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Biological Processing of Renewable Raw Materials Resources with Regard to the Environmental and Technological Criteria

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ABSTRACT

The research was devoted to studying the influence of the Tamir biological product in the loose deep-litter keeping of the cattle on the indicators of rearing stock live weight, average daily weight gain, and withdrawal of replacement heifers, cows, and first-calf heifers due to the limb diseases. The study was performed at the stud farm for breeding the black-motley breed of the Integrated Agricultural Production Company (collective farm) Udmurtia in the Vavozhsky district of the Udmurtian Republic in the period from 2013 to October 2018. The report on animals culling from the main herd, and reports on animals weighing have shown that in 2013–2014, before the use of the biological product, the number of heifers withdrawn from the herd at the age of 10–12 months was 12 (in 2013), or 1.4%, and 13 (in 2014), or 1.4%; at the age from 12 to 18 months – nine (2013), or 1.1%, and 12 (2014), or 1.3%; at the age of 18 months and older – three (2013), or 0.6%, and eight (2014), or 0.5% of the total number in the age groups of the animals. In 2015–2017, i.e., after the use of the biological product, the number of heifers withdrawn from the herd at the age of 10–12 months was nine (1.1%), six (0.6%), and seven (0.6%); at the age of 12–18 months – seven (0.8%), five (0.5%), and three (0.3%); at age 18 months and older – two (0.2%), two (0.2%), and one (0.01%) of the total number in the age groups of the animals. Withdrawal of rearing stock due to limbs diseases was also analyzed. While before the use of the biological product, in 2013–2014, 26 animals, or 3.0% (2013) and 33 animals, or 3.5% (in 2014) had been withdrawn from the herd, after the use of the biological products in 2015–2017, this figure dropped to 18 animals, or 2.2% in 2015, 13 animals, or 1.2% in 2016, and 11 animals, or 1.0% in 2017. Thus, the percentage of the withdrawn heifers after the use of the biological product decreased from 3.0–3.5% to 1.0–2.2%, or almost three times. Analysis of the average daily weight gain by young animals in all age periods has shown that after the use of the biological product, the average daily weight gain increased, compared to the period before its use, which confirms the growth of this indicator. The live weight of the replacement heifers at first insemination before the use of the product amounted to 382–381 kg, and in 2015–2017, after the use of the product, it amounted to 385–388–390 kg, which also indicated the positive effect of the product on the growth. The percentage of the cows withdrawn from the main herd after the use of the biological product reduced from 10.3–15.4% to 5.8–6.1%, i.e., by 4.5–9.3%; of first-calf heifers – from 11.0–17.1% to 3.4–7.1%, i.e., by 7.6–10.0%, by the years of withdrawal, respectively. After processing the manure with the Tamir biological product, the fraction of manure became solid (crumbly) and lost the smell. Thus, the use of the Tamir biological product in the technology of loose keeping of cattle on deep litter increased the daily weight gain in heifers and their live weight at first insemination, and reduced the share of low-productive cows and first-calf heifers, as well as the incidence rate of limb diseases.

Keywords: biological product, cattle, rearing stock, average daily weight gain, live weight, insemination, cow, manure, processing, culling.

INTRODUCTION

The use of new technologies of obtaining livestock breeding products, the introduction of modernized methods of keeping animals and removing the manure require the development of the technologies that will ensure manure removal with regard to the environmental and economically viable factors [Bryukhanov et al., 2017; Uvarov, 2015; Ratoshny, 2018].

Farm waste is an important source of plant nutrition; therefore, its use is of great importance for regulating the circulation of substances in agriculture, and for preserving and increasing the content of humus in the soils [Balesdent, 2000; Guerrero, 2000; Zverzhanovskiy et al., 2017]. Fodder and its energy are assimilated by animals only by 35 – 45 % [Koshchaev et al., 2018c; Sobol et al., 2017; Chasovshchikova et al., 2017; Koshchaev et al., 2018d]. The undigested components of the fodder excreted with feces and the litter material, which can be extracted with the help of microbiological or physicochemical technologies, have a huge energy potential [Fomicheva et al., 2018; Donnik et al., 2017; Saleeval et al., 2018]. One of the efficient ways of processing cattle manure in case of loose deep-litter keeping technology is the use of various biological products.

