The effectiveness of the use of alternative fertilizers in the conditions of the Chuvash Republic

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Abstract. The article presents for the first time the results of using organic substances belonging to the category of industrial waste as fertilizers for agricultural crops. The dairy industry has waste (hereinafter referred to as cake) generated during the cleaning of milk pipes and requiring additional costs for their disposal. Biogas plant products (hereinafter referred to as biofertilizer) obtained from fresh chicken manure by fermentation in an anaerobic environment are also promising as fertilizer for agricultural crops. Biofertilizer and cake were applied superficially at different plots at doses of 3 kg/m$^2$ (30 t/ha), 6 kg/m$^2$ (60 t/ha) and 9 kg/m$^2$ (90 t/ha). The potato tubers of the ‘Gala’ variety of German selection were planted. It was found that the higher the dose of the used substances, the greater the yield of potatoes. The yield increase in the variant of 30 t/ha of cake was 5.9 t/ha of potato tubers, 60 t/ha of cake - 11.3 t/ha, and in the variant of 90 t/ha of cake - 15.5 t/ha. The use of biofertilizers also caused an increase in yield. The use of waste as fertilizers enhances the biological activity of soils, increases the content of mobile nutrients of plants of light gray forest soil.

1. Introduction
The insufficient introduction of organic fertilizers into the soil during intensive farming leads to a decrease in humus reserves in the arable soil layer. So, over the past 2-3 decades, the humus content in the soils of the Chuvash Republic and neighboring regions decreased by 0.2-0.3% [1-4]. The authors indicate that the reason for the decrease in humus in soils is the insufficient use of organic fertilizers and siderates, and frequent mechanical treatment. According to Gilev S.V. and other authors, a violation of crop rotation can also be a cause of a decrease in soil organic matter [5]. Insufficient application of organic and mineral fertilizers in agriculture causes gradual soil degradation, which is the main reason for the insufficient economic efficiency of crop production and the appearance of deposits [6]. In this regard, the possible use of organic substances as fertilizers of agricultural crops - industrial wastes, is very important from the point of view of restoring soil fertility and saving money on disposal. For example, the dairy industry has wastes that can adversely affect the environment. However, the waste of the dairy industry is the curdled material (cake), which is formed during the cleaning of pipes through which milk products flow, has a favorable chemical composition and is enriched with biophilic chemical elements of plant nutrition. The basis of the cake is milk proteins, fats and products of their conversion, which do not contain heavy metals, radioactive elements, pesticides and other dangerous substances. Disposal of cake on specially allocated lands (landfills)
causes adverse environmental consequences - pollution of atmospheric air, groundwater, the multiplication of certain types of microorganisms, insects and rodents.

The use of cake as a fertilizer of crops could prevent environmental pollution and contribute to obtaining a high yield of the required quality with minimal cost, on the one hand, and ensure non-waste production, on the other hand. In our case, this involves the involvement of dairy industry wastes containing biophilic plant nutrition elements in a new production cycle - the production of crop products in doses that are environmentally friendly to the environment. In this direction, it is of great interest to use dairy waste - cake (paste-like, structureless, non-sticky white mass with hydrophobic properties) - as an organic fertilizer. Only at the enterprise of OJSC “Yadrinmoloko” alone tens of tons of cake are accumulated annually.

Biogas plant products, in which poultry (chicken) manure is used as the main raw material, are also promising as a fertilizer for agricultural crops. Chicken droppings, which accumulate in large quantities on the territory of poultry farms, cannot be used fresh as fertilizer in crops, as it has adverse physical and chemical properties. However, during the processing of chicken manure in a biogas plant, in addition to combustible gas, liquid and solid organic wastes enriched with microorganisms (biofertilizers) are generated, which can be used as fertilizer for crops [7].

The purpose of this research is to study the chemical composition of cake and solid biofertilizers, to assess the suitability of their use as the main fertilizer of potatoes, the effect on the biological and agrochemical properties of the soil, and to determine the optimal dose for use.

