

TECHNOLOGIES AND TECHNICAL EQUIPMENT FOR VERMICOMPOST PRODUCTION

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Abstract. The production and use of biohumus is addressed to farmers who own livestock farms, and also to those who have vegetable farms: vegetables, orchards, greenhouses, wineries, etc. and have access to animal manure from other livestock farms. Composting is biological decomposition of biodegradable solid waste under controlled conditions in a state that is sufficiently stable to allow trouble-free storage and handling and that is satisfactorily matured for safe use in agriculture. Biohumus (earthworm compost) or earthworm is a pure natural microbiological organic fertilizer, having no preservatives in its composition, resulting from a mixture of manure and biological waste produced by earthworms. Due to its special composition (it has a large proportion of all the elements that plants need), it can be used in many fields of activity: horticulture, forestry, vegetable growing. When mineral fertilizers are not available or are too expensive, compost is the most important source of plant nutrients and soil condition. The use of the biohumus loosening plant aims to adjust the natural decomposition process, ensure good conditions for the composting process, especially air (oxygen), water, and a good composition of the material introduced into the piles, and monitor them for getting a quality product. Obtaining quality biohumus requires the application of a technology that establishes all the necessary steps to be completed. In this sense, within INMA, two installations necessary in the process of obtaining biohumus were substantiated, designed and realized: the biohumus loosening plant and the IPB biohumus production plant (vermicompost). This paper will present the results of the experiments performed with technical equipment for obtaining biohumus: the IAB biohumus loosening plant and the IPB biohumus production plant.

Keywords: compost, loosening equipment, composting in piles, vermicompost.

Introduction

Vermicomposting is a biological process that uses earthworm activity to break down organic materials (usually waste) into a humic product – known as vermicompost. The main goal of vermicomposting is to process the material as quickly and efficiently as possible.

An important role in the development of sustainable agriculture is the conservation and maintenance of the natural fertility of the soils. Nicolas Bernier and Jean-François Ponge stated in 1994 that “the essence of the biological circuit of matter is that it ensures permanent resumption of the process of life, giving the soil an essential characteristic, which distinguishes it from the rocks from which it came, namely fertility” [1].

When mineral fertilizers are not available, or they are too expensive, compost is the most important source for providing plant nutrients and soil conditioning [2-4]. Many people today appreciate compost as a natural source of nutrients and humus. An organic farmer has to be interested in vermiculture and/or vermicomposting technology because [5]:

- vermicompost generally appears to be superior to conventionally produced compost in other several alternative ways;
- vermicompost is far superior to common compost;
- earthworms have a number of other possibilities for using on farms and are valuable even as high-quality animal feed;
- vermicomposting and vermiculture offer potential for organic farmers as additional sources of income.

Biohumus may be employed in a variety of industries, including horticulture, forestry, and vegetable growth, due to its unique composition, which contains a high proportion of all the components that plants require. Farmers can achieve incredible results by using a fertilizer that contains 5% humus (10 to 20 percent is considered ideal) [6].

Working with earthworms may be a more complicated process than traditional composting because:

- more resources, either financial (to acquire earthworms) or time and effort (to cultivate them), are required at the start of the process;
- the technology for obtaining vermicompost is much more vulnerable to environmental pressures, such as freezing and drought conditions;
- more work is generally needed to make the process work faster;
- more space is also needed to obtain vermicompost (because earthworms feed on the surface and will not operate in the material more than one meter deep).

The final product called compost must not be harmful in any way to nature, must not contain hazardous compounds such as heavy metals, and the decomposition process must be almost complete.

It has been scientifically proven that vermicomposting eliminates the need for thermophilic composting (processing at high temperatures), because that earthworms feed on pathogens and effectively clean potentially harmful material, making it safe to handle. The authors talk about the “elimination of the pre-composting phase”, a process that many believe to be necessary to sanitize the material even before vermicomposting. The research confirms that earthworms greatly reduce biosolid pathogens during vermicomposting, making pre-composting unnecessary [7].

Compost Science & Utilization (2001, Vol. 9, Issue 1) contains the reference publication “The efficacy of vermiculture in reducing human pathogens for the stabilization of USEPA biosolids”. The publication presents a study that confirms the effectiveness of earthworms in removing human pathogens from biosolids (wastewater residues) to obtain Class A stabilization, the highest rating of USEPA, an indication that confirms the fact that the material has been safely secured, being free from harmful organisms.

