherosclerosis. 2002. № 2(162). P. 335–344.
10. Traber M.G. Vitamin E regulation // Curr. Opin.Gastroenterol. 2005. V.21. P.223-227.
11. Соняшник: продавати або переробляти // Агробізнес сьогодні. 2018. Режим доступа: http://agro-business.com.ua/agro/ahronomiia-sohodni/item/8789-soniashnyk-prodavaty-abo-pererobliaty.html.
12. Regitanodarce M.A.B., Lima U.D. Sunflower-seed oil extraction with ethanol // Journal of the American Oil Chemists Society. 1986. Vol. 63, Issue 4. P. 428–430.
13. Aikaitė-Stanaitienė J., Grigiškis S., Levišauskas D., Čipinytė V., Baškys E., Kačkytė V. Development of fatty waste composting technology using bacterial preparation with lipolytic activity // Journal of Environmental Engineering and Landscape Management. 2010. 18(4): 296–305. DOI: https://doi.org/10.3846/jeelm.2010.34
14. Ткачук В.І. Тенденції розвитку ринку олійних культур в Україні // Вісник ЖНАЕУ Аграрний ринок та його інфраструктура. 2014. Т. 2. С. 87-93.
15. Wiliams W.L., Broquist H.P., Snell E.E. Oleic acid and related compounds as growth factors for lactic acid bacteria // Journal Biol. Chem. 1997. № 2. P 619 – 630.
16. Пешук Л.В., Носенко Т.Т. Біохімія та технологія олієжирової сировини: навч. посіб. Київ: ЦУЛ, 2011. 296 с.
17. Raes K., De Smet S., Demeyer D. Effect of dietary fatty acids on incorporation of long chain polyunsaturated fatty acids and conjugated linoleic acid in lamb, beef and pork meat: a review // Animal Feed Science and Technology. 2004. 113: 199–221.
18. Lima AGVdO, Oliveira RL, Silva TM, Barbosa AM, Nascimento TVC, Oliveira VdS, et al. Feeding sunflower cake from biodiesel production to Santa Ines lambs: Physicochemical composition, fatty acid profile and sensory attributes of meat // PLoS ONE. 2018. 13(1): e0188648. DOI: https://doi.org/10.1371/journal.pone.0188648
19. Єгоров Б.В. Технологія виробництва комбікормів. Одеса: Друкарський дім, 2011. 448 с.
20. Єгоров Б.В., Макаринська А.В., Ворона Н.В., Чернега І.С., Цюндик О.Г. Методичні вказівки до виконання лабораторних робіт з курсу «Технологія комбікормового виробництва» для студентів спеціальності 181 «Харчові технології» («Технологія зберігання і переробки зерна»), ОКР «Бакалавр» денної і заочної форм навчання. Одеса: ОНАХТ, 2018. 60 с.
21. Єгоров Б.В., Турпурова Т.М. Розробка технології виробництва мінеральної добавки для сільськогосподарської птиці // Зернові продукти і комбікорми. 2012. № 3. С. 43-47.

References:

1. Levitskiy AP, Hulavskiy VT, Selivanskaya IA, Yertikova EK. Vysokooleinovyy podsolnechnik – perspektivnoe syr`e dlya polucheniya tsennoho podsolnechnoho masla «Olivka». Zernovi produkti i kombikormi. 2010; 4: 16-17.
2. Mkhitar`yants LA, Kornena EP, Martovshchuk EV, Mustafaev SK. Tekhnolohiya otrasli (proizvodstvo rastitel`nykh masel). SPb.: HIORD; 2009.
3. Marmesat S, Velasco L, Ruiz-Méndez MV, Fernández-Martínez JM. Thermostability of genetically modified sunflower oils differing in fatty acid and tocopherol compositions. Europ. J. Lipid Science and Technology. 2008; 110: 776–782.
4. Ebrahimi M, Rajion MA, Jafari S, Faseleh Jahromi M, Oskoueian E, Qurni Sazili A. Effects of dietary *n*-6: *n*-3 polyunsaturated fatty acid ratios on meat quality, carcass characteristics, tissue fatty acid profiles, and expression of lipogenic genes in growing goats. PLoS ONE 13(8): e0188369. DOI: https://doi.org/10.1371/journal.pone.0188369
5. Antonyuk PO, Lisyuk VM. The state and progress of oilseeds market and foods of their processing trends are in Ukraine. Economic innovations. 2018; 20(66): 44-52. DOI: https://doi.org/10.31520/ei.2018.20.1(66).44-52
6. Noci F, French P, Monahan FJ, Moloney AP. The fatty acid composition of muscle fat and sub-cutaneous adipose tissue of grazing heifers supplemented with plant oil-enriched concentrates. Journal of Animal Science. 2007; 85: 1062-1073.
7. Demirel G, Wachira AM, Sinclair LA, Wilkinson RG, Wood JD, Enser M. Effects of dietary n-3 polyunsaturated fatty acids, breed and dietary vitamin E on the fatty acids of lamb muscle, liver and adipose tissue. The British Journal of Nutrition. 2004; 91: 551-565. DOI: https://doi.org/10.1079/BJN20031079
8. Cardoso CR, Souza MA, Ferro EA, Favoreto SJr, Pena JD. Influence of topical administration of ω-3 and ω-6-essential and ω-9 nonessential fatty acids on the healing of cutaneons wounds. Wound Repair and Regenerat. 2004; 12(2): 235–243. DOI: 10.1111/j.1067-1927.2004.012216.x
9. Aguilera CM, Ramirez-Tortosa MC, Mesa MD. Sunflower, virgin-olive and fish oils differentially effect the progression of aortic lesions in rabbits with experimental atherosclerosis. Atherosclerosis. 2002; 2(162): 335-344.
10. Traber MG. Vitamin E regulation. Curr. Opin.Gastroenterol. 2005; 21: 223-227.
11. Sonyashnik: prodavati abo pereroblyati. Ahrobiznes s`ohodni: [Veb-sayt]. URL: http://agro-business.com.ua/agro/ahronomiia-sohodni/item/8789-soniashnyk-prodavaty-abo-pererobliaty.html.
12. Regitanodarce MAB, Lima UD. Sunflower-seed oil extraction with ethanol. Journal of the American Oil Chemists Society. 1986; 63(4): 428-430.