2. Materials and methods

The use of waste - cake and solid biofertilizers as fertilizer for potatoes was carried out in 2018 in a field experiment in a specially allocated area, in compliance with the methodological requirements: typical experience, observing the principle of the only difference, taking into account the agrochemical parameters of the soil, the growth and development rates of plants and tubers. The soil of the experimental plot is light gray forest, heavy loamy on loesslike loam. The thickness of the arable layer is 24 cm, of the subsoil A_{2}:B - 14 cm. The humus content in the arable layer of the soil of the experimental plot varies from 2.50 to 2.53%, mobile phosphorus - 150-155 mg/kg, exchange potassium - 135-140 mg/kg (according to an agronomic estimate - high content), the pH of the exchange acidity is 5.51-5.55 (close to neutral). The amount of exchangeable bases varies from 16.4 to 17.0 mg-e/100 g of soil; hydrolytic acidity - from 1.95 to 2.05 mg-e/100 g of soil. In the experiments we used scales, containers for weighing waste, tape measure, shovel, walk-behind tractor. Micro-plot experiments were laid according to the following scheme: 1) Control; 2) Biofertilizer 3 kg/m² (based on 30 t/ha); 3) Biofertilizer 6 kg/m² (60 t/ha); 4) Biofertilizer 9 kg/m² (90 t/ha); 5) Cake 3 kg/m² (30 t /ha); 6) Kek 6 kg/m² (60 t/ha); 7) Cake 9 kg/m² (90 t/ha). The area of each plot was 10 m² in 6-fold repetition. The location of the plots is systematic. The technology for introducing cake and biofertilizers into the soil is as follows: the soil was loosened by milling to a depth of an arable layer of 20 cm, then cake and bio-fertilizer were applied superficially (figure 1).

After this, re-milling was carried out - mixing the cake with the soil. Then, Gala potato seed tubers (seeds of 1 reproduction) of German selection were planted in prepared wells. Potato planting depth - 6 cm. Planting scheme: row spacing - 75 cm, distance between tubers in a row - 35 cm. The developmental phases of potatoes were determined visually. The biological (cellulose-degrading) activity of the soil was determined by the decomposition rate of flaxseed applications. To do this, linen cloth 10x30 cm in size, previously weighed and sewn onto a plastic film of the same size, was instilled immediately after planting vertically at a slight angle in the arable layer of soil in a row of potatoes, three in each plot. During potato harvesting, applications were delivered from all experimental plots, which were then peeled and weighed. The weight loss of the application (biological activity of the soil) was calculated as a percentage. The content of mobile plant nutrients in the soil was determined by the Kirsanov method in the soil extract with 0.2 n hydrochloric acid in the ratio: 1 part of soil to 5 parts of an acid solution (GOST R 54650-2011), humus - according to the Tyurin method - oxidation of soil organic matter with a solution potassium dichromate in sulfuric acid (GOST 26213091), pH of
the exchange acidity according to GOST 26483-85, nitrates according to GOST 26951-86. The amount of soil exchange bases in the experimental plots was determined by the Kappen method, based on the reaction of the absorbed soil bases with hydrochloric acid, followed by titration of the acid residue with sodium hydroxide (GOST 27821-88), hydrolytic acidity - according to the Kappen method based on soil cultivation 1 n sodium acetate solution (GOST 26212-91). Sheet nitrogen diagnostics was carried out by changing the color of the indicator (1% solution of diphenylamine in sulfuric acid) by adding it to freshly squeezed juice from leaves on a glass plate. Mathematical processing of the analysis results was carried out in the Excel program.

![Figure 1. Surface spread of cake on a plot at a dose of 90 t/ha (9 kg/m²).](image)

The solid products of the biogas plant of LLC “Atalanu” in the Kanash district of the Chuvash Republic, obtained as a result of anaerobic digestion of organic substances, have a dark gray color, good flowability, and are reminiscent of lowland peat or urban sewage sludge in structure.

