New Materials, Compounds and Applications
Vol.9, No.1, 2025, pp.209-221
https://doi.org/10.62476/nmca.91209

DEVELOPMENT OF ORGANIC FERTILIZER PELLETS TECHNOLOGY USING LICORICE MEAL AND HYDROGEN PEROXIDE TECHNOLOGY

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Abstract. The results of a study on the production of granulated organic fertilizer based on oxidized licorice meal with hydrogen peroxide and 5% bentonite suspension have been presented in this article. Evidence shows that incorporating bentonite suspension during the granulation process of oxidized meal enhances the physical characteristics of the granules, resulting in increased strength. The commercial properties of fertilizers have been determined: hygroscopicity, moisture capacity, caking, granule strength. A basic technological scheme, an optimal technological mode and a material balance are proposed for the production of granulated organic fertilizer using oxidized licorice meal, hydrogen peroxide and a bentonite suspension.

Keywords: *Meal, hydrogen peroxide, bentonite, extractive substances, moisture capacity, oxidation.*

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Received: *9 October 2024;* ***Accepted:*** *4 February 2025;* ***Published:*** *9 April 2025.*

1. Introduction

The intensification of agriculture necessitates the use of large quantities of mineral fertilizers. According to forecasts by the Food and Agriculture Organization (FAO), published between September 10-12, 2018 (Rome, Italy), the global demand for mineral fertilizers during the period 2016-2022 is projected to range from 292.43 to 318.65 million tons of 100% nutrients, including 105.15-111.59 million tons of nitrogen (N), 44.48-49.10 million tons of phosphorus (P_2O_5) and 35.43-40.23 million tons of potassium (K_2O) (FAO, 2019). At present, in the conditions of intensive cultivation of agricultural crops, one of the main factors for maintaining soil fertility and obtaining high-quality and high-yield agricultural crops is the scientific use of high-quality organic and organomineral fertilizers containing humic substances, along with mineral fertilizers containing various nutrients.

Soil fertility depletion represents a critical challenge to global agricultural productivity. The use of mineral and organic fertilizers exerts both beneficial and adverse

How to cite (APA):
Orakbayev, A., Ataew, H., Usanbayev, N., Jumaewa, O., Alimov, U., Charyew, O. & Namazov, Sh. (2025). Development of organic fertilizer pellets technology using licorice meal and hydrogen peroxide technology. *New Materials, Compounds and Applications*, *9*(1), 209-221 https://doi.org/10.62476/nmca.91209

effects on plant growth and soil health. Organic fertilizers, while enhancing the soil's physical structure and biological activity, often contain lower concentrations of nutrients. Consequently, their application in larger quantities is required to meet optimal plant (Patyra *et al.*, 2024). The primary raw materials for producing organic or organomineral fertilizers enriched with humic substances include plant residues, organic waste from urban and suburban households, horticultural and other plant-based waste, animal and poultry by-products, coal dust, sediments from freshwater reservoirs rich in organic matter and organic by-products from the food industry. These organic wastes predominantly consist of lignin, cellulose, hemicellulose, polysaccharides, small amounts of proteins, fats and other organic compounds soluble in various solvents. The central challenge in manufacturing organic and organomineral fertilizers lies in the transformation of these organic substances into humic substances, particularly humic acids. Notably, one of the most pressing scientific objectives for researchers, producers and agricultural practitioners globally is the development of high-quality organic and organomineral fertilizers derived from these waste materials (Xu *et al*., 2024).

There has been a growing interest in the development of pharmaceuticals, nutritional supplements, cosmetics and other products derived from natural raw materials. One of the most popular ancient herbs used in traditional medicine is licorice (Glycyrrhiza glabra L) (*Yang et al*., 2023). Licorice is a herbaceous plant classified within the legume family. Its root contains a diverse range of bioactive compounds, including malic, citric and succinic acids, beta-carotene, essential vitamins and minerals such as potassium, calcium, iron, phosphorus and magnesium. The primary biologically active constituents of licorice root are glycyrrhizic acid and flavonoids, which together comprise up to 25% of its chemical composition (He *et al*., 2020). Glycyrrhizin, the primary active compound in licorice root, has been used since antiquity for both its medicinal properties and as a natural sweetener (Jayakumar *et al*., 2023; Kulikova *et al*., 2022). The therapeutic potential of licorice is attributed to its capacity to produce a diverse array of secondary metabolites.

Over thirty enterprises in Uzbekistan process licorice root, mainly in Khorezm, Bukhara and Karakalpakstan. Licorice grows in the Amu Darya and Syr Darya deltas, thriving in tugai forests, along irrigation systems and on salt marshes and fallow lands (Karomatova *et al*., 2018). In 2021, Turkmenistan produced 680 tons of dry licorice extract, with the Buýan agro-industrial complex accounting for 680 tons of dry and 610 tons of thick extract from 2,960 tons of purified licorice root. According to "Turkmenistan: Golden Age", the production plan was exceeded by 118.7%. Located in Turkmenabat, the Buýan enterprise supplies licorice-based teas, extracts, balms and capsules to the domestic medical industry and exports them internationally. Notably, the enterprise processed 17,500 tons of licorice root in 2020 and 19,000 tons in 2022.

