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Improved bovine manure treatment methods

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Abstract: On a dairy farm where 2000 milk cows were maintained, crude solid manure deriving from the mixture of excrements and wheat straw, in the ratio of 1 kg straw : 9 l excrements, was subjected to aerobic and anaerobic fermentation. During the experiment, changes of temperature, volume, water contents, organic matter contents, pH values, total macroelement contents and their low soluble forms were measured. Crude solid manure was converted by aerobic care into compost within 7 weeks; its volume was decreased by 2.3 times, macroelement contents were decreased by 4 times as compared to unit volume of compost obtained by anaerobic care. Therefore, considerably higher economic effectiveness of compost production and application to cultivated areas was achieved.

Key words: fermentation, manure, mineralization, straw, thermodisinsectization, thermophilic phase.

Introduction

Innovative technologies are of strategic importance for agriculture and environmental protection in the process of recycling organic waste deriving from agricultural production. The basic aim of new technologies should be to create the conditions for a rapid conversion of organic into mineral matter, and of mineral matter into forms available to plants, paying attention at the same time to economically rational energy input (Schuchartdt, 1985).

In the process of recycling solid manure that comes from big farms, new technologies should solve the following problems:

- the problem of recycling of pathogens contained in excrements and straw;
- the problem of recycling of weed seeds resistant to physiological processes in the animals' intestines, and the fermentation process of crude manure;
- the problem of the size of space provided for fermentation ("maturing") of crude and keeping of "mature" manure until it is used;
- the problem of the increase of nutrients in "mature" manure, reduction of its volume and energy input for its care throughout the fermentation process ("maturing"), reduction of transport and application to cultivated areas costs.

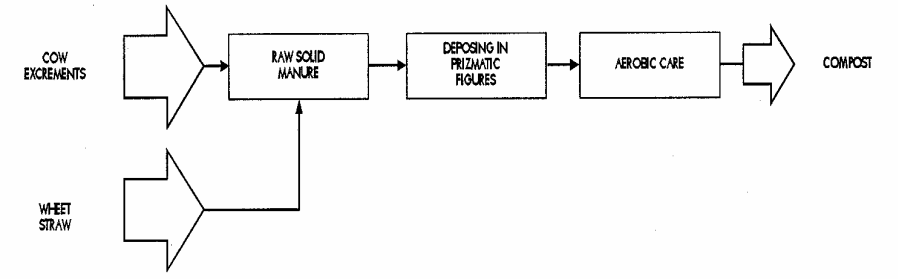
The aim of these investigations was to make an attempt in solving some of the stated problems on big farms using the experiment of solid manure aerobic care.

Material and Methods

The investigations were conducted on the farm with 2000 milk cows at the Agricultural Combine Belgrade in the Pancevo marshes.

In order to make the process of aerobic fermentation controlled, crude fresh manure containing the ingredients of wheat straw (the ratio of 1 kg straw per 7 I excrements) was deposited into prismatic figures. The size of each figure (3 m wide, 70 m long, 1 m high) was adapted by the overall dimensions of a self-propelled machine for aerobic care (3).

Prior to taking straw and excrements out of the stables and depositing them into figures, straw and excrements were homogenised inside the stables in manure handling canals (Scheme 1).



Scheme 1. Technological procedure of the experiment

The starting characteristics of crude solid manure, whose weight at the moment of introducing it into the process of aerobic care equalled 800 t, are given in Tab.1.

For the sake of comparison, the manure of the same starting characteristics was deposited in a traditional manner for aerobic care and converted into compost by anaerobic fermentation.

In the process of aerobic care, the prototype of a self-propelled machine (2) was used. Its characteristics were as follows: weight 3400 kg, engine power 58 kW, r.p.m. 2200 min^{-1}, width of engagement 3280 mm, height of clearing 1500 mm, working speed 280-720 m/h, output 200-1300 m^3/h.

Table 1. Physic-chemical properties of crude solid manure at the beginning of aerobic care process

Water content, (%)	Mineral matter, (%)	Organic matter, (%)	pH	N (%)	P_2O_5 (%)	K_2O (%)
1	2	3	4	5	6	7
78.34	2.77	97.22	7.72	0.77	0.36	0.46

Aerobic care, during which 12 treatments of crude manure turning over and mixing were performed, lasted 7 weeks.