Anaerobic fermentation in a biogas plant lowers the nitrogen content in the feedstock, as it is partially part of the combustible gas. Carbon also serves as a material for the formation of methane and carbon dioxide, as a result of which the organic matter content in biofertilizer is reduced. Phosphorus, potassium, calcium, manganese and other cations, including trace elements, remain in solid bio-fertilizer.

Cake, exported from OJSC “Yadrinmoloko” in the Yadrinsky district of the Chuvash Republic, has a matte cheesy-white color, soft pasty, slightly sticky mass with an unpleasant sour-milk pungent odor. When dried, cracking, forms granules of various sizes of dirty yellow-gray color (figure 2).
Cake does not mix or mix poorly with other substances and practically does not dissolve in water. Animals and birds are not eaten. It mixes poorly with the soil in large doses; therefore, when applying it to the soil in a large dose (90 t/ha), the milling of the soil before planting potatoes was carried out twice, and in order to comply with the principle of the only difference, similar double tillage was carried out in other versions, including options using bio-fertilizer.

The chemical composition of the soil of the plots, biofertilizers and cake was determined in the agrochemical laboratory of the Chuvash State Agricultural Academy.

3. Research results

The chemical composition of cake is diverse and exceeds other traditional organic fertilizers - cattle manure (fresh and semi-matured) in the content of the basic elements of plant nutrition. The chemical composition of cake and biofertilizers are presented in table 1.

Table 1. The chemical composition of cake and biofertilizer.

| % in dry matter | mg/kg in dry matter |
|----------------|---------------------|
| Dry matter     | Ash content         | N    | P₂O₅ | K₂O  | CaO  | MgO  | NaO  |
| Cake of OJSC "Yadrinmoloko" | 25.6 | 11.2 | 2.50 | 2260 | 132  | 2320 | 36   | 84   |
| Biofertilizer of LLC "Atalanu" | 39.8 | 33.5 | 4.25 | 850  | 1088 | 283  | 116  | 350  |

From the data of table 1 it follows that in the studied organic substances a higher content of nitrogen, phosphorus and other nutrients of plants compared to traditional fertilizer - semi-rotted manure of cattle.

The use of cake can significantly increase soil fertility with the scientifically substantiated use of it as a fertilizer. For example, manure is applied at a rate of 30-60 t/ha. For the first time, we examined cake and biofertilizer as a fertilizer, and to determine the most effective application rate, we used them in different doses - from 30 to 60 and 90 t/ha. Potatoes have higher requirements for nutrient content in the arable layer of the soil than many other crops. This is primarily due to the poorly developed root system of potatoes, mainly located to a depth of 25 cm. In combination with a high removal of nutrients per unit mass of the crop, this necessitates the introduction of increased doses of fertilizers. Previous studies have shown the high efficiency of another unconventional organic fertilizer obtained from the waste of the meat processing industry - horns and hooves of cattle and small cattle - keratin - in the production of potatoes [8].
Since the emergence of seedlings, potato plants developed better in variants with the maximum introduction of biological fertilizers and cake into the soil (figure 3).

![Image](image1)

**Figure 3.** Type of potato plots in the phase of the beginning of flowering.

From the data of figure 3 it can be seen that in the control variant, the potatoes are lagging behind in development, and only the first flowers appear. The color of potato tops in the variants with application of 30, 60 and 60 t/ha of biofertilizers and cake consistently becomes darker green, it is more massive and higher in the variants of 60 and 90 t/ha of biofertilizers and cake, which indicates excellent plant nutrition. Leaf nitrogen diagnostics carried out in the month of June using an indicator (1% solution of diphenylamine in sulfuric acid) also testified to a better supply of potato plants with nitrate nitrogen in versions with fertilizer and doses of cake of 30, 60 and 90 t/ha. The higher the dose of biofertilizer or cake, the higher and juicier the tops, the higher the supply of plants with nitrogen.

The Colorado potato beetles first populated potato bushes with cake in doses of 60 and 90 t/ha. The fight with them in all variants of the experiment was carried out by spraying the bushes with the preparations "Karate" and "Aktara".