Given the current practices of intensive agricultural cultivation, the strategic application of high-quality organic and organomineral fertilizers enriched with humic substances, alongside mineral fertilizers containing essential nutrients, is vital for sustaining soil fertility and optimizing the quality of crop yields. The study by (Temirov *et al*., 2024; Tadzhiev *et al*., 2019) offers a comprehensive analysis of the current status and emerging trends in the production and utilization of organic fertilizers in agriculture. The biologization of agricultural practices through the use of organic fertilizers highlights the potential of biologically-based fertilization systems to restore soil fertility, enhance the mineral nutrition of plants and improve the productivity of both crops and crop rotations.

The study by (Tursunov *et al*., 1990) presents over 30 innovative technologies for the production and application of various types and forms of organic fertilizers derived from materials such as peat, soil, straw, sawdust, lignin, bark, sapropel, green manure and other organogenic substances. These technologies incorporate advanced mechanization, optimized loading and unloading operations and efficient transportation methods, along with proprietary technical solutions. As a result, they enable the production of high-quality organic fertilizers while reducing production costs by 17-23% and ensuring both environmental sustainability and veterinary-sanitary safety in their application.

Research by the laboratory of agrobiotechnologies identified key resources and developed theoretical foundations and technologies for using straw and plant residues as fertilizers. This approach assesses agroecological and energy efficiency across different soil and climatic conditions. Utilizing excess straw and other residues, which comprise at least half of the non-marketable harvest, can produce 40-50 million tons over 16-20 million hectares-12-15% of the sown area. This practice could add 0.64-0.85 million tons of NPK to the soil and compensate for a humus deficiency of 170 to 200 kg/ha, with 1 ton of straw yielding 1.0-1.2 centners of crop units in field rotations.

The biotechnological method of utilizing straw as fertilizer, supported by microbiological preparations developed in the laboratory, regulates the microbial processes involved in crop residue transformation. This approach enhances the efficiency of straw utilization, increasing the humification coefficient by 1.5 times, reducing phytotoxic effects and optimizing conditions for the growth and development of agricultural plants.

Plant residues in the soil undergo humification and mineralization, driven by microflora, which release nutrients. The increase in humus content is influenced by the type, distribution and decomposition of these residues, as well as crop productivity and rotation structure. Annually, carbon replenishment from humified plant residues ranges from 0.71 to 1.34 t/ha. These residues provide significant nutrients, with nitrogen, phosphorus and potassium contributions depending on crop rotation and fertilizer application. Specifically, 27.2-49.0 kg/ha of nitrogen, 13.6-24.5 kg/ha of phosphorus and 27.2-49.0 kg/ha of potassium enter the soil, averaging 90.9 kg/ha from agricultural crop residues (Phibunwatthanawong *et al*., 2019).

The research in (Glaser *et al*., 2015) demonstrates that the use of organomineral fertilizers had a favorable impact on both the total mass of the sheaf and the elements of the crop structure. The highest yields of grain, straw and sheaf were achieved with a manure-lignin mixture at a dosage of 60 t/ha, resulting in increases of 20.04%, 23.60 g/vessel and 43.89 g/vessel, respectively. These values represent a 65% - 79% improvement compared to the control. Similar yields of oat grain were obtained with the introduction of semi-rotted manure at a dose of 60 and 80 t/ha and a dung-lignin mixture at a dose of 40 t/ha - from 44 to 46 g / vessel. The effects of the dung-lignin mixture at a dose of 80 t/ha and the lignin-sludge mixture at a dose of 40 t/ha showed a tendency to decrease oat grain, while the mass of straw and sheaf increased by 58 and 28%; 32% and 62%, respectively.

However, a limitation of organic fertilizers is the process required to convert them into granules. Consequently, the availability of granulated organic matter is essential for its effective use in agriculture.

Bentonite is one of the agronomic ore used to improve soil properties, reduce the harmful effects of mineral fertilizers, prevent nutrient leaching and protect groundwater from contamination. It is also used as a stabilizing agent in liquid complex fertilizers.

Bentonite is recommended for light soils (sandy and loamy sand), where it improves water-physical and thermal properties, increases moisture retention and reduces water permeability, thereby enhancing soil conditions for microorganisms and plant nutrition. Its high sorption capacity prevents fertilizer leaching and regulates soil pH. The application of bentonite leads to high economic benefits, with cotton yields increasing by 32.6% on loamy sand soils and 10.3% on light loam soils. For potatoes, it boosts yields by 40-48 centners per hectare on sandy soils and 14-19 centners per hectare on loamy sand soils. Uzbekistan has identified over 200 bentonite deposits with reserves exceeding 2 billion tons.

In this work, bentonite was used to improve the agrochemical and physical properties of organic fertilizers, i.e., to obtain organic fertilizer granules.

The large-scale production of hydrogen peroxide was implemented at JSC Navoiazot. In this study, the oxidizing capacity of hydrogen peroxide in relation to licorice meal was initially examined.

