Long-term aftereffect of dairy production waste on productivity and soil fertility

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Abstract. The article shows for the first time the results of studies on the aftereffect of 4 years of a single use of dairy industry waste - cake as a fertilizer for crops in the crop rotation link: potatoes - spring wheat - potatoes - barley on productivity and product quality. In the spring of 2017, the experimental plot after harvesting the remains of perennial grasses was mechanically processed with a motor cultivator and divided into plots of 10 m2 with the following experimental options: 1. Control (without fertilizers); 2. Complex mineral fertilizer - azophoska with the content of plant nutrients N - 16%, P2O5 - 16%, K2O - 16% at the rate of 100 kg/ha; 3. Cake 3 kg/m2 (30 t/ha); 4. Cake 6 kg/m2 (60 t/ha); 5. Cake 9 kg a.i./m2 (90 t/ha). Variants of experiments were studied in six repetitions. The cake substance gradually mineralizes in the soil and supplies crops with nutrients throughout the growing season. The aftereffect of the cake was studied from 2018 to 2020, and for all the years of research, the maximum yield was observed in the variants with the introduction of cake. So, if in 2020 in the control variant the yield of barley was 2.13 t/ha, then in the variant with azofoska - 2.21 t/ha; in the option of 30 t/ha of cake - 2.41 t/ha; in the option of 60 t/ha of cake - 2.95 t/ha; in the variant 90 t/ha of cake - 3.10 t/ha (HCP05 = 0.22). The agrochemical properties of the soil in the variants with cake application improved significantly: the humus content in the control variant - 3.03%, in the variant with azofoska - 3.16%, in the variant 30 t/ha of cake - 3.22%, in the variant 60 t/ha ha of cake - 3.65%, in the option of 60 t/ha of cake - 3.60%. The content of plant-available forms of phosphorus and potassium in the soil also increased. The pH values of the exchangeable acidity increased to neutral values (6.59).

1 Introduction

Disposal of waste from light industry around the world causes not only a burden on the environment, but also additional production costs. Wastes such as municipal sewage sludge, hoof shavings, biogas plant waste can be effectively used as organic fertilizers [1, 6, 7, 8, 12]. One of these wastes, or residues, of dairy production is cake - a hydrophobic viscous substance of light gray color with a sharp and unpleasant smell of spoiled cottage

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cheese. The accumulation of cake on the territory of the enterprise in the open air causes pollution of the atmosphere with gases, and ground and surface water - with leached waste substances.

According to its chemical composition, the substance of the cake is close to the dairy product - cottage cheese, it is fed by insects (woodlice, earwigs, etc. are seen in the cake) and microorganisms (it quickly decomposes in the soil).

The content of dry matter in the cake is 25.6%, ash - 11.2%. The content of nitrogen in the natural substance of the cake is 2.5%, phosphorus - 2260 mg / 100 g, potassium - 132 mg / kg, calcium - 2320 mg / kg, magnesium - 35.8 mg / 100 g, sodium - 84 mg / 100 d. Organic matter is contained in the cake up to 13.8% [3].

Based on the studied properties of the cake, it can be said that this is a biophilic substance with a diverse chemical composition, which is based on milk proteins. In this regard, the question of the possible use of cake as a fertilizer for agricultural crops is a very urgent task for the dairy industry.

In 2017, a field experiment was established on light gray forest heavy loamy soil, in which the effect of cake on the yield of agricultural crops - potatoes and spring wheat was studied. The cake was applied in large doses - at the rate of 30, 60 and 90 t/ha, and its direct effect on the yield and quality of crop products in 2017 had a positive effect. However, how long the aftereffect of the cake on yield remains an unclear question.

The purpose of the research is to study the aftereffect of cake on the yield of Elf barley in the crop rotation link: "potato - spring wheat - potato - barley" and the agrochemical properties of the soil in 2020. To compare the fertilizing effect of the cake in the experiments, a variant was used with the use of azofoska - a complex mineral fertilizer with a nitrogen content of 16%, phosphorus (P_2O_5) - 16%, potassium (K_2O) - 16%. The physical weight of azofoska 100 kg/ha in terms of nutrient content approximately corresponds to 30 t/ha cake.

2 Materials and research methods

In the spring of 2017, the light gray forest soil of the experimental field was cultivated with cutters of a motor cultivator and after that it was divided into sections (experimental options) with an area of 10 m2: 1. Control (without fertilizers); 2. Azofoska at the rate of 100 kg a.i./ha; 3. Cake 3 kg/m2 (30 t/ha); 4. Cake 6 kg/m2 (60 t/ha); 5. Cake 9 kg/m2 (90 t/ha). Then, fertilizers were evenly scattered on the soil surface according to the variants of the experiment, which were immediately mixed with the arable layer to a depth of 20–25 cm.

