THE NUTRITIVE AND ECONOMIC EFFECTS OF AEROBIC TREATMENT OF SOLID MANURE

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Summary

The aerobic treatment of solid manure increases the content of total and easily available amounts of N, P_2O_5, K_2O by 3.76 times on average in comparison with raw solid manure, and makes the maturation time eight time as short, which is significant for several reasons. In this paper, we showed that the price of the substitution of compost derived from aerobic processing is 4.24 times as high in comparison with the price of the substitution of burnt manure derived through anaerobic processing. By applying different dynamic methods for the assessment of investments, a fact was established that investing in the purchase of a machine for the aerobic processing of manure is economically justified and financially acceptable for farms with 19 and more cows.

Key words: *Aerobic treatment, manure, effects, economic justification*

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Introduction

The procedures of the treatment of solid manure should solve the following problems: the problem of the recycling of pathogens present in animal excrements and bedding; the problem of the recycling of weed seeds resistant to physiological processes in the animal intestinal tract and the process of raw manure fermentation; the problem of the size of the space for the fermentation of raw manure and the storing of mature manure until it is used; the reduction in the consumption of energy for its treatment during fermentation, transport to and distribution on an agricultural plot.

Technical-technological solutions of the means and procedures of the aerobic treatment of manure generate the possibilities of the quick transformation of the present mineral and organic matter into forms easily available to plants. In that manner, the dynamics and intensity of exploiting mineral matters significantly increase. That is what makes the first significant factor of this form of treatment. The second aspect is observed in the significant shortening of the procedure of the maturation of manure, by reducing it from 260-345 days to approximately 45 days (Radivojević, 1993).

The aim of the research is to determine the nutritive values of compost derived from the aerobic treatment of manure as well as the economic effects of manure treatment, in two ways – through the growth of the compost value in comparison with compost derived from anaerobic processing as well as through the assessment of the economic effectiveness and financial acceptability of investing in the purchase of a machine for the aerobic processing of manure.

The material and the method

For the procedure of the aerobic treatment of manure, the self-propelled machine KOMPO MAT – 1, a prototype, was used. The treatment of manure was performed periodically, for the duration of seven weeks (49 days). The dry matter content in raw manure was 22% on average at the beginning. Raw manure was deposited onto the concrete plateau in prismatic piles 3 m wide and 0.8 m high. The length of the prisms is not substantially significant for the treatment. In that time period, each prism was treated 12 times. The work speed of the machine was changed in the interval from 0.1 to 0.7 km/h, (on the 70-m prism-length route, time was measured, and the movement speed was calculated). Raw manure (secretion and wheat straw in the 7lit.:1kg ratio) was formed in the stable in the channel for discharging manure. The initial properties of raw solid manure, whose total mass was 800 t at the moment when it was being introduced into the process of aerobic treatment, are accounted for in (Table 1.).

Table 1. Physico-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 (%)
78.34	2.77	97.22	7.72	0.77	0.36	0.46

During the aerobic treatment of manure, we observed changes in the content of mineral and organic matter in the manure mass; changes in the content of macro-elements; changes in the fertilization properties of manure; the physical and nutritive properties of compost derived from the aerobic and anaerobic fermentation of raw manure (Radivojević et al. 2002a, Radivojević 1996). In order to gain an insight into the economic effects of the aerobic processing of manure, first, the price of the substitution of the compost derived from the aerobic and anaerobic manners was calculated. For that purpose, appropriate mineral fertilizers and their market prices were used, in compliance with the methodology quoted by (Gogić 2009). Then (on the basis of differential calculations) appropriate indicators for the assessment of the economic effectiveness of investing in the purchase of a machine for the aerobic treatment of manure (the net present value, the internal rate of return, the payback period) were calculated for a different number of cows on the farm. Using the mentioned methods, we determined the smallest number of cows on the farm that economically justifies the purchase of the analyzed machine. The paper also analyzes the liquidity (financial acceptability) of this investment by comparing the net cash flow from investment and the amount of the annual annuity.

The results and discussion

During the aerobic processing of manure, a change in its fertilization properties occurred. At the beginning of aerobic treatment, there was 21.66% of dry matter in the total mass of raw solid manure. In the mass of dry matter, there was 97.22% of organic matter and 2.77% of mineral matter. The dry matter content in the amalgamated mass was 25% on average at the beginning of the procedure (Radivojević et al. 2002b). Aerobic fermentation reduced the amount of organic matter by 10.93% (Table 2), and, at the same time, increased the content of mineral matter by the same. Such mineralization of organic matter increased the total content of nitrogen, phosphorus and potassium 3.76 times (from 15.9 to 59.4 kg/m^3), i.e. increased the total nitrogen by 12.7 kg/m^3, total phosphorus by 13.6 kg/m^3, and total potassium by 16.5 kg/m^3 (Table 3).

