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THE DEVELOPMENT GRANULATION TECHNOLOGY OF COMPOUND FEEDS IN THE FORM OF MIXTURE CRUMBS

Abstract

A detailed analysis of the production of granulated feed in the world and in Ukraine for the last ten years has been presented in the article. Science and practice proved the high efficiency of granulated mixed fodder products. A literature review was conducted. The urgency of the problem of the feed mill industry is presented, namely the question of improving the technology of pelleting feed. The detailed analysis of technological processes of the traditional technology of granulated mixed fodders production with the receipt of granule grains with the description of technological regimes of each process has been given. The main disadvantages of traditional technology of granulated feed production have been considered and possible solutions of these problems are presented.

As the development of the feed industry is characterized by the intensification of technological processes aimed primarily at improving sanitary quality, the methods of preliminary wet-heat preparation of mixed fodder, in particular, the application of expansion to the granulation process, have been presented as the basis for further development of the advanced granulation technology. The effect of heat treatment on the nutrient absorption of individual ingredients of compound feed has been the subject of many research. In general, the wet-heat treatment of compound feed can improve the digestibility of nutrients, including proteins, amino acids and carbohydrates.

The advantages of using expansion, the principle of the expander and the technological features of the process have been considered. The generalization of the conducted analytical and experimental studies allowed develop the advanced technology of granulation in the form of a blend granulated crumb, which will increase the output of finished products.

The purpose of the work and the tasks of research were set. The aim of the work was to substantiate obvious shortcomings in the traditional granulation technology and reduce the unit cost of electricity for the production of granulated feed in the form of crumb. The technology for the production of granulated compound feed in the form of a blend granulated crumb and expanded crumb have been presented in the article. The description of technological processes and technological regimes (moisture of products, use of sieves, vapor pressure, steam consumption, duration, etc.) has been presented too. The physical and microbiological characteristics of granulated and expanded feed, as well as granulated grains and expanded grains are given. Has been studied the dependence of specific electricity consumption for the granulation process on other factors. Has been determined the yield of finished products – mixture granulated crumb and expanded crumb;

Keywords: mixed fodder industry, technology of granulation, reduce energy consumption, the physical properties, the microbiological indicators, granules, granulated crumb, expanded crumb.

Introduction. Formulation of the problem

At the present stage of development of the agro-industrial complex of Ukraine, the problems of reducing the specific energy consumption in the production of compound feed products are important, not inferior to its quality. One of the important strategic priorities of agricultural production is to provide the population with high-quality, safe food. At the same time, the requirements for the quality of compound feeds have significantly increased. Problems finding ways or technologies that would satisfy the reduction of specific electricity consumption at all stages of the manufacture of compound feed products are relevant. [1]

The process of granulation of compound feed products, it is one of the most energy-intensive and expendable processes along with the technological process of grinding. The article has been reviewed the problem of high specific electricity consumption in the production of granulated animal compound feeds. Granu-

lation allows you to provide stable uniformity, improve sanitary and hygienic parameters, increase nutritional value, increase shelf life, and improve the physical properties of the components of the compound feed. However, despite all the advantages, the granulation lines that exist have relatively high performance and, at the same time, high unit costs of electricity. On the basis of the conducted literature and patent examinations should be said that the development of technology to improve the granulation process will not only improve the nutritional and sanitary quality of compound feed products, but will also increase the productive effect of compound feeds and reduce the specific energy consumption. [1, 2]

In this way, it became necessary to search for a new, effective concept of change in the structure of the existing granulation technology of compound feeds for its comprehensive improvement, to solve problems that are considered.



Analysis of recent research and publications

The feed industry is one of the most competitive sectors in the agricultural sector (Fig. 1). In 2018, the world compound feeds production amounted to about 1030 million tons of compound feeds. One of the largest producers of Asian compound feeds is Charoen Pokphand - a Thai company that produces 18 million tons of compound feeds in different parts of East Asia. World compound feeds production in 2019 reached approximately 1 billion tons.