With the aim of processing the initial substrate, the method of composting has become widely used, where biochemical transformations result in conversion of organic wastes into relatively stable humic-like substances [Temmoev, et al., 2018; Bakharev et al., 2018; Koba et al., 2017, Torkashvand, 2010].

With the aim of reducing the duration of the composting process, bioactivators, which are mainly bacterial strains, are increasingly used [Shcherbatov et al., 2018; Anisimova et al., 2018; Koshchaev et al., 2019; Kryukov et al., 2018]. In practice, about 100 species of microorganisms are most widely used, among which the most frequently used are bacteria of the Bacillus genera, or their consortia with other microorganisms, bacteria of the Pseudomonas, Lactobacillus genera, etc. [Kuzminova et al., 2019; Garkovenko et al., 2018; Koba et al., 2018].

Biotesting has shown that the best-quality ripe compost is obtained by sequential treatment of the source substrates with bacterial bioactivators and biological products based on T. hirsuta [Svistunov et al., 2018; Onischuk et al., 2016; Kenijz et al., 2018]. Chemical properties of the composts show that they can be recommended for introduction into the soil as fertilizers and as the basis for mixtures for container plants [Korolevet al., 2012; Tuzov et al., 2018].

The work was aimed at studying the efficiency of the Tamir biological product in the loose deep-litter cattle keeping technology. For the research, the following tasks were set:

- studying the technology of introducing the Tamir biological product for manure treatment;
- analyzing the following indicators over two years before and three years after the use of the biological product: the average daily weight gains in the rearing stock, the live weight at first insemination, and the rate of replacement heifers withdrawal from the herd due to limb diseases;
- analyzing the indicators of cows and first-calf heifers withdrawal from the main herd due to limb diseases over two years before and three years after the use of the biological product; and
- studying the results of the laboratory tests of compost suitability for its introduction into the soil at the farm.

MATERIALS AND METHODS

The study was performed at the stud farm for breeding the black-motley breed of the Integrated Agricultural Production Company (collective farm) Udmurtia in the Vavozhsky district of the Udmurtian Republic in the period from 2013 to 2018. The objects of the study were black-motley rearing stock and cows.

For the research, the data from the livestock report were used about the results of breeding dairy cattle; the animals were sampled according to the statements of animal culling from the main herd (form No. 406-APC (100) and CELEX application).

The Tamir biological product is a biologically active concentrate of soil microorganisms for removing organic wastes and eliminating odors in septic tanks and sewer and for rapid composting of biological wastes [Starostina et al., 1997; Koshchaev et al., 2018b; Koshchaev et al., 2018a].

It contains lactate, nitrogen-fixing, photosynthetic, and cellulose-decomposing bacteria, unicellate fungi, and maltodextrin. The product is not toxic to humans and animals. It is to be stored in a dark dry location at 0–20°C, away from food

products. The Tamir biological product is introduced into the manure for removing the smell and accelerating the composting process [Troshin et al., 2018b; Troshin et al., 2018a; Skvortsova et al., 2018].

In the experiment, the product had been dissolved in warm nonchlorinated water at the ratio of 1:100, and the obtained solution was used for layer-by-layer watering of the organics in the amount of 5–7 liters of the solution per 1 m^2 of 20 cm thick organic layer (until the humidity of 60% was reached). With that, one bucket of soil was added to each layer before watering; and the layers were well stirred. To prevent access of air, the compost pile was covered with plastic film. Two weeks later, when the indoor air temperature was 20–25 °C, the authors started using the obtained compost.

The studies were performed in the building where replacement heifers, bred heifers, and nonmilking cows were kept. The product was buried in the manure in chessboard order over every two meters to the depth of 20–30 cm in the amount of one liter. The overall consumption of the dissolved product for this building amounted to 200 liters. The shelf life of the diluted product did not exceed three days.