Table 2. Changes of manure fertilizing properties during aerobic fermentation

Weeks of Care	Water (%)	Dry Matter		pH	Macroelements (%)					
		Min.mat. (%)	Org.mat. (%)		N		P_2O_5		K_2O	
					Total	Soluble	Total	Soluble	Total	Soluble
1	78.3	2.77	97.22	7.92	0.77	0.16	0.36	0.29	0.46	0.27
2	77.6	3.51	96.48	8.31	0.69	0.17	0.36	0.30	0.54	0.31
3	71.6	4.82	95.18	8.75	0.90	0.20	0.46	0.41	0.69	0.34
4	63.3	6.89	93.11	8.79	1.08	0.10	0.73	0.66	0.98	0.54
5	58.2	8.57	91.41	8.74	1.09	0.07	0.80	0.49	1.03	0.55
6	51.4	10.23	89.71	8.46	1.65	0.08	1.50	0.95	1.35	0.59
7	39.0	13.71	86.71	8.31	2.04	0.08	1.79	1.6	2.11	0.61

Apart from that, aerobic fermentation also increased the content of easily available phosphorus by three times, easily available potassium by two times, while the content of easily available nitrogen was reduced by two times, because of the evaporation conditioned by high temperatures during the thermalphilic stage (Table 2). During the conducting of the process of treatment, differences in changes of the most important parameters of composting, such as the physical and nutritive changes in the mass aerobically treated and the mass not subject to aerobic treatment (control) (Table 3), were monitored.

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

Type of fermentation	Fermentation duration	Volume mass (kg /m³)		Water content (%)		Macroelements in compost						
		Raw manure	Compost	Before fermentation	After fermentatio	N		P_2O_5		K_2O		Total NPK
						%	(kg/m³)	%	(kg/m³)	%	(kg/m³)	(kg/m³)
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	0.4	17.5	10.5	10.5	0.6	21.0	49.00

To determine the values of the compost derived from the aerobic and anaerobic methods, we used the substitution price method. The nutrient matters contained in the compost (nitrogen, phosphorus and potassium) were assessed pursuant to their substitution price from mineral fertilizers. Simultaneously, the market prices for mineral fertilizers as of April 2012 were used for that purpose (Table 4). On the basis of these initial data, as well as the data presented in (Table 2, the substitution price for 1 ton of compost derived from aerobic processing (Table 4) and anaerobic processing (Table 5) was fixed. The initial data as well as the data presented in Table 2 fixed the substitution price for 1 ton of compost derived from aerobic processing (Table 5) and anaerobic processing (Table 6). On the basis of the result in Tables 5 and 6, we can conclude that the substitution price for compost derived from aerobic processing is by 4.24 times as high as the substitution price for compost derived from anaerobic processing. However, in order for us to gain a complete and full insight into the economic effects of the aerobic processing of manure, it is needed that we should gain an insight into costs incurred in that way, too, not just an income growth.

Using the data accounted for, differential calculations for the purchase of a machine for the aerobic processing of manure, and for cattle farms of different sizes (15, 20 and 25 cows), were made. For each farm size, the differential calculation was made as per individual years (for a seven-year time period), which was the basis for determining the economic effectiveness and financial acceptability of investing in the purchase of the observed machine.

Table 4. The types and properties of mineral fertilizers for substitution

Type of fertilizer	Content of nutritive matter (%)	Fertilizer price (EUR/kg)
Nitrogenous (UREA)	46	0.46
Phosphate (0:20:0 Fertil)	20	0.35
Potassic (Potassium sulfate)	50	0.94

Table 5. The substitution price for 1 t of compost derived from aerobic processing

Type of nutritive matters	Content of nutritive matters in 1 t of compost (kg)	Needed amount of mineral fertilizers for substitution (kg)	Price of fertilizer (EUR/kg)	Substitution price for 1 t of compost (EUR)
Nitrogen	20.40	44.35	0.46	20.40
Phosphorus	17.90	89.50	0.35	31.33
Potassium	21.10	42.20	0.94	39.67
Total substitution price for 1 ton of compost				91.39

Table 6. The substitution price for 1 t of compost derived from anaerobic processing