The feed industry of Ukraine is quite significant in the agro-industrial complex of the country. The industry provides livestock and food industry development. Facility of the feed industry produce feed, feed concentrates, protein-vitamin and protein-mineral-vitamin supplements, premixes and whole milk replacers and other feed products. The feed industry is quite promising on account of the existence of a powerful raw material base in Ukraine, but it strongly depends on the state of animal husbandry and poultry farming in the country. [3]

The traditional process of compound feeds production includes the following technological processes (fig. 2), such as cleaning the components of grain and protein raw materials, preliminary grinding of

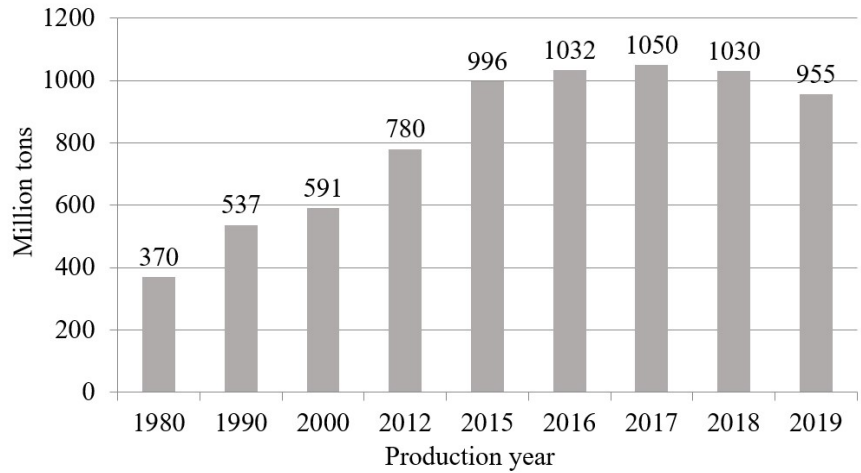


Fig. 1 - Production of compound feeds in the world according to "Alltech" – The Science of Animal Nutrition and Health. [4]

components, weighing and dosing, mixing the finished mixture of components, obtaining loose compound feeds. Loose compound feeds moistened with subsequent granulation.

In the granulator, loose compound feeds are coming in which the mixture and nutrients, minerals, amino acids, oils and others are mixed according to a specific recipe. Compound feed is pushed through the holes of the matrix of the granulator and leaves the granulator as a granulated feed - granules. After granulation, the granules are cooled. Next, the granules can be crushed, then by sieving to obtain granulated crumb. The grinding products are sifted onto individual sifters to control the amount of products. Descent from the upper