13. Aikaitė-Stanaitienė J, Grigiškis S, Levišauskas D, Čipinytė V, Baškys E, Kačkytė V. Development of fatty waste composting technology using bacterial preparation with lipolytic activity. Journal of Environmental Engineering and Landscape Management. 2010; 18(4): 296-305. DOI: https://doi.org/10.3846/jeelm.2010.34
14. Tkachuk VI. Tendentsiyi rozvitku rinku oliynikh kul`tur v Ukrayini. Visnik ZhNAEU Ahrarniy rinok ta yoho infrastruktura. 2014; 2: 87-93.
15. Wiliams WL, Broquist HP, Snell EE. Oleic acid and related compounds as growth factors for lactic acid bacteria. Journal Biol. Chem. 1997; 2: 619-630.
16. Peshuk LV, Nosenko TT. Biokhimiya ta tekhnolohiya oliye-zhirovoyi sirovini: navch. posib. Kiyiv: TSUL; 2011.
17. Raes K, De Smet S, Demeyer D. Effect of dietary fatty acids on incorporation of long chain polyunsaturated fatty acids and conjugated linoleic acid in lamb, beef and pork meat: a review. Animal Feed Science and Technology. 2004; 113: 199-221.
18. Lima AGVdO, Oliveira RL, Silva TM, Barbosa AM, Nascimento TVC, Oliveira VdS, et al. Feeding sunflower cake from biodiesel production to Santa Ines lambs: Physicochemical composition, fatty acid profile and sensory attributes of meat. PLoS ONE. 2018; 13(1): e0188648. DOI: https://doi.org/10.1371/journal.pone.0188648
19. Yehorov BV. Tekhnolohiya virobnitstva kombikormiv. Odesa: Druk. Dim; 2011.
20. Yehorov BV, Makarins`ka AV, Vorona NV, Cherneha IS, TSyundik OH. Metodichni vkazivki do vikonannya laboratornikh robit z kursu «Tekhnolohiya kombikormovoho virobnitstva» dlya studentiv spetsial`nosti 181 «Kharchovi tekhnolohiyi» («Tekhnolohiya zberihannya i pererobki zerna»), OKR «Bakalavr» dennoyi i zaochnoyi form navchannya. Odesa: ONAKhT; 2018.
21. Yehorov BV, Turpurova TM. Rozrobka tekhnolohiyi virobnitstva mineral`noyi dobavki dlya sil`s`kohospodars`koyi ptitsi. Zernovi produkti i kombikormi. 2012; 3: 43-47.

Отримано в редакцію 18.10.2018
Прийнято до друку 06.03.2019

Received 18.10.2018
Approved 06.03.2019

Цитування згідно ДСТУ 8302:2015

Yegorov B., Turpurova T., Sharabaeva E., Bondar Y. Prospects of using by-products of sunflower oil production in compound feed industry // Food science and technology. 2019. Vol. 13, Issue 1. P. 106-113. DOI: http://dx.doi.org/ 10.15673/fst.v13i1.1337

Cite as Vancuver ctyle citation

Yegorov B., Turpurova T., Sharabaeva E., Bondar Y. Prospects of using by-products of sunflower oil production in compound feed industry. Food science and technology. 2019; 13(1): 106-113. DOI: http://dx.doi.org/ 10.15673/fst.v13i1.1337