Type of nutritive matters	Content of nutritive matters in 1 t of compost (kg)	Needed amount of mineral fertilizers for substitution (kg)	Price of fertilizer (EUR/kg)	Substitution price for 1 t of compost (EUR)
Nitrogen	5.00	10.87	0.46	5.00
Phosphorus	3.00	15.00	0.35	5.25
Potassium	6.00	12.00	0.94	11.28
Total substitution price for 1 ton of compost				21.53

The economic effectiveness of the investment was determined by using the net present value method, the internal rate of return method and the payback method. These methods are the most significant ones in the theory and practice of assessing long-term investments. In case these methods generate opposite results when opting for one of several alternative investments, a priority should be given to the net present value method since (Andrić et al 2005) multiple internal rates of return, bearing no practical significance, can be calculated. As it is stated (Đuričin 2006), the net present value can be accounted for "via a difference between the current value of cash inflows and the current value of cash outflows".

In order to determine the costs of the machine's work for the aerobic processing of manure, as well as in the case of the determination of the economic effectiveness of investing in the purchase of a machine, the following parameters were considered at the beginning: The value of the machine is at 36,000 EUR; The machine's liquidation value is at 3,000 EUR; The usage life of the machine is 7 years; The consumption of fuel (Diesel D-2) is 9 liters per one working hour; The price of the diesel fuel is 1.4 EUR/l; The consumption of lubricants is 5% of the fuel value; The cost of work of a worker is 3.41 EUR/hour; The annual costs of the technical maintenance of the machine are estimated at 12% of the purchase value of the machine; The annual costs of accommodation are at 0.5% of the purchase value; The machine insurance costs are determined in accordance with the legal regulations of the mandatory insurance of agricultural machines at their registration; The annual amount of depreciation is calculated by using straight-line method; The costs of interest per individual years are determined under the conditions of the purchase of the machine for the aerobic processing of manure, financed 50% from equity and 50% from a loan; The loan repayment term is 7 years, the interest rate is 12%, and the loan is repaid in equal annual annuities; For a part of own funds (equity), there is a projection of the interest rate at the amount of opportunity costs (a 5% interest rate on savings deposits with banks); On the basis of the manners and conditions of financing, an 8.50% weighted average cost of capital (WACC) discount rate used for the assessment of the economic effectiveness of an investment by means of dynamic methods is determined; Incomes generated by the purchase of the machine are determined as a difference between the value of compost derived from aerobic processing (after the purchase of the machine)

and compost derived from anaerobic processing (prior to the purchase of the machine); When prices for mineral fertilizers are fixed, incomes from the purchase of the machine depend on number of cows on the farm.

The net present value method justifies the investment on condition that the stated indicator is higher than zero. It can be observed that, when there are 15 cows on a farm, the investment is not economically justified, whereas on a farm with 19 cows, the net present value is equal to zero, which means that this number of cows is the bottom line of economic acceptability for the purchase of the stated machine. On farms with 20 and more cows, the net present value is higher than zero, so the investment in the purchase of the analyzed machine is economically justified (Graph 1.)

**Graph 1.** The net present value for a different number of cows on a farm
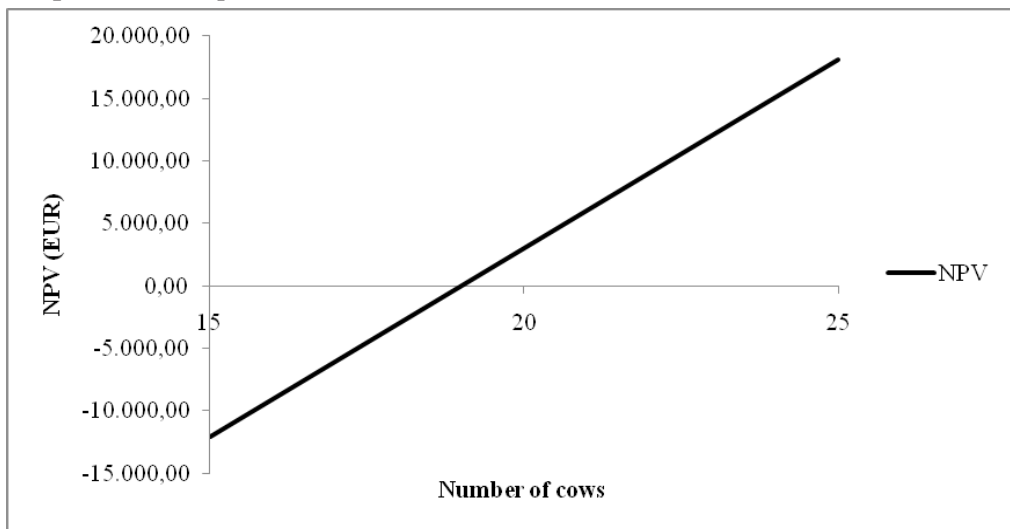
The same conclusion is also reached when applying the internal rate of return, whose amount is compared with an appropriate discount rate (WACC), which, in this case, is 8.50% (Graph 2.). The investment is economically justified if the internal rate of return is higher than the discount rate. It can be observed that, when the purchase of the analyzed machine is concerned, the internal rate of return is equal to the discount rate for the farm size of 19 cows, i.e. it is the point of the economic effectiveness of the investment, which matches the solution generated by the net present value method.