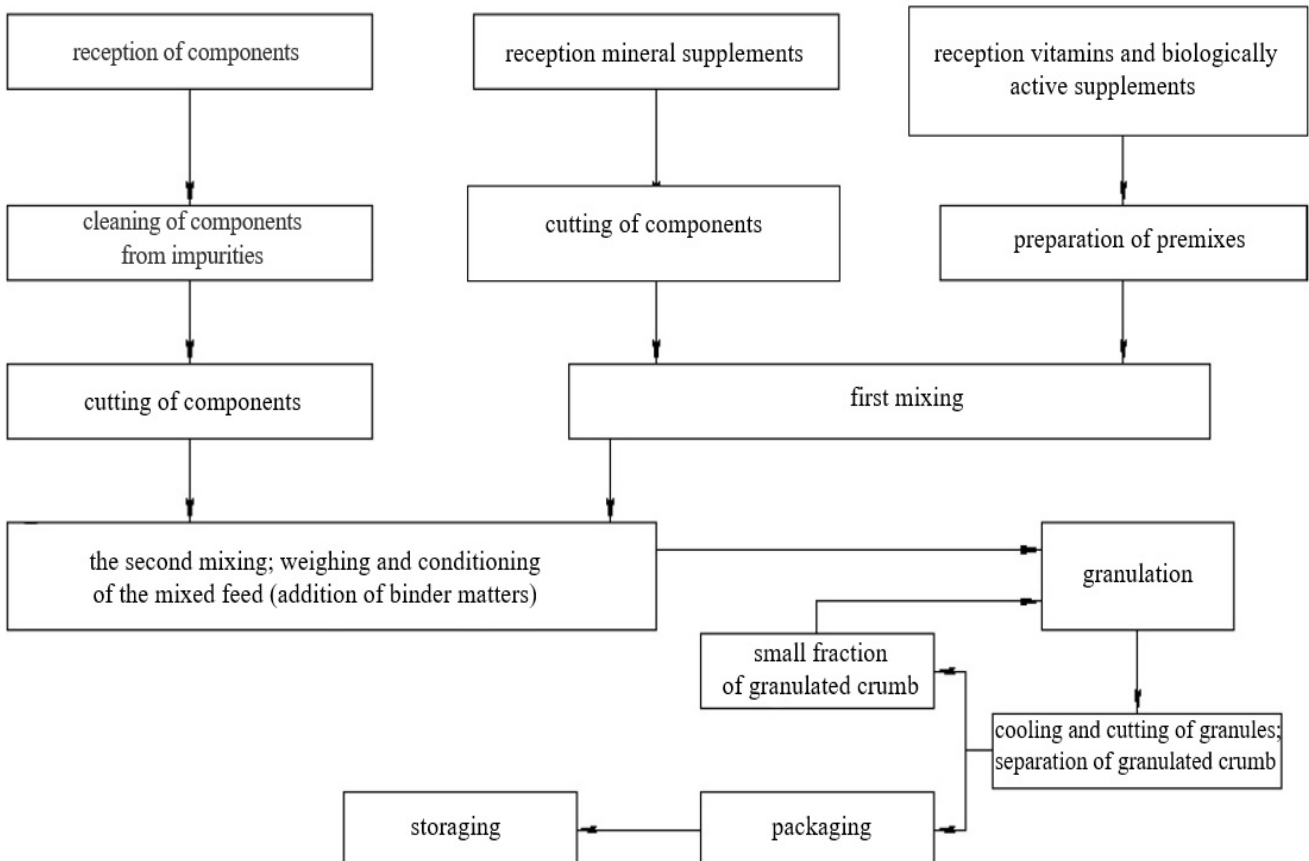


Fig. 2 - Structural scheme technologies for the production compound feeds with getting crumb of granules.



sieve is sent to regrind. Passage this sieve receives a mealy fraction, which is sent to re-granulation. Passage upper sieve and located below sieve in the sifter get *granulated crumb*. The yield of finished products (*granulated crumb*) is not more than 70%. [1, 5]. After passing through all the processing steps, the finished granulated feed in the form of granules or granulated crumb is easily stored or packaged in a compact form.

Among the main drawbacks of using traditional granulation technology are the following: disintegration of thermolabile vitamins is possible (C up to 25-30%) and thermolabile vitamins (A up to 30% E, K up to 15%). Additional installation of a dryer for drying, granules, additional costs for the purchase of auxiliary equipment (for example installation of a pre-conditioner moisturizer or expander before granulator, in order to better pre-moisten the product), additional staff for maintenance equipment. Also, with traditional granulation technology, the yield of granulated crumb is low in percentage terms (not more than 70%), which leads to the re-granulation of the product of the mealy fraction, which increases the unit cost of electricity for the process. That is, the main disadvantage is the high unit cost of electricity for this process. The existing domestic technological lines for granulating and pelletizing compound feeds have a relatively high productivity and, at the same time, a high energy intensity for producing granulated compound feeds [6, 7].

The practical application of the pre-expanding before granulation has established itself thanks to positive indicators. Such technology assumes that loose feed is initially moistened and acquires more structural and mechanical properties. There is partial denaturation of the protein, which entails an increase in protein digestibility, as well as gelatinization of starch and destruction of the pulp and lignin complexes, which significantly increases the nutritional value and assimilation of nutrients. Further, the compound feeds gets into the expander. In the expander under the influence of high pressure and temperature occur structural and mechanical and chemical changes of the product, partial destruction of fungal and bacterial microflora is carried out sanitary and hygienic properties are improved. This line was implemented in some advanced compound feed plant. This process provides sanitized compound feeds without destroying vitamins and nutrients. In the product that is processed in the expander, you can add a large amount of liquid components (up to 15-20%), while sometimes there is a need to dry the processed product. With this processing of compound feed in the expander, the performance granulator increases significantly [8].

According to the company Amandus KAHL (Germany), the use of expanders allows you to get compound feeds of high sanitary quality. Today, modern, large-scale companies for the production of high-quality technological equipment for the feed industry ("Andritz group", Austria) let out expanders, allowing to get expanded compound feed, which is ready for feeding in the form solid expandate, without the use of a further granulation process. This technological solution opens up new opportunities. This was the impetus for new

developments and research in the technology of granulation of compound feeds [9, 10].

