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RESEARCH ARTICLE

Technological methods of improving rapeseed feed and reducing their toxicity

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Abstract

The study aimed to analyze technological ways to improve rapeseed feed and determine its effectiveness. At the same time, biochemical, computational and analytical research methods were used. It is shown that cake and meal obtained from the processing of cruciferous oilseeds into oil are valuable sources of protein in the diets of farm animals and poultry, but along with nutrients they contain a number of antinutrients. The composition of antinutrients of rapeseed meal – glucosinolates, sinapine, tannins, saponins and others – has been determined, in connection with which their use in feeding farm animals and poultry has to be limited. The ways to improve the nutritional value of by-products of rapeseed processing are analyzed, the main of which are breeding and technology. It is noted that a decrease in the content of glucosinolates already to one degree or another takes place in the process of processing seeds into oil at industrial enterprises. For the subsequent reduction of the content of antinutrients, physical, chemical, enzymatic and microbiological methods of processing are also proposed, which are based on their chemical or thermal decomposition to non-toxic or low-toxic compounds, inactivation of the enzyme myrosinase, polymerization of decomposition products, their metabolization by microorganisms, etc.

Keywords: Rapeseed meal, antinutrients, Technological methods of processing, Protein, Oil, Amino acid.

Introduction

Intensification of livestock production requires an increase in the production of concentrated feed, improving their quality and reducing the grain content (Demyanchuk et al., 2003a; Long Jiang-xue et al., 2018; Dindaroglu et al., 2022; Hryhoriv et al., 2023).

The well-known problem of feed protein deficiency can be solved by animal feed – fodder, bone, blood, fish meal, skimmed milk powder and products synthesized through microbiological processes. However, the resources of these feeds are limited and, expensive. Therefore, more attention is paid to vegetable feed protein, in particular rapeseed, which has high nutritional value and low cost (Demyanchuk et al., 2003b; Mykytyn, 2007; Mykytyn et al., 2021; Karbivska et al., 2023).

Rapeseed seeds and products of their processing into oil are a source of valuable feed components, primarily protein, the biological value of which is higher compared to sunflower and soybean products (Schumacher, 1992; Mykytyn et al., 2006; Lü Hui-gang et al., 2019; Szparaga et al., 2019; Kharchenko et al., 2019; Kovalenko et al., 2023).

However, along with nutrients, rapeseed contains a number of antinutrients that in one way or another affect the health and productivity of farm animals and poultry (Demyanchuk & Mykytyn, 2005; Wallenhammar et al., 2018; Mykytyn et al., 2019; Sikora et al., 2020; Hryhoriv et al., 2021; Lopushniak et al., 2022)

Materials and Methods

The research was conducted using information sources, as well as seeds, meal and rapeseed cake, obtained in research institutions, industrial and processing enterprises of Ukraine.

Biochemical evaluation of feed was carried out by known methods: dry matter, fat, fiber, protein, ash, BER, phosphorus, calcium feed – according to the methods described by Alikaev, alkenylglucosinolates – using palladium reagent, the fatty acid composition of oil – gas chromatographic method (Demyanchuk et al., 2003b).

To analyze the results obtained, computational and analytical research methods were used. To reduce the content of antinutrients, an analysis of moisture-temperature conditions, chemical and biotechnological treatment of meal/cake was carried out.

Results and Discussion

Nutritional value of rapeseed feed

Based on literary data – rapeseed cake and meal – are highly nutritious feed, due to their chemical composition (Tab. 1). As can be seen from the table, rapeseed products are somewhat inferior to soybean and sunflower in terms of protein content, but the difference in other indicators is insignificant. The content of minerals (phosphorus, calcium, as well as iron and manganese) in rapeseed meal is superior to all others. It also contains a sufficient amount of B vitamins.

