Use of residues of the dairy industry as a fertilizer for spring wheat

O Vasilyev*, A Vasilyev, I Nursov, YU Ivanov, A Ilyin and M Terentyeva

Department of Biotechnology and Agricultural Processing, Chuvash State Agricultural Academy, 29 Karl Marx Street, Cheboksary 428003, Russian Federation

*E-mail: vasiloleg@edu.academy21.ru

Abstract. The article presents the results of scientific research on the use of residues of the dairy industry (cake) as an organic fertilizer for spring wheat. Cake refers to the residues obtained by cleaning milk pipes, and has a chemical composition and physical properties similar to cottage cheese, but has a pungent and unpleasant smell of spoiled foods. The direct effect of oilcake on the growth and development of spring wheat on light gray forest loamy soil was studied in field experiments established in 2017–2019. Scientific studies have shown that cake is an excellent organic fertilizer, and its use in doses of 30, 60 and 90 t/ha dramatically increases soil fertility and productivity of spring wheat, improves grain quality.

1. Introduction
The dairy industry in Russia is actively developing, which leads to the accumulation of large masses of cottage cheese-like waste or residues (cake) formed during the cleaning of milk-conducting pipes, and which are almost entirely made up of proteins, fats and water. In the chemical composition of cake, a high content of biophilic plant nutrients is observed, since the starting material for its formation is cow's milk, which is the most useful product in human nutrition. The chemical composition of cake is very diverse and surpasses other traditional organic fertilizers (cattle manure, peat, compost, etc.) in the content of biophilic chemical elements. The dry matter content in cake is 25.6%, ash - 11.2%. The nitrogen content in the natural cake material is 2.5%, which is four times higher than in semi-matured manure, phosphorus - 2260 mg/100 g, potassium - 132 mg/kg, calcium - 2320 mg/kg, magnesium - 35.8 mg/100 g, sodium 84 mg/100 g. The organic matter content in the cake reaches 13.8% [1, 2].

The chemical composition of the cake approximately corresponds to the solid fraction of biogas plant wastes resulting from the processing of agricultural residues - manure, straw, chicken droppings, etc. [1, 2].

Cake has a cheesy-white matte color, is a pasty soft, slightly sticky mass with an unpleasant sour-milk pungent odor. When dried, the cake gradually cracks, forming granules of dirty yellow-gray color of various sizes. Cake does not mix or mix poorly with other substances and practically does not dissolve in water. Animals and birds do not eat cake. Previously, cake was accumulated and stored in piles on the territory of the plant, polluting groundwater and the surrounding territory, and was subject to disposal as industrial waste. Due to the need for utilization of cake, the question of its use as a fertilizer of agricultural crops is very relevant both for the dairy industry and in improving soil fertility. Since agricultural lands of the Chuvash Republic are exposed to water erosion, the problem of preserving and restoring the fertility of degraded soils is an acute problem for agricultural
cooperatives. The use of cheap, unconventional fertilizers (municipal sewage sludge, biogas plant waste, crushed horns and hooves) improves the condition of arable land and increases production, as reported by many authors who have conducted research in different countries [3-8]. The use of cake as a fertilizer could ensure closed milk production, preserve soil fertility, increase crop yields and improve the ecological situation in the region.

Therefore, the goal of our research was to study the possibility of using cake as a fertilizer for spring wheat and an environmental assessment of its application to the soil.

2. Materials and methods

Studies of the chemical composition of the cake were carried out in the soil-agrochemical laboratory of the Chuvash Agricultural Academy in accordance with existing national standards (GOST) and other regulatory documents.