During the experiment, conventional methods were employed to observe changes of temperature, pH values, moisture, volume, nutrient contents in manure.

The obtained results were statistically analysed, and are presented graphically and numerically in tables.

Results and Discussion

Changes of manure physical properties

Temperature changes in manure depositories, measured daily during aerobic care (Fig. 1), conditioned three phases of solid manure fermentation differing from one another in their duration and intensity: *psychrophilic, mesophilic and thermophilic.*

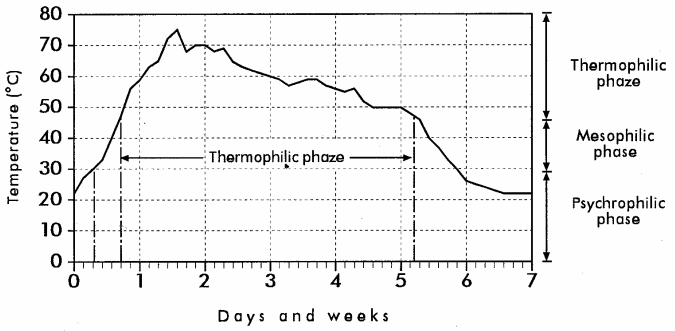


Figure 1 . Temperature changes in depositories during crude solid manure aerobic care

Psychrophilic phase that requires temperatures below 25°C was possible only in the beginning and end of aerobic care. 48 h after manure had been treated with the machine for the first time, fermentation passed into mesophilic phase in which temperatures ranging from 30-40°C provided optimum conditions for mesophilic bacteria activities. However, this phase was also short, lasting only 3 days, and it was only a transition phase to the next - thermophilic phase.

Thermophilic phase was the key phase in manure aerobic fermentation. It started 4 days after the first treatment with the machine, lasted longer than 4 weeks, or 60% of aerobic care duration. In its first part, on the 9th day from the beginning of aerobic care, the temperature reached its maximum of 75°C, and in

the next 20 days it was maintained at the 50-60°C level, which is considered to be the optimum for thermophilic bacteria activities.

After thermophilic, again through mesophilic phase, in the course of the next two weeks, temperature dropped to around 20°C and equalled environmental air temperature. Thus, the process of aerobic care, during which 12 treatments with the machine had been performed, was completed. Compost was obtained from crude solid manure, and its weight of 800 kg m-3 in the initial psychrophilic phase was reduced to 350 kg m^{-3} (Fig. 2).

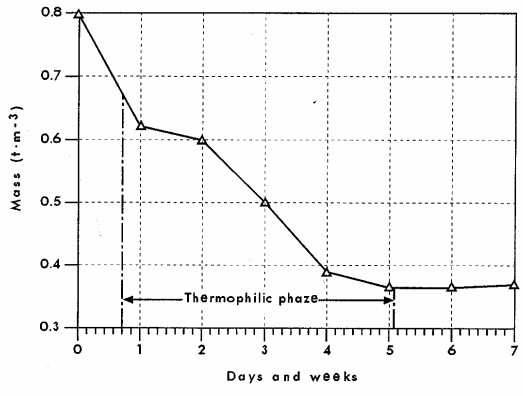


Figure 2. Depository weight changes during crude solid manure aerobic care

Lower weight of compost, by 450 kg m^{-3} (56.25%), as compared to the weight of crude solid manure at the beginning of aerobic care correlated with the loss of water from depositories, amounting to 412 l m^{-3} (50.25%) during thermophilic and mesophilic phases of fermentation (Fig. 3).

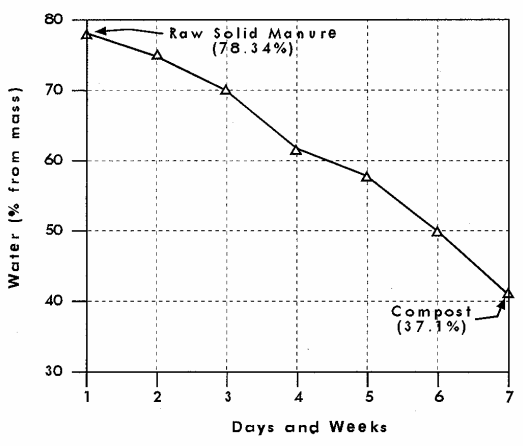


Figure 3. Water content changes in depositories during solid manure aerobic care

Changes of manure fertilising properties

At the beginning of aerobic care there was 21.66% or 173.48 kg m^{-3} dry matter in the total weight of crude solid manure. There was 97.22% or 168.66 kg m^{-3} organic and 2.78% or 4.82 kg m^{-3} mineral matter in dry matter weight.