Table 1. Comparative chemical composition and nutritional value of these cakes and meals

Product of processing		Feed units in 100 kg	Exchange energy in 100 g, Kcal	Coefficient of digestibility of organic substances, %	Chemical composition, %									
					Raw protein	Raw fat	Raw fiber	Raw ash	Lysine	Methionine	Tryptophan	Methionine + cystine	Calcium	Phosphorus
Cake	rapeseed	100	253	67	33	9	13.2	6.2	1.58	0.54	0.49	1.33	0.8	1
	sunflower	113	288	61	35.6	7.5	13.3	6.1	1.47	0.77	0.56	1.4	0.33	0.91
	soybean	118	315	88	40.2	5.8	7.3	5.4	2.26	0.45	0.55	0.94	0.42	0.63
Meal	rapeseed	91	265	71	36	2.1	12	7.4	1.78	0.55	0.51	1.68	0.6	0.8
	sunflower	94	265	60	36	1.9	14.9	6.1	1.2	0.68	0.45	1.22	0.42	0.9
	soybean	101	250	89	40	1.2	10.6	5.7	2.36	0.47	0.49	1.08	0.37	0.65

The amino acid composition of rapeseed protein is close to soybean, and the content of such essential sulfur-containing amino acids as cystine and methionine even prevails over it. It is believed that due to the better-balanced composition of amino acids, the biological value of rapeseed protein, which is 86%, is higher than that of sunflower (65%) and soybean (68%).

Antinutrients of rapeseed meal

Along with nutrients, rapeseed meal also contains a number of antinutrients – glucosinolates, sinapines, tannins, saponins, etc., and therefore its use in poultry feeding has to be limited. First of all, it concerns substances such as glucosinolates (Fig. 1).

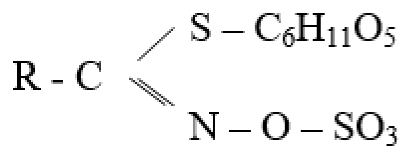

Figure 1. **The general formula glucosinolates**

Currently, more than 100 different glucosinolates are known, which differ mainly in the structure of the radical, which has an amino acid origin. Rapeseed meal is dominated mainly by three glucosinolates – progoitrin, gluconapine and glucobrascicanapine, and the first of them accounts for more than 60% of the total glucosinolate content.

Glucosinolates themselves are non-toxic, but under the influence of the enzyme "myrosinase", as well as strongly acidic and strongly alkaline solutions or high temperatures, their decomposition takes place, resulting in the formation of toxic aglucons, glucose and inorganic sulfate (Fig. 2).

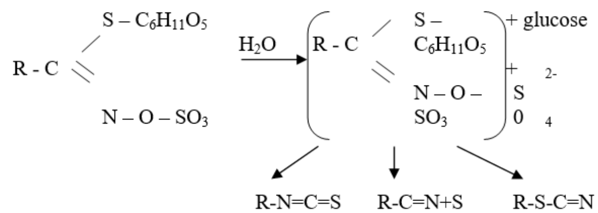

Figure 2. **Formation of toxic aglucones, glucose and inorganic sulfate**

The qualitative composition and ratio of the formed aglucons depends on the structure of glucosinolates and the conditions for their hydrolysis, including enzyme sources, pH and temperature. For example, at pH 5.5-7.0, mainly isothiocyanates are formed, and at pH 3.0-4.0 – nitriles. Thus, the decomposition products of the main glucosinolate of rapeseed – progoitrin, depending on the conditions of hydrolysis, are (L)-5-vinyl-2-thiooxazolidone (goitrin), formed spontaneously from 2-hydroxy-3-butenylisothiocyanate, and nitrile 1-cyano-2-hydroxy-3-butene. The hydrolytic breakdown of gluconapine leads to the formation of 3-butenylisothiocyanate and glucobrascicanapine to 4-pentenylisothiocyanate.

The aglucons, which are formed during the hydrolysis of glucosinolates, exert primarily a zobogenic action, depressing the activity of the thyroid gland, mainly in monogastric: the most zobogenic are 5-vinyl-2-thiooxazolidone, much less toxic in this respect isothiocyanates, nitriles and thiocyanates.

Along with the zobogenic effect, the hydrolysis products of glucosinolates contained in rapeseed meals cause a decrease in feed intake, a decrease in weight gain and weight gain of animals, and worsen the quality of poultry products.