Guided by this, the idea was born to create a line of granulation, get a separate product - solid expandate, at the same time to reduce the main load on the press granulator. Thus it is possible to produce granulated compound feed and expanded compound feed getting out of them granulated crumb and expanded crumb and mix them. So, firstly, it is necessary to prove possibility of use expandate as a separate product, it was not previously practiced. For this, it is necessary to carry out physicochemical and microbiological indicators expandate. Confirm, on the basis of the experiments performed, that expandate further use will not affect the quality in the opposite direction, and the compound feed will be of the appropriate nutritional quality. With a positive result, the next step will be an energy audit, determining the energy efficiency potential through a comparative energy audit of the basic and proposed granulation technologies.

The purpose of the work is to develop an improved granulation line with obtaining the expropriation, as a separate product, in the production of granulated compound feed in the form of crumb.

To achieve this aim, the research objectives have been defined:

- to develop improved granulation technology for the production of compound feeds in the form granulated crumb and expanded crumb;
- to develop recipe according to improved technology and determine the yield of finished products – mixture granulated crumb and expanded crumb;
- to determine physical and microbiological characteristics of granulated compound feed and expandate, produced by the improved granulation technology compound feed.
- to determine the dependence of specific electricity consumption for the granulation process on other factors, conduct the necessary experiments.

Research materials and methods.

Experimental studies were conducted at the Odessa National Academy of Food Technologies. Microbiological studies were carried out at the Department of Biochemistry, Microbiology and Nutrition Physiology, and the chemical and physical properties of the products of experience at the Department of Combined Feed Technology and Biofuels.

Results of the research and their discussion.

1. To development improve granulation technology for the production of compound feeds in the form granulated crumb and expanded crumb.

A number of studies were conducted at the department of technology of animal feed and biofuel ONAFT, and the following technological solution was proposed. (fig. 3).

The essence of the developed technology lies in the following operations. The developed technology production granulated compound feed in the form of a blend granulated crumb and expanded crumb provides: expansion raw materials, separate granulation prepared raw materials, getting granule, getting granulated crumb, get-



ting expandate, getting expanded crumb and mixing crumb getting a blend granulated crumb and expanded crumb.

As was given in the literature review, with traditional granulation technology, all 100% of the recipe for loose compound feed, it is moistened, expanded and granulated to obtain only crumbs from granules. Our advanced granulation technology differs from the traditional one, because we get a separate product, an expandate, this reduces the load on the granulator, it is not 100% loaded, getting expanded crumb and mixing with granulated crumb.

The way is carried out, in the following order. The finished loose compound feed is processed in moisturizer, where it is heated to a temperature of + 50 °C to + 85 °C for 5–10 seconds and moistened content of 18–22%. Exercise of such processing provides compound feed thermo-plastic properties. The next stage of processing is carried out using expander. Moisture compound feed in expander is 16-22%, temperature of + 110 °C to + 120 °C. The resulting product - the expandate has a moisture content of 13-14%, its temperature is approximately 85-95 °C. Expandate has the form of pieces, sizes from 20-50 mm. Part of the expandate is cooled, crushed and sieved, to obtain expanded crumb, and part granulated in a granulator under standard processing conditions.

In the granulator under the influence of high pressure and temperature occur structural-mechanical and chemical transformations of the product, increases the degree of absorption of animal nutrients. The

compound feed treated with steam has a moisture content of 15–18% and a temperature of 60–90 °C, steam pressure, as a rule, is 0.2–0.5 MPa, steam consumption is 50–80 kg/ton.

The granules obtained after granulation have a temperature of 60-80 °C, they are sent to the cooling stage. The duration of cooling is 300-900 s, depending on the type of cooler and the size of the granules. The temperature of the granules after cooling should not exceed ambient temperature by more than 10 °C, and moisture should not exceed 14.5%.