The variants of the experiments were studied in six repetitions. The location of the plots in the variants of the experiment is systematic. In the first year of cake introduction (2017), spring wheat was grown on experimental plots. In 2018, on the same variants of the experiment, potatoes were planted to study the aftereffect of the cake, in 2019 - spring wheat, in 2020 - Elf barley.

The content of mobile forms of phosphorus and potassium in the soil was determined by the Kirsanov method in a soil extract obtained with a 0.2 N hydrochloric acid solution (GOST R 54650-2011). An aliquot was examined on an AA-6300 atomic absorption spectrophotometer. The supply of barley nitrate nitrogen in the germination and tillering phase was determined by the indicator (1% solution of diphenylamine in concentrated sulfuric acid) by the Zerling method - in the juice of plant leaves on a 10-point scale. When analyzing the chemical composition of barley grain, an infrared analyzer Spectra Star 2400 (Unity Scientific, Australia) was used.

The content of organic matter in the soil was studied according to the Tyurin method - its oxidation with a solution of potassium dichromate in sulfuric acid. After stirring and

boiling, the contents of the flask are titrated with 0.1 N Mohr's salt in the presence of 0.2% phenylanthranilic acid solution. The results are recalculated for humus using a coefficient of 1.724 (GOST 26213091). The exchangeable acidity of the soil was determined by the ionometric method in a soil suspension obtained using a 1 N potassium chloride solution at a soil:solution ratio of 1:2.5 (GOST 26483-85). The content of nitrates in the soil was studied ionometrically (GOST 26951-86).

The climatic conditions during the growing season of 2020 were slightly dry, with very humid and cool May, dry June and the first half of July, and with sufficient moisture in the month of August. Mathematical processing of the analysis results was carried out according to Dospekhov, in the Excell program.

3 Research results

Barley Elf in different variants of experiments developed unevenly. Plants in the variants of the experiment with the introduction of cake at doses of 60 and 90 t/ha from the beginning of seedlings developed faster and by the end of the tillering phase were 3-5 cm higher than in the other variants; the leaves had a more intense green color. By this time, barley plants absorb more than half of the required amount of nutrients for the formation of the crop. Nitrogen foliar diagnostics of barley plants, performed in the first phases of development - germination and tillering - showed a regular change in the concentration of nitrate nitrogen in the leaves - the higher the cake dose, the higher the content of nitrate nitrogen in the leaves.

The effect of azophoska on the content of nitrate nitrogen in barley leaves for 4 years after application does not appear compared to the control variant. However, visually, the barley in the variant with azofoska aftereffect looked better, which was manifested in a slightly larger leaf width and plant height. Similar changes were observed in the variants of experiments with spring wheat in field experiments in the year of cake application in 2017, but more pronounced [4, 12]. Immediately before harvesting, six sheaves of barley with roots were removed from each plot. Some results of the sheaf analysis are presented (Table 1).

Table 1. Average height of stems, weight of sheaves and barley yield for 4 years of experimentation

No. p.p.	Options	Stems total, pieces	Sheaf weight, g	Ears, pieces	Weight of ears, g
1	Control	22.1	20.4	18.4	11.9
2	NPK 100 kg/ha	22.5	20.9	19.4	13.2
3	KEK 30 t/ha	23.0	22.7	21.1	13.8
4	KEK 60 t/ha	29.3	27.3	25.3	18.2
5	KEK 100 t/ha	30.4	28.5	26.2	18.9
	LSD_{05}	3.5	4.6	3.2	1.3

From the results presented in Table 2, it can be seen that the aftereffect of the cake caused a significant increase in the quantitative and mass data of the sheaf analysis in the variants with the application of 60 and 90 t/ha. In the variants with the use of 100 kg/ha azophoska and 30 t/ha cake, the tillering of barley, the number of stalks and the mass of sheaves and ears increased slightly compared to the control variant. The maximum indicators for the average height and average weight of the sheaves are observed in the options "cake 90 t/ha" and "cake 60 t/ha". Compared to the control variant, the options

"cake 30 t/ha" and "NPK 100 kg/ha" also look somewhat better. Quantitative grain indicators of the sheaf analysis of barley according to the variants of the experiments are shown in Table. 2.