The conditions of the growing season of 2018 were arid for potatoes: in the second half of August and September there was practically no rainfall. This affected the low potato yield in the control variant. Potato tubers were harvested manually at the end of September according to the plots of the experiment. The weighing results of harvested tubers showed that the yield of tubers is maximum in the variants with the introduction of biological fertilizers and cake in doses of 60 and 90 t/ha.

The ‘Gala’ potato tubers in the 2018 harvest were smooth, rounded in shape, with no signs of scab. In the control variant, the tubers were affected by late blight, and in the case of lozenges with the use of cake of 30 t/ha, the lesion decreased; in variants of 60 and 90 t/ha of cake, the damage to late blight tubers disappeared. Apparently, sour milk bacteria located in the cake inhibit the development of mycelium phytophthora in the soil.

The yield of potatoes in the variants of the experiment is shown in table 2.

| Variant | Yield of Potato Tuber (t/ha) |
|---------|----------------------------|
| Control | 8.4                        |
| 30 t/ha cake | 14.3  |
| 60 t/ha cake | 15.5  |
| 90 t/ha cake | 15.5  |

The use of biofertilizers also caused an increase in yield, however, slightly less than in versions using cake.

Thus, research results indicate that cake and bio-fertilizer at doses of 60 and 90 t/ha are an effective fertilizer for potatoes.
The study of the quality of the crop revealed that in the control variant the tubers were affected by late blight, and in the case of vines with the use of cake of 30 t/ha, the defeat decreased; in variants of 60 and 90 t/ha of cake, the damage to late blight tubers disappeared. Apparently, sour milk bacteria located in the cake inhibit the development of mycelium phytophthora in the soil. According to other authors (Artamonov S.G. et al., Vasiliev A.A. et al.) the quality of tubers is strongly affected by the balanced chemical composition of the soil solution [10-11]. This opinion does not contradict the results obtained in our experiment with the use of biofertilizer and cake.

The biological activity of soils in the variants of the experiment was determined by the application bookmarking method. In 2018, the decomposition of flaxseed applications in the control averaged 26.3%, and in variants with cake and bio-fertilizers, 39-53% (table 3).

Table 2. Yield of potato from experimental plots.

| No | Options                  | Productivity, t/ha | Yield increase, t/ha | Patients late blight tubers, % | Commodity potatoes, % |
|----|--------------------------|--------------------|----------------------|-------------------------------|-----------------------|
| 1  | The control              | 8.4                | -                    | 8.6                           | 83.8                  |
| 2  | Biofertilizer, 30 t/ha   | 12.8               | 4.4                  | 7.2                           | 90.4                  |
| 3  | Biofertilizer, 60 t/ha   | 17.6               | 9.2                  | 6.5                           | 92.3                  |
| 4  | Biofertilizer, 90 t/ha   | 20.4               | 12                   | 6.8                           | 95.9                  |
| 5  | Cake 30 t/ha             | 14.3               | 5.9                  | 4.0                           | 92.2                  |
| 6  | Cake 60 t/ha             | 19.7               | 11.3                 | 1.3                           | 95.8                  |
| 7  | Cake 90 t/ha             | 23.9               | 15.5                 | 0.3                           | 98.7                  |
| SSD 05 |                      | 3.2                |                      |                               |                       |

Table 3. The biological activity of the arable layer of soils in the experimental options.

| No | Options                  | The biological activity of soils, % | Excess of control, % |
|----|--------------------------|------------------------------------|----------------------|
| 1  | Control                  | 26.3                               | -                    |
| 2  | Biofertilizer, 30 t/ha   | 32.1                               | 5.8                  |
| 3  | Biofertilizer, 60 t/ha   | 39.6                               | 13.3                 |
| 4  | Biofertilizer, 90 t/ha   | 44.5                               | 18.2                 |
| 5  | Cake 30 t/ha             | 40.4                               | 14.1                 |
| 6  | Cake 60 t/ha             | 47.6                               | 21.3                 |
| 7  | Cake 90 t/ha             | 52.9                               | 26.6                 |
| SSD 05 |                      | 6.4                                |                      |

From the data given in table 3, it can be seen that in 2018, under the influence of organic materials used as fertilizers, the biological activity of the soil increases by 18.2-26.6% compared with the control. Cake contains milk proteins, which, when decomposed, release mineral nitrogen deficient in the soil and contribute to an increase in the cellulose-degrading biological activity of the soil.