The soil of the experimental plot is light-gray forestly, heavy loamy on loess-like loam, has an arable layer thickness of 25 cm; under the arable layer is located the A2B horizon with a thickness of 13 cm. Morphological features of the soil of the experimental plot are typical of light gray forest soils of the Chuvash Republic and the Middle Volga [9, 10]. The predecessor is perennial cereal grasses. 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 was investigated by the Tyurin method - by oxidizing soil organic matter with a solution of potassium dichromate in sulfuric acid. A soil sample, finely crushed and weighed on a balance, is placed in a flask and a chromium mixture is poured, then stirred, boiled for 5 minutes, and the analysis is finished by titrating the resulting suspension with 0.1 N Mohr's salt to an emerald color (GOST 26213091).

The biological activity of the soil in the experimental variants was determined by the intensity of mineralization during the growing season in the arable soil layer of the plots of pre-weighted pieces of flax material (applications).

The exchangeable acidity of the soil was determined with using 1 N solution of potassium chloride in the ratio of soil: solution as 1: 2.5 (GOST 26483-85) on a laboratory ionometer "I-160 MI". The content of nitrates in the soil was investigated by the ionometric method, while 25 ml of a 1% solution of potassium alum was added to 10 g of soil; then the resulting suspension was stirred and examined on a laboratory ionometer "I-160 MI" with a nitrate ion-selective electrode (GOST 26951-86).

The humus content in the arable layer of light gray forest soils of the experimental site varies from 2.48 to 2.55%, according to Kirsanov's mobile phosphorus - 150-155 mg/kg (high content), exchange potassium - 135-142 mg/kg (high content), the pH of the exchange acidity is 5.5-5.55 (close to neutral). The amount of exchange bases varies from 16.4 to 17.0 mg-e/100 g of soil; hydrolytic acidity - 1.95-2.05 mg-e/100 g. To evaluate the fertilizing effect of the cake, a mineral fertilizer was used – complex mineral fertilizer "nitroammofoska" (hereinafter - NPK), with content N-18%, P2O5-18%, K2O-18%, introduced at a dose of 100 kg/ha, which corresponds to 30 t/ha of cake minerals.

The supply of spring wheat with nitrogen was determined in the field by adding diphenylamine indicator to the freshly squeezed plant stem juice. The supply of plants with nitrogen was determined using a color scale with different shades of blue.

The technology of applying cake to the soil is as follows: the soil of the experimental plot was loosened by a walk-behind tractor to a depth of arable layer of 25 cm, then the plot was divided into plots and cake and fertilizer was scattered on the surface of the plots. After this, the fertilizer and cake were mixed with soil. The accounting area of the plots was 2 m², and the repetition was 6 times. Experience was laid down according to the scheme: 1). The control; 2) NPK 10 g/m² (based on 100 kg/ha); 3) Cake 3 kg/m² (30 t/ha); 4) Cake 6 kg/m² (60 t/ha); 5) Cake 10 kg/m² (100 t/ha). Spring wheat of the Moskovskaya-35 variety (elite seeds) was sown in grooves at the rate of 500 seeds/m². The location of the plots is systematic. The analysis of the biochemical composition of the grain was performed on a Spectra Star 2400 IR analyzer (Unity Scientific, Australia).

Statistical analysis of the results was carried out in the Excel program.
3. Results and discussion

Spring wheat in different types of experiments using cake and complex mineral fertilizer grew unevenly. Spring wheat plants located on the plots with the introduction of cake had a dark green leaf color, a large stalk height of 8-12 cm, more powerful flag leaves and thickened straws throughout the growing season, which is reflected in the results of nitrogen leaf diagnostics (table 1).

Table 1. Estimated points for nitrogen supply of spring wheat in the experimental variants.

| No. | Options        | June 21 | July 19 |
|-----|----------------|---------|---------|
| 1   | The control    | 1.5     | 1.7     |
| 2   | NPK 100 kg/ha  | 2.5     | 2.6     |
| 3   | Cake 30 t/ha   | 2.3     | 2.4     |
| 4   | Cake 60 t/ha   | 2.6     | 3.0     |
| 5   | Cake 100 t/ha  | 2.9     | 3.0     |
|     | SSD05          | 0.5     | 0.4     |

The data show that the effect of mineral fertilizer decreases by August 15, and spring wheat plants are not adequately supplied with nitrogen (table 1). The decomposition of cake in the soil gradually increases during the growing season, which satisfies the growing needs of spring wheat.