An important role in the formation of toxic compounds from glucosinolates is the level of activity of rapeseed meal myrosinase, which depends on the method of processing rapeseed into the oil. It should be zero because otherwise, the hydrolysis of glucosinolates will begin already from the mouth of animals and birds. And although glucosinolates partially disintegrate in the gastrointestinal tract under the influence of enzymes of bacterial microflora, the toxicity of such meal is much lower. The antinutrients of rapeseed meal include sinapine, which tends to hydrolyze to synapic acid and choline (Fig. 3)

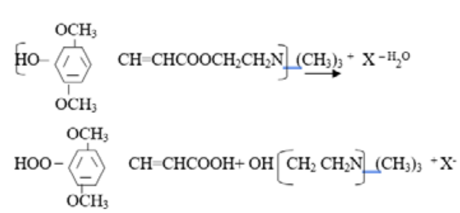

Figure 3. **Hydrolysis of sinapin to sinapic acid and choline**

The content of sinapine in rapeseed meal averages 1%. Despite the bitter taste, sinapine and its hydrolysis products do not adversely affect the feed intake and growth of animals and poultry. At the same time, it is known that increased levels of rapeseed meal in the diets of laying hens with brown plumage led to poor-quality eggs with a "fishy" or "crab" smell.

Reducing the content of sinapine in rapeseed meal can be achieved by treating the latter with calcium hydroxide, autolysis, steam and ammonia. To prevent the negative effects of sinapine, antibiotics are administered into the diet of laying hens. Along with this, rapeseed varieties are selected for reduced content of sinapine in seeds on the one hand and to increase the resistance of laying hens to the negative effects of sinapine on the other hand.

Tannins of rapeseed meal are predominantly of condensed type and are found mainly in slices of scales from processed seeds. Their content is 1.6-3.1%, so this level of tannin decreases the amount of metabolic energy. To reduce the tannin content in rapeseed meal, technological (heating, treatment with sulfuric acid, urea, ammonium, removal of scales before extracting oil, etc.) and breeding methods are used.

Saponins are glycosides that consist of monosaccharides (galactose, glucose or rhamnose) and aglyconic steroid units or related compounds. They attract attention due to their presence in alfalfa and participation in the swelling of ruminants, cause hemolysis of red blood cells, and also affect the level of cholesterol in the blood and liver, growth and absorption of nutrients, inhibit enzymatic activity and smooth muscle activity.

Although the reports indicate rather large amounts (from 0.62 to 2.85%) of saponins in rapeseed meal, there is no evidence of the negative effect of saponins of this product on the poultry organism in the literature. Phytin (calcium-magnesium salt of inositol hexaphosphoric acid) is a component containing a large amount of phosphorus and is characteristic of all types of seeds, including rapeseed meal. By itself, it does not show an anti-nutritional effect, but due to the low availability of phosphorus in the gastrointestinal tract of animals and birds, it increases the yield of fecal phosphorus and binds ions of divalent metals (Zn, Mg, Mn), significantly reducing their digestibility. The phytin content in rapeseed meal averages 3.6%.

To reduce the phytin content in the meal, treatment using phytases obtained from mushrooms is proposed. A fairly high level of fiber in rapeseed meal (an average of 13%) reduces protein digestibility (83.3% compared to 93.4% of soybean).

Ways to improve the feed value of rapeseed products

According to the results of foreign and domestic research, the main ways to solve this problem are selection and technological. Through the implementation of breeding programs, it has already been possible to bring, in particular, a number of low-glucosinolate rapeseed varieties (the so-called "00" varieties), which made it possible to expand the use of processed products from such seeds in the diets of animals and poultry. Technically, it is possible to significantly improve the quality of soybean meal (tosturing, extrusion), rapeseed (toasting), ammonium treatment (peanuts), etc. However, the disadvantage of the latter is the need for high temperatures, which lead to a decrease in protein solubility and the availability of amino acids due to the so-called Millard reactions.