2. Experimental part

In laboratory settings, the licorice meal (waste) was taken from the production of the Uzbek-Chinese JV LANEXTRAKT LLC. The meal was dried to an air-dry state and then ground to a particle size of 0.25 mm. After drying and grinding, an average representative sample of the meal, weighing over 50 kg, was created for analysis and research. From this sample, sub-samples were taken to determine moisture, ash content, extractive substances with water and an alkaline solution. Briefly, a weighed portion of the meal (250 ml) is mixed with 100 ml of 1% NaOH, heated using water bath, Faithul, China for 2 hours, centrifuged for 15 minutes at 210 sec^{-1} (Eppendorf, Germany) and decanted into flask B. The precipitate is washed twice with 100 ml NaOH, centrifuged and the washing solutions are combined. The filtrate (100 ml) is mixed with 60 ml HCl to precipitate acids, centrifuged, filtered using filtration system CH0446F, India and washed with water until peptization (yellow color). An additional 5 ml HCl is added and the solution is filtered through an ash-free filter dried at (90 ± 5)°C. The filter with the precipitate is dried, cooled and weighed until stable (≤0.001 g), then calcined at (600 ± 25)°C, cooled and weighed. The dry, ash-free organic portion of the liquid and solid phases is the oxidized meal, calculated based on the original meal's organics. The residual meal, after removing alkali-soluble substances, was washed, dried and the yield determined. The difference in organic content between the solid phase and residue indicates the amount of substances dissolved in 1% NaOH. The results of the analysis of the original meal are presented in Table 1.

Table 1. Chemical composition of the original licorice root meal

Humidity, %	Ash content, %	Content of extractive substances extracted by 1% NaOH solution, %	Content of extractive substances extracted by water, %	Insoluble organic matter, %
5.41	4.66	5.87	15.78	68.28

Hydrogen peroxide (60% H_2O_2) was supplied by JSC Navoiazot and was subsequently diluted to be ranged 10 to 30% with distilled water. The hydrogen peroxide oxidation process was carried out at a concentration of 10 to 30% and a weight ratio of meal (organic part) to H_2O_2 ranging from 1:0.1 to 1:0.6. Under optimal conditions, the oxidation degree of the meal reached 65.5%. The resulting oxidation product contains 37.17% of extractive substances (ES) in a 1% NaOH solution, 26.57% of water-soluble organic substances and 36.26% of residual meal. This moist, dense mass of oxidized meal was used as the initial component for producing granulated organic fertilizers.

After oxidation of the sweet scrotum under the aforementioned optimal conditions. The process of obtaining granulated organic fertilizers at a H_2O_2 concentration of 10% and a slag ratio of: H_2O_2 = 1: 0.1 at a temperature of 60°C and a duration of 2 hours was investigated by introducing 5% suspension of finely ground bentonite from the above-mentioned deposits into the moist solid phase of the oxidized slag. The mass ratio of the organic part of the oxidized shroud to the bentonite clay in relation to the dry mass varied within the range of the organic part of the licorice shroud: bentonite 100: (0.5-5). Granulation was carried out by rolling. The product was then dried in a thermostat at 80°C.

In this study, bentonite clays such as Bestyube, Krantau and Khujakul from Karakalpakstan were used. Their composition is presented in Table 2.

Table 2. Chemical composition of bentonite, %

No	Bentonite deposit	SiO_2	T_1O_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	P_2O_5	SO_3	CO_2	LOI
1	Beshtyube	64.9	0.77	15.63	4.55	0.91	0.98	2.09	2.78	0.11	0.42	0.59	6.27
2	Krantau	67.34	0.46	10.97	7.75	1.51	1.54	0.44	2.63	0.20	0.40	0.60	6.61
3	Khajakul	57.70	0.67	16.70	6.10	1.80	1.10	1.50	3.10	0.20	0.60	0.40	10.13

The chemical composition of the obtained organic fertilizers with the addition of bentonite clays for granulation is presented in Table 2 and the strength of the granules of these organic fertilizers with bentonite clay additives was determined according to known methods (Statestandard 21560.2-82), with the results presented in Table 3. It is evident that adding bentonite to the oxidized licorice meal significantly increases the strength of the granules. It should also be noted that the injection of bentonite suspension during the granulation of the oxidized licorice meal facilitates the formation of granules from the oxidized licorice meal. As the number of additive increases, the strength of the organic fertilizer granules gradually increases. Thus, when Bestyubensky bentonite is added to the oxidized licorice meal at a mass ratio of oxidized licorice meal (OLM): bentonite 100:0.5, the strength of the product granules is 2.15 MPa; at 100:1 - 2.26 MPa; at 100:1.5 - 2.39 MPa. When Krantau bentonite is added to the oxidized meal at a mass ratio of OLM: bentonite 100:0.5, the strength of the product granules is 2.25 MPa; at 100:1 - 2.37 MPa; at 100:1.5 - 2.53 MPa. When Nazarkhan bentonite is added to the oxidized meal at a mass ratio of OLM: bentonite 100:0.5, the strength of the product granules is 2.05 MPa; at 100:1 - 2.07 MPa and at 100:1.5 - 2.13 MPa, respectively. Research and experiments have established that adding bentonite significantly increases the strength of organic fertilizer granules. Therefore, it is possible to obtain granulated organic fertilizers with a high content of organic substances of humic nature by oxidizing the licorice meal with hydrogen peroxide and subsequently granulating it using a suspension of bentonite clays through spraying, drying and granulation.