Monitoring the composting process is a very important action to provide the optimal conditions in the pile in order to obtain a good and useful final product, namely, compost [8; 9]. For producing quality bio-humus requires the application of a technology that establishes all the necessary phases that must be completed. In this paper, two installations needed in the process of obtaining biohumus are presented: the biohumus loosening equipment and the biohumus production plant (vermicomposting installation), that were designed and produced within a research and innovation project by INMA Bucharest Institute.

Materials and methods

Figures 1 and 2 show the two installations made and tested within INMA Institute [10; 11].

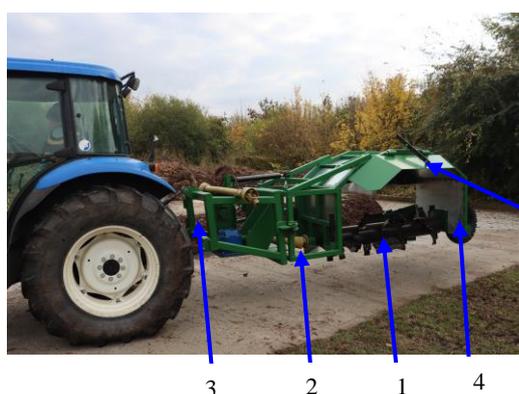


Fig. 1. IAB biohumus loosening equipment [10]: 1 – rotary drum IAB1.0; 2 – support frame IAB2.0; 3– towing support IAB4.0; 4 – side wheel IAB6.0; 5 – steering blade IAB11.0

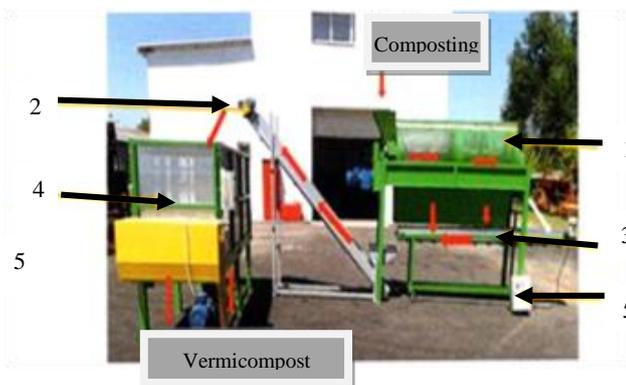


Fig.2. Biohumus production equipment (Vermicompost production) [11]: 1 – cylindrical sieve SC0; 2 – convex conveyor belt TIB-0; 3 – belt conveyor TB0; 4 – vermicompost system SV0; 5 – electric panel TE0

The experimental model, the IAB biohumus (vermicompost) loosening plant here is presented in Fig.1, it is designed for a faster and better-quality production of biohumus. The plant allows operation in variable temperature range and humidity conditions, both in summer and winter for loosening-production of compost, necessary to be used in the vermicompost technology. Loosening accelerates the

decomposition process – slow fermentation of various plant and animal waste, mixed with some mineral substances, which are located on a concrete platform.

The IPB biohumus (vermicompost or earthworm) process is presented in Fig. 2. Position 1 shows the SC0 cylindrical sieve, which is part of the IPB biohumus (vermicompost) production plant, its role is to sort the compost fractions resulted from organic matter decomposition of raw material mixed from various sources – animal manure, crop residues, residues from the meat industry and the wine industry, waste. The interphase transportation is performed with the use of belt conveyors. The vermicompost system SV0 from Fig. 2 – position 3, shows a metal construction provided at the bottom with a grate and the vermicompost scraping system (compost subjected to the action of earthworms).

The drum IAB-1.0 depicted in Fig.3 is a component part of the IAB biohumus (vermicompost) loosening plant and represents the active organ of the equipment.

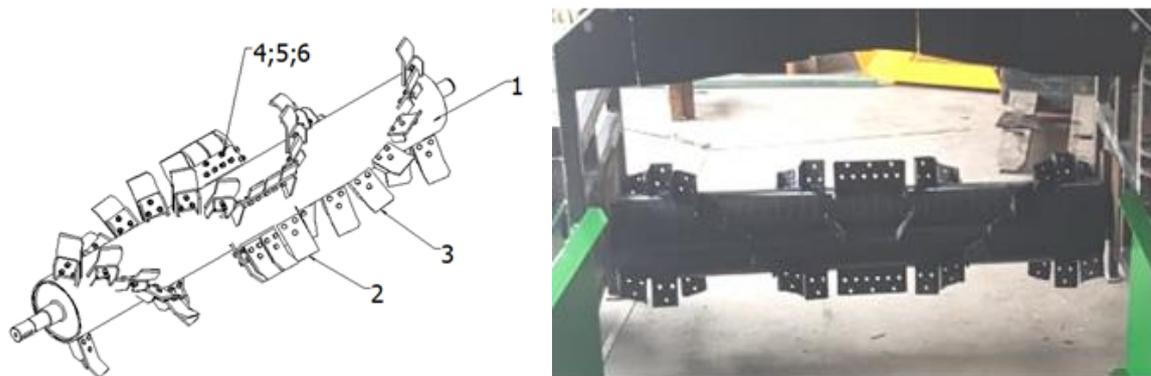


Fig. 3. **Rotary drum IAB-1.0:** 1 – drum body; 2 – type 1 knife;
3 – type 2 knife; 4, 5, 6 – assembly elements