As previous studies have shown, one of the effective and effective ways to improve the quality, in particular, of rapeseed meal, is its biotechnological processing, which not only significantly reduces the content of antinutrients, but also increases the solubility of the protein, the availability of amino acids, improves the taste of feed, etc. As a result, feed consumption increases, protein costs per unit of growth decrease and production costs are reduced. This indicates that biotechnological processing increases the level of transformation of feed nutrients into livestock products.

Reduction of glucosinolate content in the industrial process of rapeseed processing

It was also found that the content of antinutrients, in particular glucosinolates, can be reduced in the process of processing seeds into oil.

Samples of seeds, meal and cake taken this year at domestic enterprises, which in recent years are the main processors of rapeseed seeds, were analyzed for the content of the main antinutrients – glucosinolates (Tab 2).

Table 2. The content of glucosinolates in rapeseed seeds, meal and meal taken at domestic processing enterprises

Company name	Like	Moisture, %	Oil content, %	Glucosinolate content, μMol/g natural mass	Glucosinolate content, μMol/g absolutely dry matter
ViOil	seed	10	44.74	25.5	56.3
	meal	11.7	2.78	22.8	26.7
“Oliyar”	seed	9.1	44.15	24.5	52.4
	meal	11.9	2.24	22.1	25.7
LLC "Agrotekhnika"	seed	8.9	43.47	19.4	40.7
	cake	9.3	14.2	23.4	30.6

The analysis of changes in the content of glucosinolates in the process of processing marketable seeds into oil showed that due to the conditions of the technological process at oil extraction plants, it decreases by more than 50%, which is obviously due to the action of high temperatures during the process of toasting meal. At the same time, at the oilseed plant, where there is no stage of oil extraction by organic solvents, the content of glucosinolates decreased only by 25%.

Technological ways to reduce feed toxicity

The analysis of methods for processing rapeseed feed in order to reduce the content of antinutrients showed that physical, chemical, enzymatic and microbiological processing methods are proposed for this, which are based on chemical or thermal decomposition, hydrolysis of glucosinolates, their decomposition into non-toxic or low–toxic compounds, inactivation of the myrosinase enzyme, polymerization of decomposition products, their metabolization by microorganisms, etc.

In the process of physical treatment, myrosinase is either inactivated, which prevents the formation of toxic products of autolysis or evaporation or conversion of glucosinolates into biologically less active components. The main methods of myrosinase activation include dry heating, heating in the aquatic environment, autoclaving and microwave treatment. The degree of inactivation of the enzyme depends on the duration of the heating temperature, as well as the humidity regime. Short treatment of whole seeds at a temperature of 100 °C and high humidity is considered more effective than for a long (30 minutes) heating time at a temperature of less than 100 °C and a limited water content. In addition to the specified parameters in the process of inactivation is also important openness or closeness of systems; In microwave treatment, the essential parameters are also the water content, the amount of energy and the duration of processing. However, this is desirable not only for the maximum inactivation of the enzyme but also for the complete or partial decomposition of glucosinolates, since toxic compounds from them can still be formed by the influence of enzymes in the gastrointestinal tract of animals. It should be added that complete inactivation of myrosinase can occur in the technological process of processing rapeseed into the oil.

Heat treatment of rapeseed for the purpose of neutralization of glucosinolates includes dry-heat treatment, autoclaving and extrusion. Their decomposition in rapeseed productsbegins intensively with a heating temperature of 125 °C. With similar heating during the tosturation of rapeseed meal in the technological process of rapeseed seed processing, the content of goitrin and isothiocyanates is halved, although the amount of soluble protein decreases by a third.

In the process of dry-heat treatment, a noticeable decrease in the content of goitrin and isothiocyanates takes place at high (130-150 °C) temperatures and a long (2-5 hours) time of its action. There are different opinions regarding the effectiveness of this method of neutralizing glucosinolates, however, it is well known that under the influence of high temperatures, there is a deterioration in the quality of the feed, in which the solubility and digestibility of protein, as well as the content of available lysine, are significantly reduced.