Table 3. The chemical composition of organic fertilizers produced from licorice meal oxidized with hydrogen peroxide and supplemented with a bentonite suspension during granulation

The ratio of organic oxidized licorice meal: bentonite	Organic compounds, %	Extractive substances in a 1% NaOH solution, %	Acid containing organic acids	Moisture, %
When using Beshtuben bentonite				
100: 0.5	70.15	37.37	10.41	4.33
100: 1	69.90	37.64	10.24	4.26
100: 1.5	69.67	38.07	10.07	4.18
100: 2	69.42	38.39	9.9	4.06
100: 4	68.48	38.66	9.6	3.85
100: 5	67.01	39.01	9.1	3.64
When using Krantau bentonite				
100: 0.5	69.85	36.87	10.01	4.82
100: 1	69.62	36.44	9.64	4.69
100: 1.5	69.34	37.07	9.27	4.58
100: 2	69.14	36.69	8.89	4.50
100: 4	67.08	36.06	8.46	4.31
100: 5	66.51	35.71	8.11	4.17
When using Nazarhan bentonite				
100: 0.5	68.55	34.77	9.21	5.42
100: 1	68.22	34.14	8.64	5.19
100: 1.5	67.84	33.47	7.77	5.08
100: 2	67.54	33.09	6.89	4.80
100: 4	67.18	32.56	6.06	4.61
100: 5	66.81	32.01	5.21	4.47

Based on the conducted research and obtained results, a technology for producing granulated organic fertilizer was proposed and special experiments were conducted to test this technology. The technological process of obtaining granulated organic fertilizer based on licorice meal oxidized with hydrogen peroxide and a bentonite suspension consists of the following main stages: drying the licorice meal to an air-dry state and grinding it; oxidizing the licorice meal with a hydrogen peroxide solution (10%); granulating the oxidized meal with the addition of a bentonite suspension; drying the product; crushing, sieving and packaging the product. To produce the granulated organic fertilizer, licorice meal with the following composition (wt. %) was used: moisture 5.41; ash 4.66; organic substances 89.93; extractive substances extracted by 1% sodium hydroxide solution 5.87; extractive substances extracted by water 15.78; insoluble organic matter 68.28. Additionally, 10% hydrogen peroxide and bentonite clay from the Krantau deposit were used.

Table 4. The strength of organic fertilizer granules produced from licorice meal oxidized with hydrogen peroxide and with the addition of a bentonite suspension during granulation

The ratio of organic oxidized licorice meal: bentonite	Organic compounds, %	Granule strength		
		kg/granule	kgs/sm^2	MPa
When using Beshtuben bentonite				
100: 0.5	70.15	1.09	21.97	2.15
100: 1	69.90	1.14	22.98	2.26
100: 1.5	69.67	1.21	24.39	2.39
100: 2	69.42	1.26	25.50	2.50
100: 4	68.48	1.34	27.01	2.65
100: 5	67.01	1.44	29.03	2.85
When using Krantau bentonite				
100: 0.5	69.85	1.14	22.98	2.25
100: 1	69.62	1.20	24.17	2.37
100: 1.5	69.34	1.28	25.80	2.53
100: 2	69.14	1.40	28.22	2.77
100: 4	67.08	1.43	28.83	2.83
100: 5	66.51	1.47	29.64	2.91
When using Nazarhan bentonite				
100: 0.5	68.55	1.04	21.78	2.05
100: 1	68.22	0.90	22.27	2.07
100: 1.5	67.84	0.78	24.30	2.13
100: 2	67.54	0.70	26.42	2.17
100: 4	67.18	0.57	28.53	2.23
100: 5	66.81	0.48	30.64	2.31

To increase the content of extractive substances in the licorice meal, it was first oxidized with a 10% hydrogen peroxide solution at a temperature of 60-70°C. The licorice meal was oxidized with hydrogen peroxide in a reactor equipped with a stirrer driven by a motor. The mass ratio of the organic part of the licorice meal to the anhydrous part of hydrogen peroxide was 1:0.1. Initially, the sweet scrotum was ground to a size of no more than 0.25 mm. Then, in a tubular reactor, where a hydrogen peroxide solution was pre-filled, when stirred, a crushed malt extract was added and the resulting mass was processed for 2 hours. As a result of oxidation, the resulting oxidation product contained 37.17% of extractive substances in a 1% NaOH solution, 26.57% of water-soluble organic substances and 36.26% of residual slag. This moist, dense mass of oxidized scrap was used as the starting material for obtaining granulated organic fertilizer.

Tests of the technology for obtaining granulated organic fertilizer based on oxidized meal and bentonite suspension were conducted using a weight ratio of the organic part of licorice meal to bentonite of 100: (0.5-5). The mixing duration was 10-15 minutes. Subsequently, the resulting moist product was first air-dried outdoors, then in a drying cabinet until reaching a residual moisture content of 4.5-5.0%. Granulation of the mixed products was carried out by simulating the granulation process in a plate granulator to obtain round granules, whose appearance closely resembles the shape of traditional fertilizer granules, but with a brown color. To establish the necessary technological parameters for the granulated organic fertilizer production process, the experiments were conducted in triplicate. The average compositions of the obtained samples are presented in Table 5.

Table 5. The chemical composition of organic fertilizers produced from licorice meal oxidized with hydrogen peroxide and the addition of a bentonite suspension during granulation

The ratio of organic oxidized licorice meal: bentonite	Organic compounds, %	Content of extractive substances extracted by 1% NaOH solution, %	Acid-containing organic acids	Moisture, %
When using Krantau bentonite				
100: 2	69.14	36.69	8.89	4.0
100: 4	67.08	36.06	8.46	4.31

Based on the testing of the technology for producing granulated organic fertilizer at the pilot plant, the main technological parameters of the process were determined, material flow diagrams were developed and a basic technological scheme for production was created (Figure 1).