The laboratory studies were performed at AO Agrokhimtsentr Udmurtsky in the Udmurt Republic. The data were statistically processed in Microsoft Excel.

RESULTS AND DISCUSSION

At the Integrated Agricultural Production Company (collective farm) Udmurtia in the Vavozhsky district of the Udmurtian Republic, replacement heifers from 10 months of age, bred heifers, and nonmilking cows are loosely kept on deep litter. The manure was removed twice a year and taken to the fields after processing with biological products. Since 2013, the Tamir biological product has been used for manure treatment at the farm.

The authors analyzed the replacement heifers withdrawn from the herd due to limb diseases before and after the use of the biological product. The results show that in 2013–2014, i.e., in the period before the use of the biological product, 12 heifers (2013), or 1.4%, and 13 heifers (2014), or 1.4%, at the age of 10 months were withdrawn from the herd; at the age of 12 months – nine heifers (2013), or 1.1%, and 12 heifers (2014), or 1.3%; at the age of 18 months – three heifers (2013), or 0.6%, and eight heifers (2014), or 0.5% of the total number of age groups of animals (Table 1).

The authors also analyzed the replacement heifers withdrawal from the herd due to limb diseases before and after the use of the biological product. The results showed that in the period of using the biological product (2015–2017), nine (1.1%), six (0.6%), and seven (0.6%) heifers, respectively, were withdrawn from the herd; at the age of 12 months – seven (0.8%), five (0.5%), and three (0.3%) heifers; at the age of 18 months – two (0.2%), two (0.2%), and one (0.01%) heifers of the total number of the age groups of the animals.

Withdrawal of rearing stock due to limbs diseases was also analyzed. While before the use of the biological product, in 2013–2014, the total of 57 animals, or 6.3% (2013) had been withdrawn from the herd, after the use of the biological products in 2015–2017, this figure dropped to 42 animals, or 4.4%. Thus, the percentage of the withdrawn replacement heifers after the use of the biological product decreased on average by 1.9%, or 1.3 times.

Along with that, the average daily weight gain by young animals was analyzed by age periods before and after the use of the biological product. The authors found that in the heifers at the age of 10–12 months, the daily weight gain before using the product was 770 g and 734 g in 2013 and 2014, respectively; in 2015, 2016 and 2017, after using the product, it was 744 g, 767 g, and 780 g; at the age of 12–18 months, the weight gain was 738 g, 672 g, 740 g, 730 g, and 760 g, and at the age from 18 months and older – 705 g and 710 g, 729 g, 729 and 741 g, which confirmed improvement of these indicators.

The authors studied the live weight of the replacement heifers at first insemination. For instance, in 2013–2014, before the use of the product, the live weight of the replacement heifers at first insemination had been 381–382 kg, and in 2015–2017 after the use of the product, it was 385–390 kg, which also shows the positive effect of the product on their growth.

Further analysis was made based on the withdrawal rate of first-calf heifers and cows from the main herd due to various reasons, including limb diseases, before and after the use of the product. The withdrawal rate of cows and first-calf heifers

Table 1. Live weight of the replacement heifers by age periods and by the number of culled animals due to limb diseases

Heifers age, months.	Availability of the replacement heifers at the beginning of the year	The replacement heifers withdrawn from the herd due to lymph diseases	Percentage of the animals withdrawn from the herd	Average daily weight gain, g	Live weight, kg	Live weight at first insemination, kg
Before using the product						
2013						
10 months	132	12	1.4	770	270	382
12 months	360	9	1.1	738	305	
18 months	364	3	0.6	705	422	
Total	856	24	2.8	X	X	
2014						
10 months	149	13	1.4	734	259	381
12 months	343	12	1.3	672	281	
18 months	440	8	0.5	710	425	
Total	932	33	3.5	X	X	
After using the product						
2015						
10 months	123	9	1.1	744	262	385
12 months	377	7	0.8	740	306	
18 months	306	2	0.2	729	435	
Total	806	18	2.2	X	X	
2016						
10 months	121	6	0.6	767	269	388
12 months	472	5	0.5	730	302	
18 months	488	2	0.2	729	435	
Total	1081	13	1.2	X	X	
2017						
10 months	165	7	0.6	780	273	390
12 months	450	3	0.3	760	313	
18 months	535	1	0.1	741	442	
Total	1150	11	1.0	X	X	

from the herd due to diseases before the use of the biological product may be assessed by the data in Table 2.