The content of goitrin and isothiocyanates decreases in proportion to the length of time in the process of autoclaving rapeseed meal, but at the same time, there is a parallel process of reducing the quality of protein, in particular, the amount of available lysine, methionine, cystea and, to a lesser extent, other essential amino acids, while methionine partially passes into methionine sulfoxide.

The extrusion process can also affect the content of glucosinolates and the activity of myrosinase in rapeseed products, but in general, this effect is ineffective; so, at extrusion parameters – temperature 290 °C and processing time 12 seconds. The total glucosinolate content decreased by only 21.2%.

The use of micronization for the neutralization of rapeseed glucosinolates and meal is known. Due to microwave exposure for 90 seconds, at a temperature of 195 °C, the content of 5-vinyl-2-thiooxazolidone in the treated seeds decreased by more than half, and isothiocyanates – more than fourfold. It should be noted that the content of available lysine increased significantly (from 0.45 to 0.85%).

Under the influence of gamma radiation (^{60}Co) at a dose of 50 milliradian, the content of total glucosinolates in the meal decreased by 39.2% and nitriles by 44.5%. According to other data, at a dose of 50-100 milliradian, the content of WTO decreased by 2-6 times. However, this decreased the content of amino acids and their availability.

A well-known method of removing toxic substances from rapeseed seeds and meal is their extraction with water, aqueous solutions of acids, alkalis, salts and organic solvents (methanol, ethanol, acetone, etc.). Leaching of glucosinolates is carried out using a variety of methods of the technological process, where the ratio of solid and liquid phases, the temperature of the solvent, the multiplicity of stages and their duration, etc. are important. To prevent the decomposition of glucosinolates, intact seeds are placed for 3 minutes. in boiling water followed by extraction of 0.01 H NaOH with a temperature of 60 °C, or extracted intact glucosinolates with water at a temperature of 0 °C. Two-stage aqueous extraction of rapeseed meal, although not completely removed 5-vinyl-2-thiooxazolidone (WTO) and isothiocyanates (ITC) (by 84% and 77%, respectively), nevertheless significantly increased the utilization rate of its protein (from 40 up to 69%). Extraction in two stages with boiling water with a total duration of 15 minutes. allowed to remove more than 80% of glucosinolates from rapeseed meal. In another way, using a two-hour water extraction, in which isothiocyanates and 97% goitrin were completely removed, a product with a WTO content of only 0.02% was obtained. However, the use of such meal in feeding experiments on rats revealed, unlike other organs, histological changes in the thyroid gland on a par with animals of the group that received raw meal. Based on this, it is concluded that, firstly, the thyroid gland is a more sensitive organ to the action of residual amounts of WTO and it is assumed that in addition to WTO and ITC, there are other goitrogens in rapeseed meal that are not extracted by water.

Satisfactory results of glucosinolate removal are obtained by extraction with aqueous solutions of methanol, ethanol and acetone from both crushed seeds and meal, with 70% acetone solution determined to be the most suitable. For selective extraction of toxic components from rapeseed (glucosinolates, their decomposition products, phenolic compounds, etc.), which have different properties, combined extractants (alcohols, ammonia, hydrocarbons) are used.

Chemical treatment of rapeseed products is aimed at the breakdown or transformation of glucosinolates with the formation of non-toxic or volatile products. For this purpose, various reagents are used – acids, alkalis, salts, heavy metals, aldehydes and peroxides, combining them mainly with the action of elevated temperatures. Salts of iron (II), copper (I) and nickel-containing 0.1-4% actively decomposed glucosinolates. And although the lysine content in the meal protein practically did not change, the decomposition products, mainly nitrile and non-volatile 1-cyano-2-hydroxy-butene remained in the meal. Treatment of whole seeds by acidic hydrolysis, in particular sulfuric acid, can completely deprive them of WTO and TIC, but the quality of the oil deteriorates. Complete hydrolysis of glucosinolates, as well as the main products of their decay – WTO and ITC in the industrial process of rapeseed processing is achieved by treating with 15% acid for 4 hours at a temperature of 96-98 °C. The enzymatic digestibility of the obtained meal is higher than that of the tured meal, but there are losses of lysine. Application of hydrogen peroxide for Processing rapeseed flour also effectively reduces the content of glucosinolates, but at the same time, oxidation of sulfur °C containing amino acids takes place, which reduces the nutritional value of protein.