The loosening equipment produces a thinner, less compacted and crushed granular material. The module has to be attached to the tractor before conducting operations through the cardan shaft and the gear unit situated on the system. The speed received from the tractor is multiplied by the gear unit and transmitted to the drum. The module is positioned on the side of the tractor so as to cover the entire compost line. When moving the tractor forward, the equipment also moves and its operation produces accelerated loosening of the composting line and also shreds the compost components. The equipment is brought to the transport position (along the tractor) while driving. The installation is equipped with a water spray nozzle, for the case when the compost is dehydrated and needs moisture [10].

The compost obtained after loosening the organic matter is introduced into the feeding hopper that feeds the cylindrical sitz using the inclined conveyor with the belt TIB. The cylindrical sieve is equipped with a rotating brush cleaning system. The screened material passes through a circular sieve and then reaches the discharge funnel, while the refuse is removed through another refuse discharging funnel.



Fig. 3. **SV-0 Vermicomposting system**

The screened material is subsequently fed into the vermicompost system using a TIB inclined belt conveyor.

Under the action of the earthworms found at the bottom of the vermicompost system (which will have an upward movement) the compost will be transformed into vermicompost. As the earthworms

move to the upper part of the container, the scraping knife electrically operated found at the bottom (which is part of the vermicompost system) performs the evacuation (when scraping the sieve surface) thus producing biohumus. The present paper will present the results obtained with an experimental biohumus production equipment designed and executed by the INMA institute.

The following relationships were used to determine the functional parameters in the load:

Power transmitted through the PTO (power take-off), P_p , can be calculated using the following relation:

$$P_p = M_p \cdot \omega_p \cdot 10^{-3}, \text{ kW} \quad (1)$$

where M_p – PTO shaft torque, Nm;

$$\omega_p = \frac{\pi \cdot n_p}{30} \text{ – PTO shaft angular speed, rad} \cdot \text{s}^{-1};$$

n_p – PTO speed, rpm.

The power required to tow the installation on the horizontal ground P_t , can be calculated with the relation:

$$P_t = F_t \cdot V_l \cdot 10^{-3}, \text{ kW} \quad (2)$$

where F_t – traction force is measured at the coupling bar, N.

V_l – equipment working speed (movement), $\text{m} \cdot \text{s}^{-1}$.

Total power P_{tot} , for towing and operating the working organs was calculated with the equation:

$$P_{tot} = P_p + P_t = \left(M_p \cdot \frac{\pi \cdot n}{30} + F_t \cdot V_l \right) \cdot 10^{-3} \text{ kW} \quad (3)$$

Results and discussions

The IAB biohumus (vermicompost) loosening plant experimentation phase has been performed within the INMA institute experimental platform, Ecological Plant for Vegetal and Animal Waste Management – SEG, as can be seen in Fig. 4 [10].



Fig. 4. Ecological Plant for Vegetal and Animal Waste Management – SEG [10]

Fig.5 depicts several images from the experimentation phase conducted with the designed composting equipment on the ecological waste management platform.

The composting plant has the following constructive and functional characteristics:

- useful width of the drum equipped with knives, 2000 mm;
- drum diameter, 270 mm;
- diameter of the drum with attached knives, 600mm;
- 48 knives;
- 14 knives type 1;
- 34 Knives type 2;
- drum speed, 194 rpm;
- transport length, ~ 2.620 m;
- width while working, 4.405 m;
- installation height, 1.600 m.



Fig. 5. Images during the experimental phase using the IAB equipment [8]

In order to determine the most effective compost recipes, 2 types of mixtures were tested as follows.

Recipe No. 1:

- shredded sweet sorghum stalks;
- chopped apple waste;
- chopped vegetables (waste tomatoes and peppers from the greenhouse);
- waste from a poultry farm;
- onion leaves and deciduous leaves.

Recipe no. 2:

- shredded sweet sorghum stalks;
- chopped apple waste;
- waste from a poultry farm;
- wood material from the grooming of fruit trees.