As a result, it has been established that in 2013, the total of 319 cows were withdrawn from the herd, which amounted to 21.0% of the total number of cows, of which the number of first-calf heifers was 82, or 15.2% of the total population of first-calf heifers. In 2014, 429 cows, or 26.9 % were withdrawn from the herd, of which the number of first-calf heifers was 64, or 13.1%, respectively.

The analysis of the reasons that determine cows withdrawal has shown that in 2013 and 2014, the greatest number of cows was withdrawn from the herd due to low productivity – 44.8 and 34.8%, or 143 and 149 animals, respectively. Out of the number of first-calf heifers, 41 animals were withdrawn for this reason, or 50% of the number of the withdrawn first-calf heifers. This is due to the fact that the farm is increasing milk productivity of cows, and less productive animals, especially first-calf heifers, are withdrawn from the herd. The second place among the reasons for cows withdrawal was taken by gynecological diseases and infertility of cows. In 2013, 58 cows, or 18.2% were withdrawn, and 12 first-calf heifers, or 14.7%; in 2014 – 53 cows, or 12.3%, and eight first-calf heifers, or 17.2%. In the third place are udder diseases, which in 2013 were observed in 53 cows, or 16.6%, and in three first-calf heifers, or 3.7%, in 2014 – in 86 cows, or 20%, and in five first-calf heifers, or 14.3%. In the fourth place, there are limb diseases, which in 2013 were the reason for withdrawing of 49 cows, or 15.4%, in 2014 – 44 cows, or 10.3%, of which there were nine first-calf heifers, or 11.0%, and eight first-calf heifers, or 17.1%, respectively.

Table 2. Withdrawal of cows and first-calf heifers from the herd for various reasons before the use of the biological product

Indicator	Year							
	2013				2014			
	cows		first-calf heifers		cows		first-calf heifers	
	animals	%	animals	%	animals	%	animals	%
Availability of cows	1,520	100	539	100	1,596	100	487	100
Total withdrawn	319	21.0	82	15.2	429	26.9	64	13.1
low productivity	143	44.8	41	50.0	149	34.8	11	20.0
Diseases:								
gynecological and infertility	58	18.2	12	14.7	53	12.3	8	17.2
udder	53	16.6	3	3.7	86	20.0	5	14.3
limbs	49	15.4	9.0	11.0	44	10.3	8	17.1
injuries, accidents	10	3.1	8	9.6	12	2.8	3	3.8
other	6	1.9	9	11.0	85	19.8	29	27.6

After using the biological product, the cows and first-calf heifers withdrawal from the herd over the 2015–2017 period was analyzed (Table 3).

The research data showed that in 2015, the total of 408 cows had been withdrawn from the herd for various reasons, which amounted to 24.3% of the total number of cows, in 2016 – 260 cows (14.8%), in 2017 – 322 cows (16.9%). Among the first-calf heifers, the share of the animals withdrawn in the analyzed years was 68 (8.9%), 56 (16.3%), and 89 (18.9%), respectively. Analysis of the reasons for cows withdrawal from the herd in the period from 2015 to 2017 shows that many cows were withdrawn due to udder diseases, and varied in the range between 25.5% and 36.9%, or 82–122 animals.

Thus, it was found that in 2015, 408 cows had been withdrawn from the entire herd, which amounted to 24.3% of the total number of cows; in 2016 – 260 cows (14.8%); in 2017 – 322 cows (16.9%) of the total number of cows. As to the first-calf heifers, these indicators were the following: 68 animals (8.9%) in 2015, 56 animals (16.3%) in 2016, and 89 animals (18.9%) in 2017.