In chemical treatment, mixtures of chemicals are often used and also combined with the action of physical factors – frying, steam treatment and extrusion. It should be added that the degree of decomposition of glucosinolates and the negative impact on the amino acid composition during acid or alkaline catalysis strictly depends on the pH of the medium and humidity in the system, as well as on the reaction temperature and duration of treatment, which causes certain inconveniences.

The basis of microbiological methods of detoxification of rapeseed products is the enzymatic decomposition of glucosinolates, which takes place using microbial strains (monocultures or their mixtures), or their fermentation (separately or together with other material).

The effectiveness of such processing depends on the metabolic activity of microorganisms and fermentation conditions, in particular pH and temperature. For this purpose, fungi (Geotrichum candidum, Rhizopus oligosporus, Oospora lactis, some species of the genus Penicillium, etc.), yeast (Sacharomyces cerevisae), bacteria (Escherichia coli, Lactobacillus helveticus, Streptococcus lactis are used in both pure and mixed cultures etc.). The degree of detoxification of rapeseed meal under the action of individual microorganisms was quite significant: for example, under the action of mold fungus Byssochlamys fulva, the content of WTO decreased by almost 94%, and TICs °C by 100%.

Unlike a number of physicochemical methods of processing rapeseed meal, microbiological treatment, along with a decrease in the content of toxic substances, improves protein, and the biomass of bacteria and fungi contains a significant (7.1-9.2 g/16 g) amount of lysine and vitamins of group B.

Microbiological and enzymatic methods of glucosinolate neutralization include high cost and duration. Enzymatic treatment of rapeseed meal is carried out using crushed white mustard seeds as a source of exogenous myrosinase for hydrolysis of glucosinolates. After incubation under known conditions (temperature 40 °C, duration 1 hour, hydromodulus 2, activation of the enzyme by ascorbic acid), the decomposition products of glucosinolates were removed by extracting 75% ethanol.

Anaerobic fermentation is simpler, in particular, silage of rapeseed meal with high-carbohydrate feeds (beetroot crops, corn cobs in the phase of milky ripeness, steamed potatoes), as well as fermentation with the participation of rapeseed products mixed with apple, squeezes with the participation of Aspergillus, Rhizopus and Mucor mushrooms. The enzymatic reaction takes place at a hydromodule of 5-20, a temperature of 20-40 °C, pH 5-7 for 150 hours. There is a known method of reducing the content of glucosinolates by fermentation of moistened meal, in which, due to the activity of facultative anaerobes, the content of WTO decreased from 1.1 to 0.05%, and ITC – from 0.3% to 0%. Stimulants of fermentation can be acids, crushed fodder plants, sugar-rich foods, silage juice, and antifungal drugs to prevent the development of molds.

The main disadvantages of the latter method of neutralization are the long-term processing (60 days) and the relatively short shelf life of the finished product (10-100 days).

Significantly reduces the processing time during anaerobic fermentation by adding waste from the processing industry (beer grains, molasses), preservatives (low molecular weight fatty acid concentrate, lactic acid) in combination with elevated temperatures (25-37 °C).

The proposed method of processing rapeseed cake or meal consists in keeping it in mixtures with waste from the processing industry and preservatives under anaerobic conditions at an ambient temperature of 25-37 °C for 2-4 weeks.

The study of the dynamics of changes in the content of one of the main decomposition products of glucoselates – 5-vinyl-2-thiooxazolidone (WTO, goitrin) depending on the temperature conditions of treatment revealed certain regularities in the detoxification process. Thus, at an ambient temperature of 25 °C, the level of goitrin in the cake treated with conservants decreased by 38-61%, and in the cake with molasses and bards practically by 100%, moreover, in the last versions this happened after 14 days of exposure. Due to the combination of mixtures at a higher (37 °C) ambient temperature, the WTO level was almost leveled in all variants and was minimal, starting from the 2nd week of maintenance.