Table 2. Average grain indicators of barley sheaf analysis

No. p.p.	Options	Weight of grains, g	Number of grains, pieces	Grain output from a sheaf, %	Weight of 1000 seeds, g	Biological yield, t/ha
1	Control	8.50	216	41.7	39.4	2.13
2	NPK 100kg/ha	8.82	219	42.2	40.3	2.21
3	KEK 30 t/ha	9.64	234	42.5	41.2	2.41
4	KEK 60 t/ha	11.81	272	43.3	43.4	2.95
5	KEK 100 t/ha	12.38	279	43.4	44.4	3.10
	LSD_{05}					0.22

The results of sheaf analysis and biological yield indicate a significant aftereffect of the cake in the 4th year of use.

As annual studies show, even very high doses of cake (60 and 100 t/ha) did not cause an excess of the maximum allowable concentrations of nitrates in soil and crop production, which is observed when chicken manure is introduced at similar doses in the first year of research [2].

When studying cake as a fertilizer in the first years, a sharply increased biological activity of the soil was noted in the variants with the introduction of high doses of cake - 60 and 100 t/ha. In the variants with the use of cake, an increased amount of soil meso- and macrofauna was also noted [4, 12]. Apparently, during the decomposition of the biophilic substance of the cake in the first two or three years after the introduction, biological absorption of minerals and nitrogen by soil microorganisms is observed, i.e. their immobilization, which does not affect the nutrition of barley plants. A rapid change in the generations of microorganisms contributes to an increased content of mobile nutrients in the arable soil layer during the growing season, both due to the mineralization of plant residues of the precursor and dead organisms of soil animals and bacteria [5, 9, 10, 11]. Microorganisms in the process of life secrete various enzymes and plant growth stimulants, which are absorbed by the root system and contribute to a more vigorous development of crops.

The effect of using different doses of cake contributes to an increase in the fertility of light gray forest soil, which is recorded by the results of agrochemical analyzes (Table 3).

Table 3. Average agrochemical indicators of the soil in autumn 2020

No. p.p.	Options	Humus, %	P_2O_5, mg/kg	K_2O, mg/kg	NO_3^-, mg/kg	pHкс1
1	Control	3.03	149	121	5.7	6.21
2	NPK 100kg/ha	3.22	154	117	4.7	6.58
3	KEK 30 t/ha	3.16	165	110	9.4	6.63
4	KEK 60 t/ha	3.65	187	109	10.3	6.71

5	KEK 100 t/ha	3.60	218	116	18.6	6.59

The cake material is especially rich in nitrogen and phosphorus, which is reflected in the results of soil tests. A decrease in the content of exchangeable potassium in the soil for the 4th year of using the cake causes a negative balance due to its removal by the crop and a relatively low content in the fertilizer. The acidity of the arable layer of the soil is stably maintained in the neutral range of pH values.

There is also a slight positive aftereffect of the mineral complex fertilizer azophoska both on the yield of barley and on the agrochemical properties of the soil. In the first year, azophoska significantly increased the yield of spring wheat, and in the second year, potatoes. In subsequent years, the increase in crop yields in this variant was small.

4 Conclusion

Scientific studies conducted in 2017-2020 showed that one-time application of residues (waste) of the dairy industry - cake as a fertilizer at doses of 30, 60 and 100 t/ha under various crops (potatoes, spring wheat, barley) increases their yield for 4 years. The aftereffect of other non-traditional fertilizers can be traced for 2-4 years [1, 3, 4, 6, 7, 8] [12]. The agrochemical properties of light gray forest soil in the variants with the introduction of cake for the 4th year of use improved significantly: if the humus content in the control variant was 3.03%, and in the variant with azofoska - 3.16%, then in the variant 30 t/ha of cake - 3.22%, in the option of 60 t/ha of cake - 3.60%, in the option of 60 t/ha of cake - 3.65%. The content of phosphorus forms available to plants in the soil also increased. However, the content of exchangeable potassium in the arable layer slightly decreased, which is explained by its increased removal with an increased crop yield in the variants using cake for all the years of research (2017-2020). The pH units of the exchangeable acidity of the arable layer as a result of the use of cake increased to neutral values (from 6.21 in the control variant to 6.71 and 6.59 in the variants with the introduction of cake at doses of 60 and 100 t/ha). Despite the high doses of cake, rich in nitrogen, the content of nitrates in the soil and crop production remained within the MPC.

Thus, cake is a very good organic fertilizer with a long aftereffect, which can be applied as a fertilizer for agricultural crops to the soil "in reserve" in very high doses up to 100 t/ha. At the same time, for all the years in the variants with the use of cake, a high yield and good quality of crop production in the crop rotation link "spring wheat - potatoes - spring wheat - barley" is noted.

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