After this stage, chilled products are obtained in the form of granulated compound feed, which are crushed. Crush products on roller shredders, using the following modes: the number of flute 2.0-2.8 per 1 cm of the surface of the roller; roll gap 0.1 to 0.2 mm. Next, the grinding products (granulated crumb and expanded crumb) are sifted onto separate screeners to control the amount of products. The grinding products are sent to a separator, in which two sieves are installed: upper is №30. Descent from upper sieve sent for re-grinding. The bottom sieve in the separator set №10. The passage of this sieve is received mealy fraction, which is sent to re-granulation. The passage upper sieve and descent sieve getting crumb. [1].

2. Recipe development according to improved technology. Definition the yield of finished products – mixture granulated crumb and expanded crumb.

With the help of the software package "Optima Expert Expert", at the department "Technology of feed and biofuels" calculated compound feed recipe for young broiler chickens from 2 to 3 weeks. (table 1). On the basis of the obtained improved granulation technology, the physical properties, chemical composition, sanitary quality and permissible storage periods of the studied products were determined.

The prepared components, according to the compiled recipe, in an amount of 5 kg, were mixed together in a batch mixer. All components of the recipe were mixed for 60...360 seconds at a frequency of rotation of the mixing unit n=1,33 c-1 Next, the prepared components in the mixer were sent to the grinding stage. Grinding was carried out on a laboratory hammer crusher. Experimental

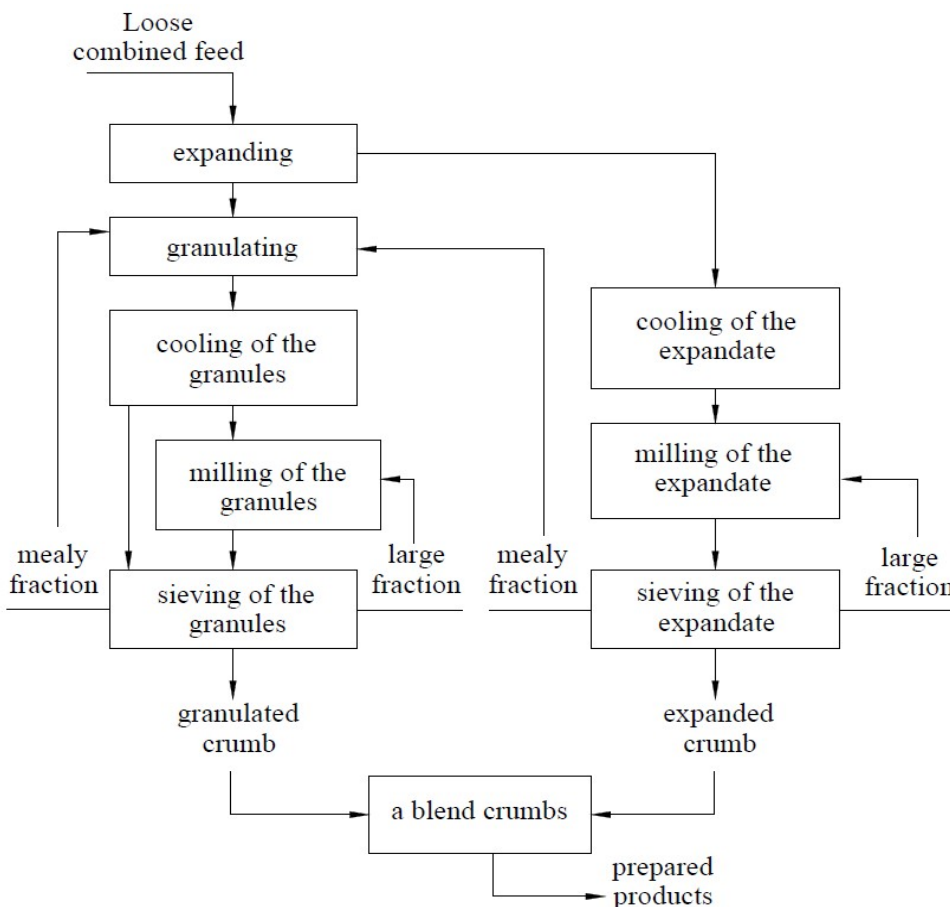


Fig. 3 - Scheme of the granulation technology with using pre-expanding and obtaining granulated crumb and expanded crumb



Table 1 - Composition compound feed recipes for young broiler chickens from 2 to 3 weeks, %