The optimal technological process for producing granulated organic fertilizer:

milling of the sugar beet meal to particle size – less than 0.25 mm;
the concentration of hydrogen peroxide – 10%;
the weight ratio of the organic part of licorice meal to H2O2 – 1: 0,1;
Bentonite suspension concentration, % – 5,0;
the mass ratio of licorice meal: bentonite – 100: 4;
mixing process temperature, °C – less than 50-60;
process duration, min – 120;
drying temperature, °C – 70-80;
speed of ribbon, $m \cdot min^{-1}$ – 2-4;
wet of product, % – 7-8.

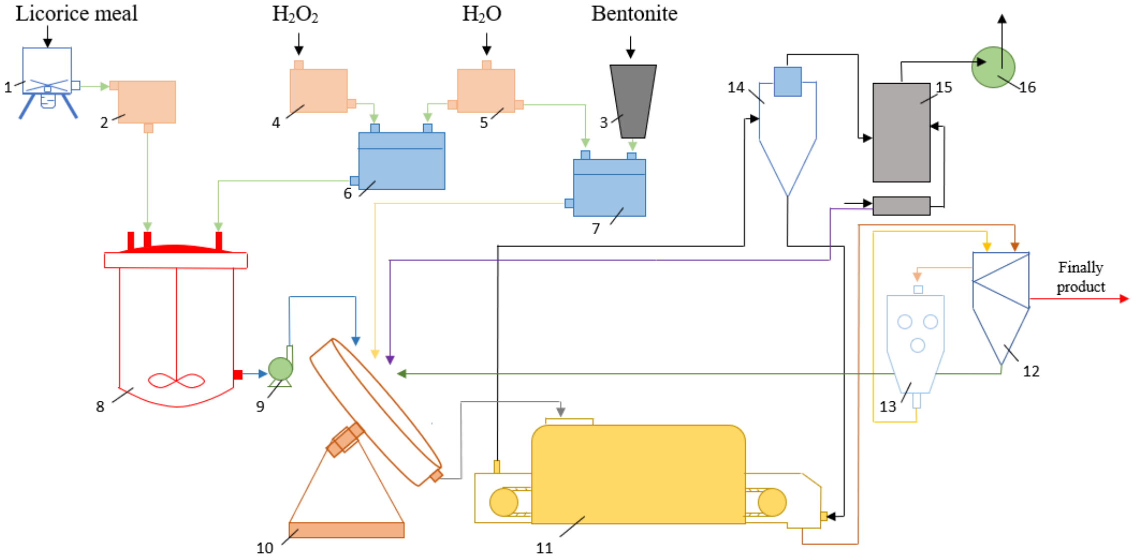

Figure. 1. The principal technological scheme for producing granulated organic fertilizer
1 – chopper; 2,3 – feeder bunker; 4,5 – containers; 6,7 – automatic concentrator; 8 – reactor; 9 – pump; 10 - plate granulator; 11 – ribbon dryer; 12 – classifier; 13 – grinding machine; 14 – cyclone; 15 – absorber;16 – ventilator.

Hydrogen peroxide with a concentration of 60% from the storage tank is fed into pressure tank 4, then into automatic concentrator 6, where it is diluted to 10% with water. From the concentrator, the oxidizer is directed to reactor 8, where ground licorice meal is also fed. In a special mixer 7, bentonite is mixed with water. The resulting suspension is directed to a plate granulator 10, where the oxidized licorice meal and recycled material are fed. After thorough mixing, the resulting mass is sent to the belt dryer 11 and to the screening machine 12. To clean the gas (steam) phase from dust, it is directed from the belt dryer to cyclone 14, absorber 15, which is irrigated with water and then to the atmosphere. It should be noted that while dust is directed to the cyclone, particles with 30-50 microns are separated by about 85% and particles with less than 1-2 microns are directed to the absorber (GTS OCT 108.838.10 - 80, 1980; Statestandard 31837-2012, 2012). The cyclone equipment, which has label CN-15 having height of inlet pipe, *a* 0.66 m, height of exhaust pipe *h* 1.74 m, height of cylindrical part H 2 m with capacity 4.5 $m^3 \cdot h^{-1}$. The absorber named label as foam high-speed absorber with layer stabilizer (FHALS) has an irrigation density 19-40% and absorption degree 96%. In the absorber remaining dust is wet by water entering below the scrubber and caught by about 98%. Further clean air, steam and dust with 10 mg/m^3 release via a ventilator 16 (Statestandard 5976-2020, 2020). Whereas, the wet dust particles are entered to the plate granulator.

The finished fertilizer from the drying drum is sent to the classification shop, then to the finished product warehouse. Thus, a technology for obtaining granulated organic fertilizer has been developed by oxidizing the licorice meal with hydrogen peroxide and adding a bentonite suspension during granulation of the oxidized meal before drying. This, on the one hand, allows for a significant improvement in agrochemical properties and on the other hand, improves the commercial properties of the resulting fertilizer. When applying granulated organic fertilizer in agriculture, it will undoubtedly increase the humus content in the soil and significantly improve the structure and physical-mechanical properties of the soil. Due to the content of all the nutrients necessary for plants, it creates the possibility of obtaining higher quality yields, enhances the nutritional properties of plants and increases their resistance to diseases.