During aerobic fermentation (Fig. 4), the amount of organic matter was decreased by 10.93% (18.43 kg m^{-3}), and at the same time mineral matter content was increased as much as that (10.93% or 18.96 kg m^{-3}).

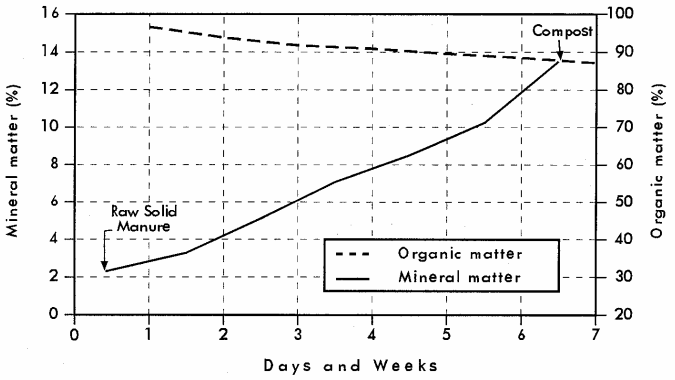


Figure 4. Mineral and organic matter content changes in the depository during solid manure aerobic care

Such mineralization of organic matter during aerobic fermentation increased total NPK contents by 3.76 times, i.e. from 15.9 to 59.4 kg m^{-3}; total N by 12.7 kg, total P by 13.6 kg, total K by 16.5 kg m^{-3} (Fig. 5).

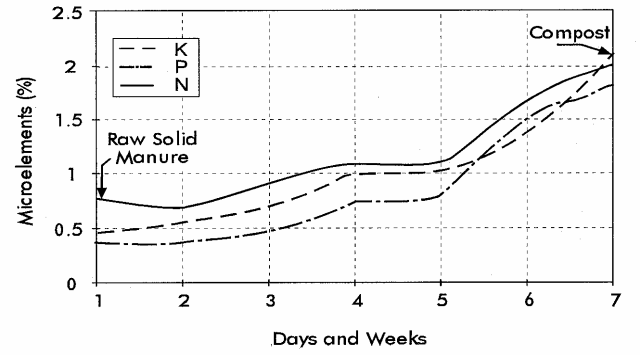


Figure 5. Macroelement content changes in depositories during solid manure aerobic care

In addition, aerobic fermentation increased available P content threefold, available K content twofold, while available N content was decreased twofold

due to evaporation caused by high temperatures in the course of thermophilic phase. In this phase of fermentation high temperatures also performed manure thermodisinsectization killing pathogens and germination ability of weed seeds that had reached manure through animals' intestines. Heavy metals such as Pb, Cd and As were found in traces (Tab. 2).

Table 2. Changes of manure fertilising properties during aerobic fermentation

Weeks of Care	Water (%)	Dry Matter		pH	Macroelements (%)						Heavy Metals (mg kg $^{-1}$)		
					Nitrogen		P_2O_5		K_2O				
		Min. Mat. (%)	Org. Mat. (%)		Total	Soluble	Total	Soluble	Total	Soluble	Pb	Cd	As
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	78.34	2.77	97.22	7.92	0.77	0.16	0.36	0.29	0.46	0.27	1.22	0.102	0
2	77.65	3.51	96.48	8.31	0.69	0.17	0.36	0.30	0.54	0.31	1.53	0.087	0
3	71.60	4.82	95.18	8.75	0.90	0.20	0.46	0.41	0.69	0.34	1.47	0.11	0
4	63.39	6.89	93.11	8.79	1.08	0.10	0.73	0.66	0.98	0.54	1.56	0.27	0
5	58.21	8.57	91.41	8.74	1.09	0.07	0.80	0.49	1.03	0.55	1.79	0.38	0
6	51.43	10.23	89.71	8.46	1.65	0.08	1.50	0.95	1.35	0.59	2.93	0.37	0
7	39.01	13. 71	86.71	8.31	2.04	0.08	1.79	1.16	2.11	0.61	3.23	0.15	0

Agroeconomic effects of manure aerobic fermentation

According to the total macroelement contents (Tab. 3, column 13), compost obtained by aerobic fermentation was by 3.7 times more valuable in both nutritive and cost-effective respect than manure obtained by aerobic process.