Composition of recipe	The content in the recipe, %	Calculation per 5 kg of recipe in order to do research	Calculation per g of recipe	Wholesale price for 1 ton, UAH
Corn	54,6	2,73	2730	5 400,00
Wheat	15,0	0,75	750	4 000,00
Oil meal CII 46%	0,9	0,045	45	13 800,00
Sunflower meal CII 40%, CK 14%	7,0	0,35	350	7 000,00
Meat flour CII 56%	6,00	0,3	300	8 500,00
Fish flour CII 69%	9,37	0,4685	468,5	23 000,00
Fish fat	2,0	0,1	100	14 000,00
Feed yeast CII 44%	3,00	0,15	150	6 900,00
Lysine sulfate	0,44	0,022	22	41 000,00
Methionine 98,5%	0,20	0,01	10	110 000,00
Treonin 98%	0,07	0,0035	3,5	85 000,00
Tryptophan 98%	0,02	0,001	1	83 750,00
Limestone flour	0,4	0,02	20	450,00
Premix	1,0	0,05	50	30 000,00
In all	100	5	5000	

Table 2 – Characteristics the physical properties of research products

Parameters	Granulated compound feed (granules)	Expanded compound feed (expandate)
Moisture content, %	12.3	11.2
Bulk density, kg/m ³	680	460
Flowability, cm/s	7.7	7.4
Angle of repose, degree	38	43
Crushability, %	11	-

manufacture of samples of granules and exporters conducted, guided by the "Rules of the organization and conduct of the technological process of production of feed industry" at the production press granulator and production expander on the basis of the department of technology of animal feed and biofuels. Ready mix (5 kg) expanded, then (3,5 kg) was granulated, cooled, crushed and sieved. The remainder of pure expandate in the amount (1,5 kg) was cooled and also crushed and sieved.

To determine the yield of finished products conducted the following studies. Separated on a set of sieves appropriate diameter of the separator holes according to the technology. Upper sieve with a diameter of 3.0, bottom sieve with a diameter of 1.0. The samples were screened on a laboratory separator for 300 seconds manually or for 600 seconds.

Remainder on the sieve weighed on a technical scale with an accuracy of $\pm 0,1$ g and expressed as a

percentage relative to the weight of the sample. As a result of sieve analysis of the distribution of grinding products, the following results were obtained.

A sample of the crushed granules was (3,5 kg). Descent from upper sieve amounted to 25% (875 g), it sent for re-grinding. The passage bottom sieve amounted to 13% (455 g), which is sent to re-granulation. The passage upper sieve and descent sieve getting granulated crumb amounted to 62% (2 kg 170 g).

A sample of the crushed expandate was (1,5 kg). Descent from upper sieve amounted to 33% (495 g), it sent for re-grinding. The passage bottom sieve amounted to 38% (570 g), which is sent to re-granulation. The passage upper sieve and descent sieve getting expanded crumb amounted to 27% (405 g). As a result of the application of an improved granulation technology, according to the proposed method, the total yield of finished products - a blend granulated crumb and expanded crumb amounted to 85±4%, taking into account losses. (62% granulated crumb and 27% expanded crumb). With the traditional technology

of granulation of loose compound feed, the yield granulated crumb is up to 70% [1].

3. Research the physical properties and microbiological indicators of the quality of research products as a result use preliminary wet-heat treatment.

The physical properties granulated compound feed and expanded compound feed, as well as granulated crumb and expanded crumb, have been determined; determined the quantitative and qualitative composition of microflora during storage of finished products granulated crumb and expanded crumb; all definitions were carried out using standardized research methods. [12, 13, 14] The results are presented in table 2.

In the process of preliminary expansion, the mass fraction of moisture decreased. Granule and expandate have satisfactory physical performance: in the process of expansion, the angle of repose increased by 13.15%, and the flowability improved by 3.9%. The profound structural-mechanical changes that occurred during the process of additional expansion are indicated by a decrease in bulk density of the feed mixture by 32.4%.

In the research products were determined: the number of mesophilic aerobic and facultative anaerobic microorganisms (MAFANM) the presence of paratyphoid bacteria (Salmonella), the number of micromycetes (fungi and yeast) [15, 16, 17]. The results of studies of the effect of extrusion on the microbiological indicators of research products are given in table. 3.