It is known that the physicochemical properties of fertilizers are one of the most important characteristics. The preservation during storage, transportation and application in the soil is a combination of the properties of fertilizers and other products. Fertilizer hygroscopicity, caking, strength and bulk density are important physical indicators, as they determine storage conditions, transportation and direct application of fertilizers. Based on the above, the physicochemical properties of the granulated organic fertilizer were studied. Two types of fertilizers were selected for the study, the composition of which is presented in Table 5.

To determine the hygroscopic point of granulated organic fertilizers, the desiccator method by N.E. Pestov was used at a temperature of 25°C, with granules of 2-3 mm size (Figures 1-3). The initial moisture content of the granulated organic fertilizer samples was 5.17% and 5.21%, respectively. The measurements showed that the tested fertilizers had the following hygroscopic points: sample 1 - 74.21%; sample 2 - 79.14% relative humidity. According to N.E. Pestov's scale of hygroscopicity, the granulated organic fertilizers are classified as weakly hygroscopic substances (Figure 4). Additionally, the kinetics of water vapor sorption at 25°C was determined for two samples of granulated organic fertilizers. It was established that the equilibrium between water vapor pressures over the fertilizers is reached: at 65% relative air humidity - after 2-4 days, at 90% - after

5-7 days and at 95% - after 14-15 days. At 100% relative air humidity, the equilibrium was established slowly, taking 21-22 days (Figures 2, 3).

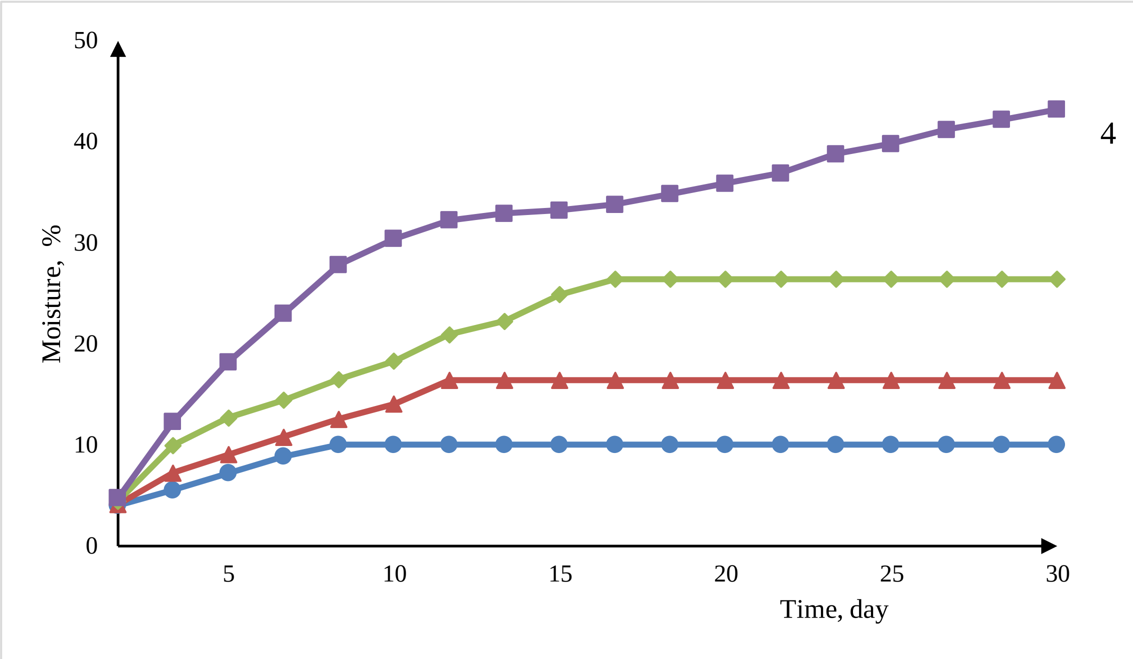

Figure 2. The kinetics of water vapor sorption by fertilizer sample No.1 at relative air humidity: 1 - 70%; 2 - 80%; 3 - 90%; 4 - 95%