When harvesting potatoes and digging out flaxseed applications in the variants using cake and biofertilizers in the soil, numerous soil animals were observed - earthworms, ground beetles, millipedes, etc., which is also a sign of an increase in the biological activity of the soil.

After harvesting potatoes from the arable soil layer of the experimental variants, mixed samples were taken for agrochemical analyzes. Before chemical analyzes, soil samples were thoroughly cleaned of organic residues, biofertilizers and cake.
Microparticles of organic fertilizers were inseparable from soil particles, which influenced the results of the analysis and overestimated the content of humus and mobile nutrients of plants. However, the obtained results indirectly reflect the influence of organic fertilizers on the agrochemical properties of the soil and directly indicate an increase in its fertility (table 4).

Table 4. Agrochemical properties of the arable soil layer of the experimental options after harvesting potatoes.

| No | Options          | Humus, % | NO₃, mg/kg | P₂O₅, mg/kg | K₂O, mg/kg |
|----|------------------|----------|------------|-------------|------------|
| 1  | Control          | 2.51     | 2.4        | 125         | 132        |
| 2  | Biofertilizer, 30 t/ha | 2.69     | 6.1        | 218         | 175        |
| 3  | Biofertilizer, 60 t/ha | 2.85     | 8.2        | 307         | 205        |
| 4  | Biofertilizer, 90 t/ha | 3.15     | 9.5        | 341         | 280        |
| 5  | Cake 30 t/ha     | 3.08     | 8.9        | 194         | 160        |
| 6  | Cake 60 t/ha     | 3.25     | 12.5       | 240         | 252        |
| 7  | Cake 90 t/ha     | 3.65     | 20.7       | 281         | 249        |
|    | SSD 05           | 0.16     | 1.2        | 29          | 23         |

From the data of table 4 it is seen that the soil in the plots fertilized with cake is richer in plant nutrients than the soil of the control variant, or the variant fertilized with bio-fertilizer.

4. Conclusion
Scientific studies conducted in 2018 showed that the use of solid biofertilizers produced in a biogas plant and cake - the remains of sour milk production in doses of 60-90 t/ha increase the yield and improve the quality of potato tubers, as well as increase biological activity, the content of mobile plant nutrients and, in general, the fertility of light gray forest soil. The biological activity of the soil in variants using 60 and 90 t/ha of biofertilizer and cake, compared with the control variant, increases by 13.3–26.6%. Biofertilizer in the version with 30 t/ha increased the biological activity of the soil slightly, and cake in the same dose - very significantly (by 14.1%). Cake contains milk proteins, which, when decomposed, release mineral nitrogen deficient in the soil and contribute to an increase in the cellulose-degrading biological activity of the soil.

The agrochemical parameters of the soil as a result of the application of biofertilizer and cake sharply improved in all cases, but they can be taken conditionally, since the particles of organic matter were inseparable from the soil particles. However, according to the results of the analysis, a high aftereffect of biofertilizers and cake can be expected in subsequent years under other crops.

Despite some imbalance in potato plants of some plant nutrition elements in cake, primarily nitrogen, phosphorus and potassium, the maximum yield was obtained in these variants. The most effective dose for applying bio-fertilizer and cake for potatoes, taking into account the additional costs of introducing the maximum dose (90 t/ha) into the soil, is 60 t/ha. In addition, the use of biofertilizers and cake as fertilizers for crops reduces the amount of industrial waste requiring special disposal, and thereby helps to maintain a clean environment.

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