The analysis of the conducted research indicates that bulk compound feed is characterized by a significant presence of microbes, which argues the need for heat



Table 3 - Research of microbiological indicators of the quality of research products as a result use preliminary wet-heat treatment

Parameters	Before granulation	After granulation	After expansion	After granulation with preliminary expansion	Decrease, % after granulation	Decrease, % after expansion	Decrease, % After granulation with preliminary expansion
MAFAnM, column forming unit /g	18*10 ⁴	2.6*10 ⁴	2,0*10 ⁴	1.1*10 ⁴	86	88,9	94
Yeast, column forming unit /g	Not found				-	-	-
Mushrooms parasites mycelial, column forming unit /g	0.9*10 ²	0.4*10 ²	0,3*10 ²	0.1*10 ²	55	66,7	75
Salmonella	Not found				-	-	-

treatment to disinfect the product. Studies in all samples prior to granulation showed a large amount of the presence of yeast, Escherichia coli and Salmonella bacteria. As a result of the preliminary expropriation process, the sanitary properties of research products (granules and expandate) are significantly improved. Under the influence of high temperature, the total number of bacteria decreased by 94%, and mushrooms parasites mycelial by 75%, which allows you to effectively store granulated crumb and expanded crumb.

4. Decision the dependence of specific electricity consumption for the granulation process on other factors.

Was held phased moistening loose compound feed and then expansion and definitions of the extension index followed by granulation of the samples (figure 4).

Established, that with increasing mass fraction of moisture unit costs of electricity on granulation process are reduced from 29.3 to 21.5 kWh / t, the expansion index also are reduced from 3 to 1.5. Decrease in expansion index can be explained by the formation of amylose-lipid and protein-lipid complexes in the process of expanding, which affect the dextrinization of starch. Considering, that expansion index should be at least 2.0 then process is considered effective when the product is moistened to 17.0% and 17.5%. As a result of the study, the specific cost of electricity for the granulation process amounted to was 22.4 kW * h / t, through a preliminary process expansion.

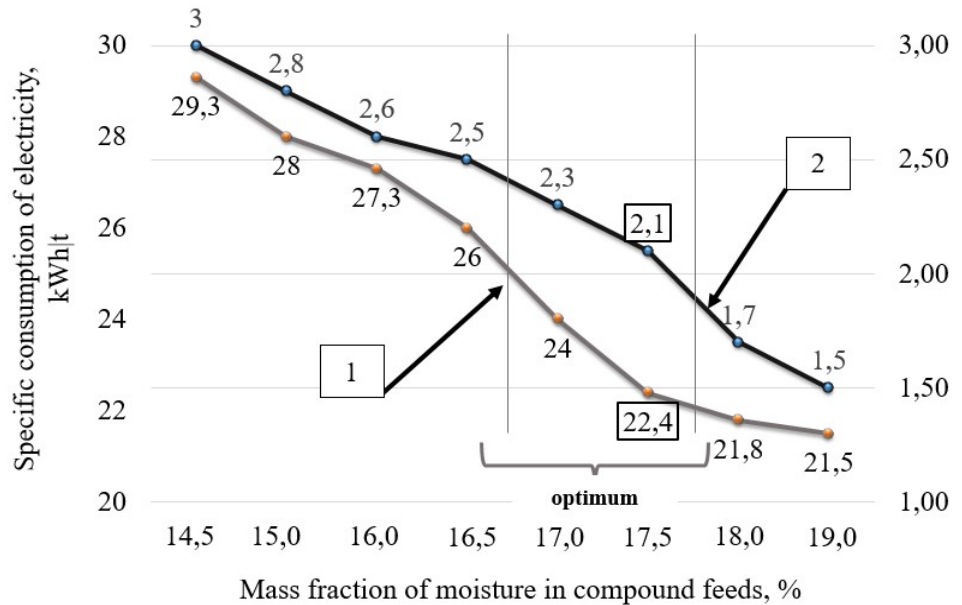


Fig. 4 - The graph of the dependence of electric consumption on the granulation process (1) and expansion index (2)

Conclusions

1) Improved technology granulating the production compound feeds, with getting expandate as a separate product, getting granulated crumb and expanded crumb was developed.