In addition, its looseness, lower volume, lower water content and volume (by 2.3 times) provided its easier and more uniform application to cultivated areas, lower energy input at application, and by 2.5 times lower transport costs as compared to compost obtained by anaerobic fermentation, whose volume rose even by 9.2% due to getting compact during fermentation.

Economic and organisational advantages of aerobic over anaerobic care were particularly in that that fermentation process was shortened by 5.7 to 7.4 times. This means that within the same area the depository can "recycle" by 5.7 to 7.4 times higher amounts of fresh solid manure, and can decrease the costs of a depository construction and maintenance as much as that, as well as decrease the size of surrounding area that is under threat by ecological consequences produced by fermentation and manure keeping in open air.

Table 3. Physical and nutritive properties of compost obtained by aerobic and anaerobic crude manure fermentation

Type of fermentation	Fermentation duration	Volume mass (kg x m^{-3})		Water content (%)		Macroelements in compost						
						N		P_2O_5		K_2O		Total NPK
		Raw manure	Compost	Before fermentation	After fermentation	%	(kg x m^{-3})	%	(kg x m^{-3})	%	(kg x m^{-3})	(kg x m^{-3})
1	2	3	4	5	6	7	8	9	10	11	12	13
Aerobic	42 - 49	800	350	78.34	39.01	2.04	71.40	1.79	36.26	2.11	73.85	181.51
Anaerobic	260 - 345	800	870	78.34	72.00	0.5	17.5	0.3	10.5	0.6	21.0	49.00

However, it should be pointed out that aerobic fermentation requires some extra investments in machinery for manure care which is not the case with anaerobic fermentation. Concerning much shorter cycle of compost production, its considerably higher nutritive value per unit weight, lower transport and application to cultivated areas costs, it is evident that equipment and manure aerobic care inputs cannot affect economic advantages of aerobic over anaerobic fermentation.

Conclusions

The results of experiments with crude solid manure aerobic care as compared to anaerobic care allow for the following conclusions:

- Crude solid manure was converted by aerobic care into fine, loose compost within the period of 7 weeks. Thus, the process of manure "maturing", as compared to traditional care, was shortened, on average, by 6 times.
- From both economical and ecological aspects, much more efficient utilisation of storage capacities for crude manure deposition and fermentation was achieved. In the thermophilic phase of aerobic care, manure was released

from pathogens and germination ability of weed seeds was destroyed by thermodisinsectization due to temperature rise even to 75°C.

- Finally, a considerable portion of organic matter was mineralized by aerobic fermentation, and along with changes of physic-chemical properties such as weight reduction, volume reduction, looseness increase, compost fertilising value was increased by 4 times, and as much as that economic effectiveness of its application to cultivated areas was achieved.
- Accordingly, aerobic fermentation of crude manure is a necessity in the technology of preparation and evacuation of manure from large farms to cultivated areas.

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UNAPREĐENE METODE TRETMANA GOVEĐEG STAJNJAKA

- originalni naučni rad -

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Rezime

U radu su prikazani rezultati istraživanja koje je sprovedeno na farmi sa 2000 muznih krava. Mešavina naturalnog čvrstog stajnjaka i slame strnih žita, u odnosu 1 kg slame sa 9 l ekskremenata, je izlagana aerobnoj i anaerobnoj fermentaciji. Praćene su promene temperature, zapremine, sadržaja vlage, sadržaja organske materije, pH vrednosti i sadržaja teškorastvorljivih makroelemenata u masi. Naturalni čvrsti stajnjak je aerobnom fermentacijom prevođen u kompost tokom nege u trajanju od 7 nedelja. Njegova zapremina se smanjila 2.3 puta, a sadržaj makroelemenata je opao 4 puta, u poređenju sa kontrolnim tretmanom dobijanja komposta anaerobnom fermentacijom stajnjaka. Time je postignuta značajno veća efikasnost i ekonomičnost proizvodnje komposta i njegove primene na poljoprivrednim zemljištima.