Similar changes in variants of experiments using organic fertilizers with grain crops were observed by foreign researchers [11-13].

In each experimental plot before harvesting, sheaves with roots were removed to determine the mass of plants (4 sheaves were removed from one plot, each with an area of 400 cm²) (table 2).

Table 2. The average height of the stems, the mass of sheaves and the yield of spring wheat.

| No. | Options        | Height, cm | Weight, g | Productivity, t/ha | Productivity increase, t/ha |
|-----|----------------|------------|-----------|--------------------|------------------------------|
| 1   | The control    | 56.4       | 37.1      | 1.82               |                              |
| 2   | NPK 100 kg/ha  | 63.5       | 52.6      | 2.17               | 0.35                         |
| 3   | Cake 30 t/ha   | 66.9       | 52.5      | 2.56               | 0.74                         |
| 4   | Cake 60 t/ha   | 71.8       | 63.2      | 3.42               | 1.60                         |
| 5   | Cake 100 t/ha  | 75.6       | 72.3      | 3.47               | 1.65                         |
|     | SSD05          | 3.5        | 3.1       | 0.32               |                              |

From the data of table 2 it is seen that the introduction of cake in doses of 30, 60 and 100 t/ha caused an increase in grain yield of 0.74 t/ha, 1.60 and 1.65 t/ha, respectively. The use of NPK 100 kg/ha also significantly increased the yield - 0.35 t/ha.

In the variants "Cake 100 t/ha" and "Cake 60 t/ha" the height of the stems and the mass of sheaves of spring wheat had the maximum values in the experiment. In the options "cake 30 t/ha" and "NPK 100 kg/ha" these indicators also significantly exceeded the control option.

The sizes of ears of spring wheat in the control variant were 7–7.5 cm, in the variant with complex mineral fertilizer - 7.5–8 cm, and in the variants using cake - 13–14 cm. The weight of 1000 grains was the maximum in the cake version 60 t / ha and amounted to 51.7 g. The comparative sizes of ears of spring wheat in the experimental variants are shown in figure 1.
Figure 1. Ears of spring wheat (left) and 100 grains (right) in experimental options. a) Options from left to right: Control, 100 kg/ha complex mineral fertilizer, 30 t/ha cake, 60 t/ha cake, 100 t/ha cake; b) Options from left to right: Control, 100 kg/ha complex mineral fertilizer, 30 t/ha cake, 60 t/ha cake, 100 t/ha cake.

The use of cake as a fertilizer also affected the quality of spring wheat grain. The results of analyzes of spring wheat grain Moskovskaya-35 are presented in table 3.

Table 3. The Quality of grain of spring wheat in the variants of the experiment, %.

| No. | Options       | Moisture | Crude | Ash | Fiber | Gluten | Raw protein | Raw fat | P | Ca |
|-----|---------------|----------|-------|-----|-------|--------|-------------|--------|---|----|
| 1   | The control   | 9.35     | 2.7   | 4.4 | 24.2  | 16.0   | 2.3         | 0.4    | 0.1 |
| 2   | NPK 100 kg/ha | 9.48     | 2.8   | 4.5 | 24.5  | 16.3   | 2.3         | 0.4    | 0.1 |
| 3   | Cake 30 t/ha  | 10.16    | 2.8   | 4.5 | 25.6  | 16.9   | 2.4         | 0.4    | 0.1 |
| 4   | Cake 60 t/ha  | 10.69    | 3.2   | 4.7 | 32.4  | 18.6   | 2.4         | 0.5    | 0.1 |
| 5   | Cake 100 t/ha | 10.28    | 3.1   | 4.2 | 31.6  | 18.5   | 2.3         | 0.5    | 0.1 |
|     | SSD<sub>0.05</sub> | 0.72 | 0.2  | 0.1 | 1.2   | 2.0    | 0.1         |        |

The results presented in table 3 show the relationship between the dose of fertilizer and cake, and the increase in the content of crude protein and gluten in the grain. The use of cake at a dose of 30 t/ha increased the crude protein content in spring wheat grain by 0.9%, 60 t/ha - by 1.6%, 100 t/ha - by 2.5%.