2) The recipe compound feed recipes for young broiler chickens from 2 to 3 weeks, % was made. As a result of the application of an improved granulation technology, according to the proposed method, the total yield of finished products - a blend granulated crumb and expanded crumb amounted to 85±4%, taking into account losses (62% granulated crumb and 27% expanded crumb). With the traditional technology of granulation of loose compound feed, the yield granulated crumb is up to 70% [1].

3) The physical properties granulated compound feed and expanded compound feed, as well as granulated crumb and expanded crumb, have been determined. In the process of preliminary expansion, the mass fraction



of moisture granulated crumb and expanded was decreased and amounted to 11.2% That will contribute to long-term storage of finished products. Granule and expandate have satisfactory physical performance, namely: angle of repose is 43 degree; flowability is 7.4 cm/s; bulk density accounted for 460 kg/m³. Such a decrease in bulk density is indicative of profound structural-mechanical changes.

4) Microbiological studies have been carried out. In products that have been researched such as granulated crumb and expanded crumb, definitely: the number of mesophilic aerobic and facultative anaerobic

microorganisms (MAFANM) accounted 1.1*10⁴ column forming unit /g; quantity of micromycetes (fungi and yeast) accounted 0.1*10² column forming unit /g; the presence of bacteria of the paratyphoid group (salmonella) was not revealed.

5) Has been studied the dependence of specific electricity consumption for the granulation process on other factors. Determined that as a result of the study, the specific cost of electricity for the granulation process amounted to was 22.4 kW * h / t, through a preliminary process expansion.

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РОЗВИТОК ТЕХНОЛОГІЇ ГРАНУЛЮВАННЯ КОМБІКОРМІВ У ВИГЛЯДІ СУМІШІ КРУПОК

Анотація

У статті представлено детальний аналіз виробництва гранульованих комбікормів в світі та в Україні за останні десять років. Наука і практика довели високу ефективність гранульованих комбікормів. Був проведений огляд літератури. Представлена актуальність проблеми комбікормової галузі, а саме питання по удосконаленню технології гранулювання комбікормів. Надано детальний аналіз технологічних процесів традиційної технології виробництва гранульованих комбікормів з отриманням крупки гранул з описанням технологічних режимів кожного процесу. Розглянуті основні недоліки традиційної технології виробництва гранульованих комбікормів та представлені можливі рішення даних проблем.

Так як розвиток комбікормової промисловості характеризується інтенсифікацією технологічних процесів, направлених, в першу чергу, на підвищення санітарної якості. Представлено способи попередньої волого-теплової підготовки комбікорму, зокрема застосування експандування перед процесом гранулювання, як основу для подальшої розробки удосконаленої технології гранулювання. Вплив волого-теплової обробки на засвоюваність поживних речовин окремих інгредієнтів комбікорму було предметом багатьох досліджень. Загалом, во-



лога-теплова обробка комбікорму дозволяє покращити засвоюваність поживних речовин, включаючи білки, амінокислоти і вуглеводи.

Розглянуто переваги використання саме експандування, принцип дії експандера та технологічні особливості. Узагальнення проведених аналітичних та експериментальних досліджень дозволило розробити удосконалену технологію гранулювання у вигляді суміші крупок, яка дозволить збільшити випуск готової продукції.

Поставлена мета роботи, та завдання досліджень. Мета роботи полягала у обґрунтуванні явних недоліків в традиційній технології гранулювання комбікормів, та зниженні питомих витрат електроенергії на виробництво гранульованих комбікормів у вигляді крупки. У статті представлена розроблена технологія виробництва гранульованих комбікормів у вигляді суміші крупки гранул та крупки експандату. Представлений опис технологічних процесів та технологічні режими (вологість продуктів, використання сит, тиск пари, витрати пари, тривалість та інше). Визначено методи дослідження фізичних властивостей, та мікробіологічних показників гранульованого та експандованого комбікорму, а також гранульованої крупки та крупки експандату. Була визначена залежність питомих витрат електроенергії на процес гранулювання від інших факторів. Було визначено вихід готової продукції – суміші крупок: гранульованої крупки та крупки експандату за удосконаленою технологією.

Ключові слова: комбікормова промисловість, технологія гранулювання, питомі витрати електроенергії, фізичні властивості, мікробіологічні показники, гранули, гранульована крупка, експандована крупка.

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