Graph 2. The value of the internal rate of return for a different number of cows
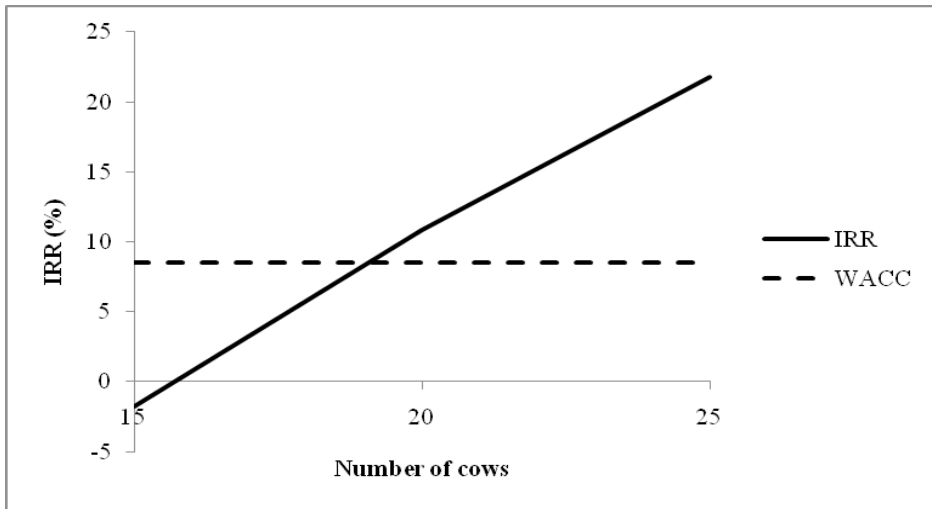
The payback period is considered to be an ancillary method which, in a certain way, expresses the risk of long-term investments (Jackson and Sawyers, 2003), and its results are accounted for in (Graph 3.).

Graph 3. The payback period of the investment for a different number of cows on a Farm
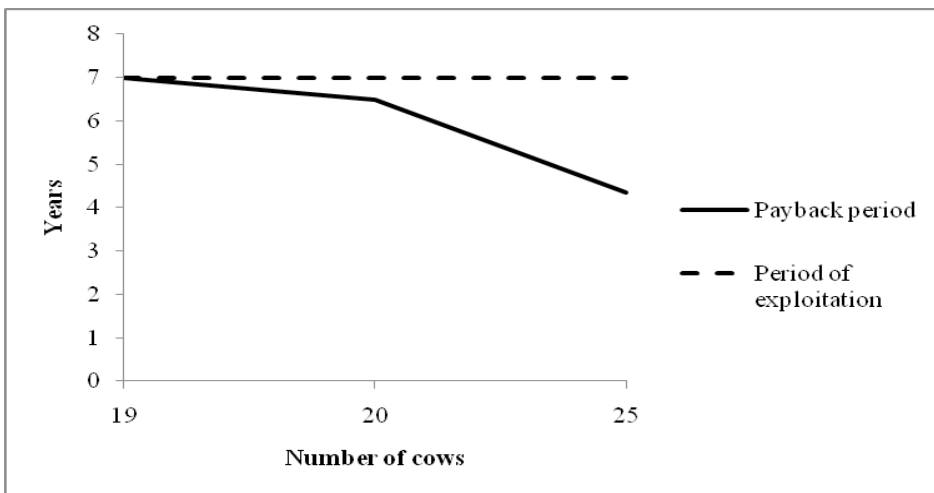

Having in view the results generated through the previous methods, it is obvious that the payback period of the investment for farms with fewer than 19 cows is longer than the time period of its exploitation (7 years).