In mixtures with different humidity (20, 40, 60 and 80%) of Art, the decrease in WTO was practically the same, but depended on the concentration of additives, in particular molasses and low molecular weight fatty acid concentrate (CNMK).

Conducting a microbiological and biochemical evaluation of the original and treated cake showed that the process of detoxification and other transformations in its biochemical composition is associated with the activity of fermentation microflora, the intensity of vital activity of which depends both on the type of component, its concentration, and to a greater extent on the topics of the processing temperature. Thus, in cake treated with a preservative (CNMK) at t = 16-18 °C glucosinolate content has not changed much. There is no growth of colonies of lactic acid and propionic acid bacteria, and the yeast content even decreased. At the same time, when treating the cake with an aqueous solution of molasses at the same temperature, intensive growth of colonies of fermentation microorganisms was observed, the number of which increased to tens of thousands (yeast) and tens and hundreds of millions (lactic acid, propionic acid bacteria) individuals per 1 g of product. In this embodiment, there is an intensive decrease in the content of 5-vinil-2-thiooxazolidone. This process is deepened by keeping the cake with the addition of molasses at temperatures and the environment of +37 °C, but on the 6th day after treatment from fermentation microorganisms, there is only rod-shaped yeast, similar morphologically to Candida. Also, only yeast, but morphologically similar to Saccharomyces, is found in a cake aged under anaerobic conditions for 12 months.

Organoleptic evaluation of ox products obtained during production inspection with an ox of 55-65% showed that they taste sour, have a light brown (with post-yeast bard) and dark brown (with preservatives and molasses) color with a pleasant smell of rye bread or freshly fermented vegetables. Analysis of the pH, the content of low molecular weight organic acids, ethanol and ammonium nitrogen revealed the similarity of the obtained products in these indicators to those obtained as a result of biological and chemical preservation.

As a result of the proposed biotechnological treatment, it was found that the content of 5-binyl-2-thiooxazolidone decreased by 5-22 times, isothiocyanates – by 13-20 times, thiocyanates – by 1.5-1.8, sinapine – by 1.2-2 times. At the same time, the amount of raw fat increases (on average by 3%); the content of dry matter and raw protein practically did not change, but the water-soluble fraction of the latter increased significantly against the background of a low amount of ammonium nitrogen.

It should also be noted a number of other positive changes in the biochemical composition of fermented cake. So, despite some decrease in total lysine, the content available increased by 1.5-2.2 times. The fatty acid composition of the products improved, where the ratio of linoleic/linolenic acid was 3.0, whereas in the original cake this figure was 2.3.

As a result of research, it was also noted that in the process of fermentation of the cake, the tendency to increase the oxygen lot and peroxide numbers of oil, which is characteristic of the stored natural cake, disappears.

Analysis of the quantitative and group composition of the microflora of feed obtained under production conditions on the basis of the developed technology revealed an improvement in their sanitary condition by reducing the number of viable bacteria and mold, which made it possible to evaluate it as not dangerous for feeding it to animals.

This allows to increase the rate of introduction of rapeseed meal / cake into the rations of farm animals and poultry by 1.5-2 times compared to one-zero varieties, but it is necessary to continue to look for ways to reduce the content of glucosinolate to a level below 20 μMol g^{-1}.

Conclusions

It is shown that cake and meal obtained from the processing of cruciferous oilseeds into oil are valuable sources of protein in the diets of farm animals and poultry, but along with nutrients they contain a number of antinutrients.

The use of meals in feeding is limited not only by their cost but also by nutritional value, nutrient content (primarily protein) and anti-nutrients. Technologies for the use of rapeseed meal depend primarily on the content of glucosinolates in it. The main ways to reduce the toxicity of anti-nutritional factors are technological and selective.

The content of the main antinutrients in rapeseed meal / meal of domestic production for this period is 25.1-25.8 μMol g^{-1}, which is still higher than the level that allows using these products of rapeseed processing in feeding monogastric animals without restrictions. For the effective use of rapeseed feed, it is necessary to look for ways to reduce glucosinolate levels below 20 μMol g^{-1}.

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