The biological activity of soils in the experimental variants was determined by the application bookmarking method. In 2017, due to greater precipitation than in 2015 and 2016 and a cool summer period, the decomposition of linen in the control variant amounted to 40-45%, and in the cases using cake - 60-80%.

In 2017, in the variants with the use of complex mineral fertilizer and cake, the biological activity of the soil increased by 20-39% compared with the control variant. Cake contains proteins that, when decomposed, release mineral nitrogen deficient in the soil and contribute to an increase in the cellulose-degrading biological activity of the soil.

The introduction of complex mineral fertilizer also increased the biological activity of the soil (table 4).
Table 4. Characteristics of the arable layer of soils in experimental variants under spring wheat.

| Options        | Humus, % | Nitrates mg/kg | Mobile P₂O₅, mg/kg | Exchange K₂O, mg/kg | pH exchange | The biological activity of soils, % |
|----------------|----------|----------------|-------------------|--------------------|-------------|-----------------------------------|
| The control    | 2.49     | 2.4            | 153               | 132                | 5.52        | 41.5                              |
| NPK 100 kg/ha  | 2.48     | 2.8            | 158               | 140                | 5.50        | 49.6                              |
| Cake 30 t/ha   | 2.84     | 8.4            | 162               | 145                | 5.58        | 61.6                              |
| Cake 60 t/ha   | 3.20     | 11.5           | 173               | 165                | 5.80        | 79.1                              |
| Cake 100 t/ha  | 3.53     | 16.4           | 198               | 210                | 6.25        | 79.9                              |
| SSD₀₅         | 0.15     | 1.9            | 16                | 14                 | 0.10        | 5.6                               |

From the data given in table 4, it can be seen that in 2017, under the influence of applied fertilizers and cake, the biological activity of the soil in comparison with the control increases by 20–39%. 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 properties of the arable layer of soil as a result of the use of lactic acid waste have significantly improved. Under the influence of cake, the exchange acidity shifted to the neutral side, the content of organic matter (humus), mobile phosphorus, potassium, nitrates increased sharply simultaneously with the improvement of biological activity.

4. Conclusion

The use of cake as a fertilizer for spring wheat has been very effective. Spring wheat plants were provided with nitrogen evenly throughout the growing season. In the variant with the use of 100 kg/ha of complex mineral fertilizer, the effect of fertilizer decreases by August 15, and by the time of ripening the grain of the spring wheat plant, there is insufficient nitrogen. The decomposition of cake in the soil is accelerated during the growing season, which satisfies the growing needs of spring wheat. The introduction of cake in doses of 30, 60 and 100 t/ha caused a gain in grain productivity of 0.74 t/ha, 1.60 and 1.65 t/ha, respectively.

The use of cake as a fertilizer improved grain quality: in the 30 t/ha cake variant, the crude protein content in spring wheat grain increased by 0.9%, 60 t/ha - by 1.6%, 100 t/ha - by 2.5%.

In variants with the use of complex mineral fertilizer and cake, the biological activity of the soil, compared with the control variant, increased by 20-39%.

Scientific studies conducted in 2017 on spring wheat showed that the remains of the dairy industry - oil cake - are an effective fertilizer that increases productivity, grain quality of spring wheat and the fertility of light gray forest loamy soil.