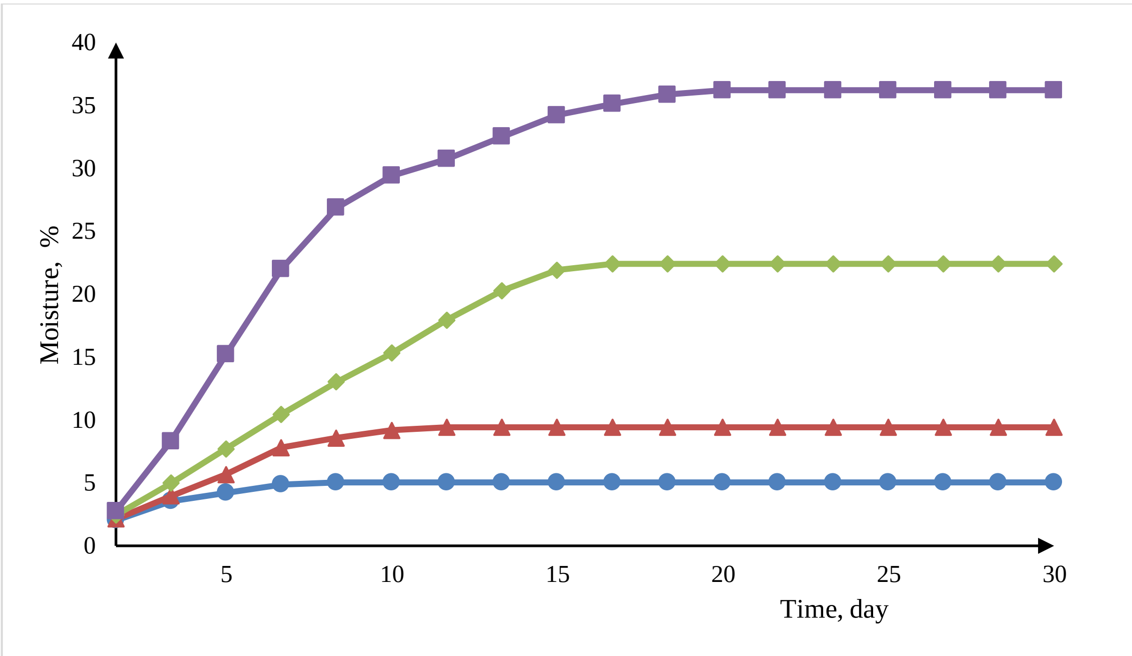

Figure 3. The kinetics of water vapor sorption by fertilizer sample No.2 at relative air humidity: 1 - 70%; 2 - 80%; 3 - 90%; 4 - 95%

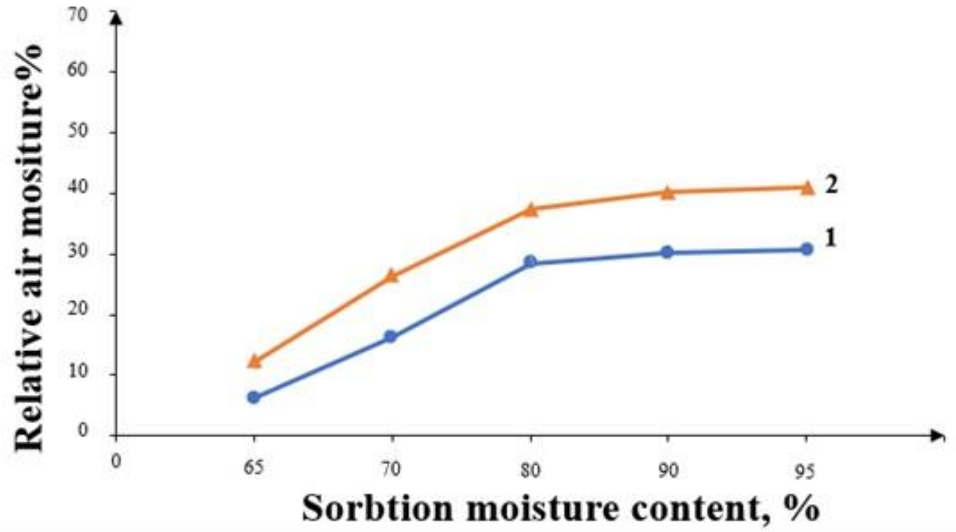

Figure 4. The dependence of the sorption moisture content of fertilizers on the relative humidity of the air: the numbering of the curves corresponds to the sample numbers in the table

The sorption moisture capacity of granulated organic fertilizers was determined at relative air humidity levels of 65, 70, 80, 90 and 95%. The results show that at a relative air humidity of 65%, sample 2 absorbs 2.3% moisture, while at 80% humidity, its moisture content reaches 4.2%. The granules maintain their appearance, but their friability decreases as moisture increases. As humidity rises, the fertilizer granules begin to moisten due to the transition of the soluble part of the organic fertilizer into the liquid phase. At 65% humidity, both fertilizers retain their full friability. To determine the caking tendency of granulated organic fertilizers at 65% relative air humidity, fertilizer with a specific particle size distribution was placed in gauze bags and pressed for 24 hours. Afterward, they were dried at 100-105°C to a constant weight, then dropped from a height of 1.5 m and sieved through a 3 mm diameter sieve. The caking tendency of granulated organic fertilizers was determined based on initial moisture content and load. With initial moisture content and moistening up to 2.1%, the fertilizer showed practically no caking. The strength of granulated organic fertilizers with granule sizes of 2-3 mm was determined using N.E. Pestov's well-known method. The average strength of the granules for the sample was 2.31 and 2.72 MPa, respectively.

3. Conclusion

Thus, the processes of oxidation of licorice meal with hydrogen peroxide were studied depending on concentration, temperature, duration and mass ratio of meal to oxidizer. The process of obtaining granulated organic fertilizer based on hydrogen peroxide-oxidized meal using a 5% bentonite suspension to improve the commercial and agrochemical properties of the resulting fertilizer was investigated. It was established that adding a bentonite suspension during granulation of the oxidized meal improves the physical characteristics of the granules, i.e., increases their strength. Granulated organic fertilizer for agrochemical tests was produced on a scaled-up laboratory setup. The commercial properties of the fertilizers were determined: hygroscopicity, moisture capacity, caking tendency and granule strength. A basic technological scheme is proposed and the optimal technological regime for the production of granulated organic fertilizer using hydrogen peroxide-oxidized meal and bentonite suspension is provided. The fertilizers do not cake and even with high moisture content, they maintain complete looseness.