The tables below describe the test results obtained in the experimental phase. The Tables 1-4 and Fig. 6 below show the chopped results obtained from the tests performed with the IAB installation. As the IAB plant is a machine required by major compost manufacturers, the tests specifically looked at the machine operating indicators and less compost process indicators. Table 1 describes the characteristics of the raw material made using recipe 1 in the composting process.

Table 1

Characteristics of the raw material (recipe 1) used in the experiments [12]

Parameters	Obtaining compost/Characteristics
Environment	Aerobic (with air)
Frequency of pile return	Temperature method; the piles returned if the temperature dropped at values between 40 °C and 30 °C
Temperature	44 °C
Humidity	Optimal according to the analyzes based on the fist test
Degree of decomposition	Degree of decomposition III: ($T_{max} = 40-50\text{ °C}$)
Water content	43% WS
pH value	8.5 (slightly alkaline)
Volume of airless material	40% (the volume of the gaps in the pile depends on the composition of the material introduced)
Proportion C: N	33

Table 2

Main operating parameters of the engine in idle operation mode

Parameters	units	Probes			
		Idle operation at the stationary operating mode			
		P.I	P.II	P.III	Average
Tractor engine speed, M_n	rpm	1853	1850	1850	1851
Power take - off (PTO) speed, n_p	rpm	556	555	555	555.3
(PTO) Power take – off momentum, M_p	daNm	7.75	7.70	7.75	7.73
Coupling bar traction force, F_T : - without towed equipment - with towed equipment	daN	- -	- -	- -	- -
Tractor pressure force, F_{ap}	daN	255	256	255	255.3
Actual power at the power take-off, P_{pef} .	kW HP	5.90 8.02	5.60 7.61	5.90 8.02	5.8 7.88
Actual power for towing equipment: P_{tef} - without towed equipment - with towed equipment	kW HP	- -	- -	- -	- -

Table 3

Qualitative and functional parameters with load - operating conditions

Parameters	units	Probes/ recipe 1			
		Operation on workload			
		Probe I	Probe II	Probe III	Average
Tractor engine speed, M_n	rpm	1813	1813	1812	1812,66
Power take – off (PTO) speed, n_p	rpm	544	544	543	543.66
Power take – off (PTO) momentum, M_p	daNm	46.3	46.8	46.5	46.3
Traction force at the coupling bar, F_T : - with towed equipment	daN	750	750	750	750
Pressure force on the tractor, F_{ap}	daN	355	354	356	355
Actual power at the power take-off, P_{pef} .	kW HP	28.24 38.39	28.56 38.83	28.44 38.67	28.41 38.63
Actual power for the towing equipment: P_{tef} - with towed equipment	kW HP	13.65 18.55	13.65 18.55	13.42 18.24	13.58 18.45
Total actual power for towed equipment while working, P_{tot}	kW HP	41.89 56.95	42.21 57.39	41.86 56.91	41.99 57.09
Working speed, V_l	$m \cdot s^{-1}$	6.1	6.1	5.9	5.96
Capacitate working capacity, W_{ef}	$t \cdot h^{-1}$	7.6	7.9	8.1	7.9
Working speed, V_l	$m \cdot s^{-1}$	5.8	6.1	6.3	6.1
Effective working capacity, W_{ef}	$t \cdot h^{-1}$	7.6	7.9	8.1	7.9