Thus, non-traditional organic fertilizers, which include the remains of the light and food industries - cake, crushed animal horns and hooves, biogas plant wastes compete with traditional organic fertilizers both in improving soil fertility and improving the ecological situation in the region, as well as increasing productivity and product quality [1-9, 11-13].

References

[1] Vasilyev O A, Ilyin A N, Nursov I N, Zaitseva N N, Vasilyev A O, Fadeeva N A and Lozhkin A G 2020 The effectiveness of the use of alternative fertilizers in the conditions of the Chuvash Republic IOP Conf. Ser.: Earth Environ. Sci. 433 012050

[2] Zaitseva N N and Fadeeva N A 2019 Consequences of solid products of the biogas plant on the yield yield and quality of spring wheat Bulletin of the Chuvash State Academy 4 27
[3] Shashkarov L G, Eliseev I P and Eliseeva L V 2017 Efficiency of using horned ungulate and zeolite-containing tripoli for row crops on light gray forest soils *Bulletin of Kazan State Agrarian University* 2 30

[4] Eliseev I P, Shashkarov L G, Vasiliev O A, Eliseeva L V and Mitrofanov E L 2020 Optimization of plant nutrition using unconventional organic fertilizers and zeolite-containing tripoli *IOP Conf. Ser.: Earth Environ. Sci.* 433 012017

[5] Huang H, Rizwan M, Li M, Song F, Zhou S, He X, Ding R, Dai Z, Yuan Y, Cao M, Xiong S and Tu S 2019 Comparative efficacy of organic and inorganic silicon fertilizers on antioxidant response, Cd/Pb accumulation and health risk assessment in wheat (Triticum aestivum L.) *Environmental Pollution* 255 (1) 113146 doi: 10.1016/j.envpol.2019.113146

[6] Arif M, Ilyas M, Riaz M, Ali K, Shah K, Ul Haq I and Fahad S 2017 Biochar improves phosphorus use efficiency of organic-inorganic fertilizers, maize-wheat productivity and soil quality in a low fertility alkaline soil *Field Crop Res* 214 25-37 doi: 10.1016/j.fcr.2017.08.018

[7] Xin X, Qin S, Zhang J, Zhu A, Yang W and Zhang X 2017 Yield, phosphorus use efficiency and balance response to substituting long-term chemical fertilizer use with organic manure in a wheat-maize system *Field Crops Research* 208 27-33 doi: 10.1016/j.fcr.2017.03.011

[8] Chaudhary S R, Dheri G S and Brar B S 2017 Long-term effects of NPK fertilizers and organic manures on carbon stabilization and management index under rice-wheat cropping system *Soil and Tillage Research* 166 59-66 doi: 10.1016/j.still.2016.10.005

[9] Vasiliev O A 2007 Eroded soils of the Chuvash Republic (Monograph) p 250

[10] Lisitsyn S V, Akhmetshin Sh M and Belov O A 2019 The state and dynamics of fertility of arable land in the Chuvash Republic *Achievements of science and technology of the agro-industrial complex* 4 31

[11] Kumar N, Rao O P, Singh M, Singh P and Khan S 2017 Effect of fertilizer and organic manures on growth and yield attributes of wheat and paddy variety under casuarina (Casuarina equisetifolia) based agrisilviculture system *Int. J. Pure App. Biosci.* 5(5) 879-887 dx.doi.org/10.18782/2320-7051.5573

[12] Litoriya N S, Modi A R and Talati J G 2018 Nutritional evaluation of durum wheat with respect to organic and chemical fertilizers *Agricultural research* 7(2) 152 doi: 10.1007/s40003-018-0301-2

[13] Singh V K, Dwivedi B S, Mishra R P, Shukla A K, Timsina J, Upadhyay P K, Shekhawat K, Majumdar K and Panwar A S 2019 Yields, soil health and farm profits under a rice-wheat system: long-term effect of organic and chemical manures applied alone and in combination *Agronomy* 9 1 doi: 10.3390/agronomy9010001