It should be noted that after the use of the biological product, the share of the cows and first-calf heifers withdrawn from the herd due to limb diseases reduced. The data in the zootechnical report about the results of breeding dairy cattle over years 2013 through 2017 showed that the percentage of cows withdrawn from the main herd after the use of the biological product had decreased from 10.3–15.4% to 5.8–6.1%, i.e., by 4.5–9.3 abs. %.

At AO Agrokhimtsentr Udmurtsky of the Udmurt Republic, the samples of organic fertilizer taken from the building for nonmilking cows were studied (Table 4).

The results showed that the mass share of dry substance amounted to 7.9% with the norm not less than 3% and not more than 8%; the mass share of organic matter was 90% with the norm not less than 70%; the mass share of total nitrogen amounted to 4.6% of dry product with the norm not less than 0.1%; the mass share of total phosphorus was 1.7% with the norm not less than 0.05%; and the mass share of total potassium was 0.9% with the norm not less than 0.05%. Thus, it may be stated that the samples corresponded to the introduction of organic fertilizer into the soil.

No viable helminth eggs and cysts of pathogenic intestinal protozoa were found in the samples. According to the studies, the content of heavy metals in organic fertilizer GOST R 53117–2008 was the following: the mass share of lead was 1.5 mg/kg with the norm not exceeding 130 mg/kg, of cadmium – 0.14 mg/kg with the norm not exceeding 2.0 mg/kg; arsenic – 0.5 mg/kg with the norm not exceeding 10.0 mg/kg; mercury – less than 0.025 mg/kg with the norm not exceeding 2.0 mg/kg; HCH and its isomers – 0.002 mg/kg with the norm not exceeding 0.1 mg/kg of dry matter; and specific effective activity of technogeneous radionuclides was 0.08 relative units according to GOST R 53117–2008 with the norm not exceeding one relative unit.

By the content of heavy metals, the sample corresponded to the parameters of organic

Table 3. Withdrawal of cows and first-calf heifers from the herd for various reasons after the use of the biological product

Indicator	Cows		First-calf heifers	
	animals	%	animals	%
2015				
Availability of cows	1,676	100	762	100
Total withdrawn	408	24.3	68	8.9
low productivity	58	14.2	22	32.4
Diseases:				
gynecological and infertility	73	17.9	14	20.6
udder	122	30.0	2	2.9
limbs	25	6.1	3	4.4
injuries, accidents	5	1.2	1	1.5
other	124	30.6	26	38.2
2016				
Availability of cows	1,760	100	344	100
Total withdrawn	260	14.8	56	16.3
low productivity	10	3.9	8	14.4
Diseases:				
gynecological and infertility	44	16.9	11	19.6
udder	96	36.9	14	25
limbs	15	5.8	4	7.1
injuries, accidents	10	3.8	2	3.6
other	85	32.7	17	30.3
2017				
Availability of cows	1,910	100	472	100
Total withdrawn	322	16.9	89	18.9
low productivity	52	16.1	38	42.7
Diseases:				
gynecological and infertility	49	15.2	11	12.4
udder	82	25.5	6	6.7
limbs	19	5.9	3	3.4
injuries, accidents	9	2.8	1	1.1
other	111	34.5	30	33.7

fertilizers according to GOST R 53117–2008. The organic fertilizer is safe in terms of heavy metals for the soil of the Integrated Agricultural Production Company (collective farm) Udmurtia in the Vavozhsky district of the Udmurtian Republic in the summer period.

The studies showed that the mass share of dry substance amounted to 7.5% with the norm not less than 3% and not more than 8%; the mass share of organic matter was 90% with the norm not less than 70%; mass share of total nitrogen amounted to 4.6% of dry product with the norm not less than 0.1%; the mass share of total phosphorus was 1.7% with the norm not less than 0.05%; and the mass share of total potassium was 0.9% with the norm not less than 0.05%. Therefore, it may be stated that the samples corresponded to the introduction of organic fertilizer into the soil. No viable helminth eggs and cysts of pathogenic intestinal protozoa were found in the samples either.