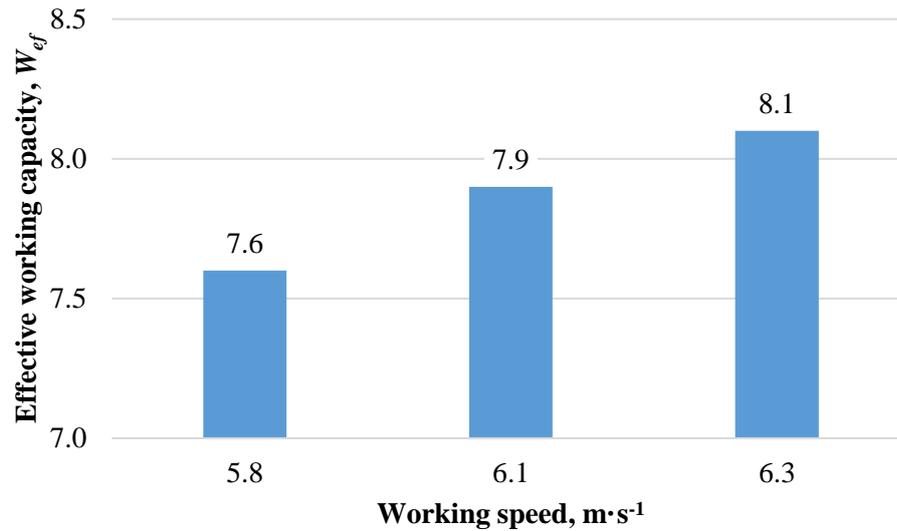


Fig. 6. Variation of operating indices according to the working speed

Table 4

Qualitative work indices

No.	Specification	U M	Values- Recipe 1/Recipe 2			
			Probe I	Probe II	Probe III	Average
1	Knife 1 rotation	rpm	194/194	194/194	194/194	194/194
2	Knife 2 rotation	rpm	194/194	194/194	194/194	194/194
3	Working width	mm	2002	2001	1999	2000.6
4	Degree of shredding	%	85/79	87/81	85/78	85/79.3
5	Loosening depth	mm	600/588	600/591	600/595	600/591.3
6	Compost pile interior temperature measured in center pile, <i>T</i>	°C	46/42	45/41	46/43	45.66/42
	Decomposition rate	°C	III (<i>T</i> _{max} = 40-50 °C)			
7	Compost moisture	%	Optimal according to the fist-test analysis			
8	Glass, plastic	%	0.43/0.40	0.46/0.48	0.41/0.47	0.43/0.45
	Remarks [10]		> 2 mm is maximum of 0.5% of the dry matter mass			
	Vegetable waste (>2 mm)	%	0.48/0,7	0.50/0.6	0.45/0.7	0.48/0.66
	Remarks [10]		> 2 mm is maximum of 0.5% of the dry matter mass			
	Stones	%	0.5/0.6	0.6/0.8	0.4/0.4	0.5/0.6
	Remarks [10]		the stone content will not exceed 5% by mass			
	Metal	%	0.12/0.3	0.1/0.25	0.08/0.31	0.1/0.29
	Remarks [10]		> 2 mm is maximum of 0.5% of the dry matter mass			

Analyzing the results presented in the tables above, the following deductions can be made:

- Temperature is the most important value to be monitored during the composting process, as it can be very easily measured and shows the progress of the process. Decomposition of organic matter as a result of the microorganism activity is the reason for the temperature variation in the compost pile. Microorganisms have the ability to self-heat, heat release taking place differently depending on where the process takes place, either in the center of the pile or in the extremities.
- Being a very important indicator in the composting process, the temperature in the center was measured in at least 3 places in the pile length.
- Outdoor temperature is also important because it significantly influences the variation of indoor temperature.

- According to German regulations [13] the quality of the compost was divided into 5 phases depending on the decomposition rate and the maximum registered temperature (T_{max}). These phases are: decomposition rate I at $T_{max} = 60-70$ °C; decomposition rate II at $T_{max} = 50-70$ °C; decomposition rate III at $T_{max} = 40-50$ °C; decomposition rate IV at $T_{max} = 30-40$ °C; decomposition rate V at $T_{max} = 20-30$ °C. If the maximum temperature is below 40 °C, the compost is ready for use (according to literature). In our situation, the compost with the third degree of decomposition phases is called fresh, unfinished compost.
- Loosening depth is influenced by the decomposition rate and the raw material composition · m³ material recipe. This conclusion is drawn regarding the results when recipe 2 is used, where integrated chopped wood material, derived from the grooming of fruit trees/trees, plant residues (larger than 2 mm) and at the end were observed their presence in the compost mass.
- The experimental model of the composting plant fulfills the work indicators established by the project.
- The installation was designed and built according to the requirements of the economic agent who owns a biohumus producer company, which validated the information in practice for similar recipes.

Conclusions

Based on the results obtained in the experimental study, the following conclusions can be drawn:

1. The IAB installation is a machine that realizes through the working organ-drum with knives deep loosening of the compost pile and also chopping of the wood residues from the compost recipe.
2. It was found while working with the installation that the degree of loosening is influenced by the following indicators: indoor temperature in the compost pile; compost moisture; compost components and the degree of rot.
3. Temperature is the most important value to be monitored during the composting process, as it can be very easily measured and shows the progress of the process. The difference in temperature between the core of the pile and the surrounding temperature is attributed to the breakdown of organic waste as a result of microbe activity, related to their capacity to self-heat. The temperature curve also goes hand in hand with the processes of mineralization and decomposition.
4. The entire volume and the volume of the pile reduce during the composting process. The particle size reduces as a result of abrasion by other materials and maceration. As a result, the overall volume of the pile decreases and its density rises.
5. A number of variables impact the compost quality and, by extension, the decomposition process. The speed of the decomposition process is influenced by these factors and their interactions. These process variables assist in the monitoring and management of the composting operation.

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