References

Abudurezike, A., Liu, X., Aikebaier, G., Shawuer, A. & Tian, X. (2024). Effect of different irrigation and fertilizer coupling on the liquiritin contents of the licorice in Xinjiang arid area. *Ecological Indicators*, 158, 111451. https://doi.org/10.1016/j.ecolind.2023.111451

Food and Agriculture organization of the United Nations (2019). Rome, 40.

Glaser, B., Wiedner, K., Seelig, S., Schmidt, H.P. & Gerber, H. (2015). Biochar organic fertilizers from natural resources as substitute for mineral fertilizers. *Agronomy for Sustainable Development*, 35, 667-678. https://doi.org/10.1007/s13593-014-0251-4

He, C., Cui, J., Chen, X., Wang, W. & Hou, J. (2020). Effects of enhancement of liquorice plants with dark septate endophytes on the root growth, glycyrrhizic acid and glycyrrhizin accumulation amended with organic residues. *Current Plant Biology*, 23, 100154. https://doi.org/10.1016/j.cpb.2020.100154

Jayakumar, M., Prabhu, S.V., Abo, L.D., Daba, B.J., Periyasamy, S. & Jabesa, A. (2023). Microbial conversion of agricultural residues into organic fertilizers. In *Agricultural Waste to Value-Added Products*. Springer, Singapore. https://doi.org/10.1007/978-981-99-4472-9_6

Karomatov, I.D., Aslanova, D.K. (2018). Licorice a herbal remedy with antitumor properties. *Electronic Scientific Journal Biology and Integrative Medicine*, 8, 4-12.

Kulikova, A., Isaichev, V., Yashin, E., Volkova, E., Cherkasov, M. (2023). The role of organic fertilizers and zeolite in growing organic produce. In *XV International Scientific Conference INTERAGROMASH 2022*, 2378-2384. https://doi.org/10.1007/978-3-031-21219-2_266

Li, Y., Luo, W., Li, G., Wang, K. & Gong, X. (2018). Performance of phosphogypsum and calcium magnesium phosphate fertilizer for nitrogen conservation in pig manure composting. *Bioresource Technology*, 250, 53–59. https://doi.org/10.1016/j.biortech.2017.07.172

Low and medium pressure remote cyclones for boilers. General technical specifications. GTS OCT 108.838.10 - 80. 1980. 40 p.

Patyra, E., Osiński, Z. & Kwiatek, K. (2024). Residues of veterinary antibiotics in solid natural and organic fertilizers-method development and sample analysis. *Environmental Science and Pollution Research*, 1-15. https://doi.org/10.1007/s11356-024-33956-w

Petrosyan, H.R., Nigaryan, A.A., Hovhannisyan, H.A., Soloyan, A.M., Vardapetyan, V.V. & Martiryan A.I. (2023). Evaluation of antioxidant activity and heavy metals content in licorice (Glycyrrhiza glabra L.) growing wild in Armenia. *Heliyon*, 9, e22442. https://doi.org/10.1016/j.heliyon.2023.e22442

Phibunwatthanawong, T., Riddech, N. (2019). Liquid organic fertilizer production for growing vegetables under hydroponic condition. *International Journal of Recycling of Organic Waste in Agriculture*, 8, 369-380. https://doi.org/10.1007/s40093-019-0257-7

Sánchez, Ó.J., Ospina, D.A. & Montoya, S. (2017). Compost supplementation with nutrients and microorganisms in composting process. *Waste Management*, 69, 136-153. https://doi.org/10.1016/j.wasman.2017.08

Statestandard 21560.2-82. (1982). Mineral fertilizers. Test methods. Moscow: Gosstandart, 30.

Statestandard 31837-2012. (2012). *Absorption gas cleaners safety requirements and testing methods*. Gosstandart, 12.

Statestandard 5976-2020. (2020). *General purpose radial fans general specifications*. Moscow: Gosstandart, 30.

Tadzhiev, S.M., Tozhiboev, M.M. & Abdullaeva, M.A. (2019). Production of thermostable ammic nitrogen with the addition of bentonites. *Universum*, *11-2*(68), 40-43.

Temirov, G.B., Alimov, U.K., Seytnazarov, A.R., Reymov, A.M., Namazov, S.S. & Beglov, B.M. (2024). Rheological properties and composition of products of phosphogypsum conversion with sodium carbonate. *Russian Journal of General Chemistry*, *94*(7), 1837-1847.

Tursunov, A.A., Ollaberganov. R.I., Nuraliev, U.K., Batirov, M.A., Akhatov, A., & Bobozhonov, M.B. (2023). The process of studying agrochemical properties of soil in the republic of Uzbekistan in connection with climate change and intensive farming. *Science and innovation*, *2*(Special Issue 8), 1924-1927. https://doi.org/10.5281/zenodo.8372799

Xu, J., Yang, A., Yan, Y., Xu, Y., Tang, M., Li, P., ... & Ren, Z. (2024). Quantification and identification of microplastics in organic fertilizers: the implication for the manufacture and safe application. *Water, Air & Soil Pollution*, *235*(3), 169. https://doi.org/10.1007/s11270-024-06977-x

Yang, Q., Zhang, M. (2023). Effect of bio-organic fertilizers partially substituting chemical fertilizers on labile organic carbon and bacterial community of citrus orchard soils. *Plant and Soil*, *483*(1), 255-272. https://doi.org/10.1007/s11104-022-05735-4