If there are 20 cows on a farm, the payback period is 6.48 years, whereas on farms with 25 cows, the payback period of the investment is 4.36 years. The investment is liquid (financially acceptable) if its financial benefit is more than zero (Graph 4.). At the same time, a financial benefit is defined as a difference between the net cash flow from an investment and the annual annuity for loan repayment.

Graph 4. The amount of the financial benefit from the investment for a different number of cows on a farm
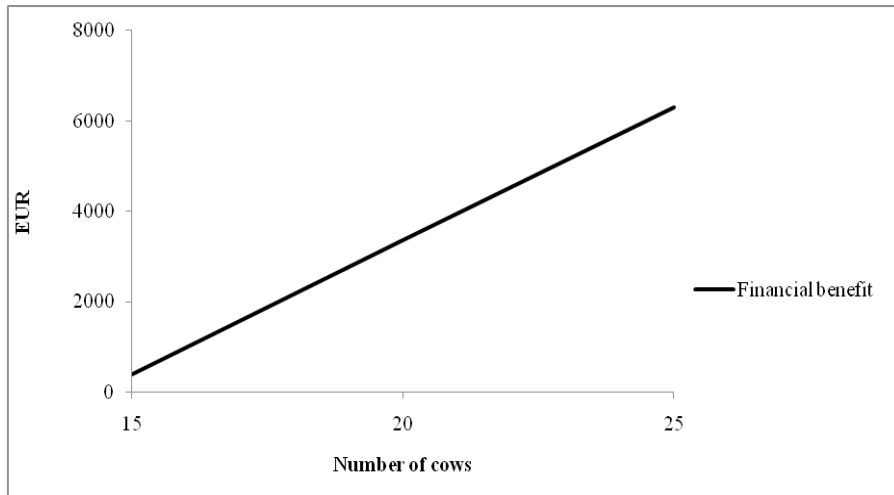
It can be observed that the financial benefit from the investment for all observed sizes of a farm is above zero, i.e. the investment is financially acceptable. It is the case even with those farms where there are fewer than 19 cows, which means that even suchlike farms would be able to pay back a loan for the purchase of the analyzed machine, although their purchase of the machine would not economically be justified. This is the case because the purchase of the machine has been assumed not to be made fully from the loan, and that only 50% of its value is financed in this way.

It is important to know that it is possible to pay back a loan for the machine because Petrović et al. (2011) determined that most of the farmers consider financing as the most significant barrier for purchasing of machinery. On the other hand, on the basis of research of family dairy farms, Ivanović et al. (2008) concluded that farms which have the biggest total investments in contemporary technical and technological systems achieve more favorable business results. But such investments are impossible without favorable (subsidized) loans.

Conclusion

The analysis of the aerobic processing of manure by means of an appropriate machine (prototype) for that purpose revealed that the process of the aerobic processing of

manure lasts for seven weeks, which is several times as fast as classical anaerobic processing. Also, it was determined that, during aerobic fermentation, and compared with raw solid manure, there is an increase in the total content of nitrogen, phosphorus and potassium 3.76 times. The paper reveals that the substitution price for compost derived from aerobic processing is 4.24 times as high as the substitution price for compost derived from anaerobic processing.

By applying different dynamic methods for the assessment of investments, a fact was established that investing in the purchase of a machine for the aerobic processing of manure is economically justified and financially acceptable for farms with 19 and more cows. So, on a farm with 20 cows, the payback period is 6.48 years, and, if a farm has 25 cows, the payback period is only 4.36 years (while the exploitation life of the machine is 7 years).

Acknowledgements

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NUTRITIVNI I EKONOMSKI EFEKTI AEROBNE NEGE ČVRSTOG STAJNJAKA

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Rezime

Aerobnom negom čvrstog stajnjaka povećava se sadržaj ukupnih i lako pristupačnih količina N, P_2O_5, K_2O, u odnosu na sirovi čvrsti stajnjak prosečno za 3,76 puta, a vreme dozrevanja skraćuje osam puta što ima višestruki značaj. U radu je pokazano da je cena zamene komposta dobijenog aerobnom obradom 4,24 puta veća u odnosu na cenu zamene zgorelog stajnjaka dobijenog anaerobnom obradom. Primenom različitih dinamičkih metoda za ocenu investicija utvrđeno je da je investicija u nabavku mašine za aerobnu obradu stajnjaka ekonomski opravdana i finansijski prihvatljiva za farme koje poseduju 19 i više krava.

Ključne reči: *Aerobna nega, stajnjak, efekti, ekonomska opravdanost*

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