According to the test report, the content of heavy metals in organic fertilizer GOST R 53117–2008 was the following: the mass share of lead was 0.4 mg/kg with the norm not exceeding 130 mg/kg, of cadmium – 1.59 mg/kg with the norm not exceeding 2.0 mg/kg; arsenic – 0.4 mg/kg with the norm not exceeding 10.0 mg/kg; mercury – less than 0.025 mg/kg with the norm not exceeding 2.0 mg/kg; HCH and its isomers – 0.011 mg/kg with the norm not exceeding 0.1 mg/kg of dry matter; and specific effective activity of technogeneous radionuclides was 0.3 relative units according to GOST R 53117–2008 with the norm not exceeding one relative unit.

Table 4. Data for the samples of organic fertilizer test report

Indicator	ND for the method	Norm	Test results in the yards for nonmilking cows	
			(vill. Volkovo) (n = 5)	(vill. Makarovo) (n=5)
Mass share of moisture, %	GOST 26713–85	Dry matter not less than 3 and not more than 8	92.1 ± 0.9 (7.9)	92.5 ± 0.9 (7.5)
Mass share of organic matter, % (for the dry product)	GOST 27980–88	Not less than 70 %	79.5 ± 0.8	90.3 ± 0.8
pH of salt extract, units	GOST 27979–88		8.9 ± 0.3	6.3 ± 0.3
Mass fraction of total nitrogen, % (for the dry product)	GOST 26715–85	Not less than 0.1 %	4.5 ± 0.3	4.6 ± 0.3
Mass share of total phosphorus (P_2O_5), % (for the dry product)	GOST 26717–85	Not less than 0.05%	1.6 ± 0.1	1.7 ± 0.1
Mass share of total potassium (K_2O), % (for the dry product)	GOST 26718–85	Not less than 0.05 %	4.5 ± 0.1	0.9 ± 0.05
Mass share of mercury, mg/kg	MI 2878–2002	Not more than 2.1	<0.025	<0.025
Mass share of arsenic, mg/kg	Methodical Guidelines for arsenic determination using the photometric method, M, CIASA, 1993.	Not more than 10.0	0.5 ± 0.1	0.4 ± 0.1
Mass share of lead (gross), mg/kg	Methodical Guidelines for determining heavy metals content in the soils of agricultural lands and crop production, M., 1992.	Not more than 130	1.5	0.4
Mass share of cadmium (gross), mg/kg		Not more than 2.0	0.14	1.59
Mass fraction of DDT and its metabolites, mg/kg of dry matter	Methodical Guidelines 1766–77	Not more than 0.1 mg / kg	0.002 ± 0.001	0.004 ± 0.001
Mass share of HCH and its isomers, mg/kg of dry matter			0.002 ± 0.001	0.011 ± 0.002
The specific effective activity of natural radionuclides (^{22}Ra, ^{232}Th ^{40}K), Bq/kg of dry matter	GOST 53745 (laboratory)	Not more than 300	25.1	6.9-
The specific effective activity of technogeneous radionuclides (^{137}Cs ^{90}Sr)	GOST R 53117–2008	No more than 1 relative unit	0.08	0.3-
Viable helminth eggs per one kg	Methodical Guidelines 4.2.2661–10	Not allowed	Not found	
Viable cysts of pathogenic intestinal protozoa in 100 g	Methodical Guidelines 4.2.2661–10	Not allowed	Not found	

By the content of heavy metals, the sample also corresponded to the parameters of organic fertilizers according to GOST R 53117–2008. The organic fertilizer was considered safe in terms of heavy metals content for the soil of Integrated Agricultural Production Company (collective farm) Udmurtia in the Vavozhsky district of the Udmurtian Republic in the summer period.

CONCLUSION

Thus, the use of the Tamir biological preparation for treating organic fertilizers ensured a positive effect. It was the most manifested by the decreased withdrawal rate of the replacement heifers and increased average daily weight gain and weigh at first insemination, as well as by the decreased withdrawal rate of the first-calf heifers from the main herd due to limb diseases. This technology ensured excellent results in recycling organic waste at buildings.

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