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ALTERNATIVE UTILIZATION OPTIONS IN MULTI-FUNCTION COMPOSTING TECHNIQUES

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Abstract

Composting is a long-known and used process to treatment of biodegradable (and thus recyclable) waste containing organic materials. Here we undertake to review and analyse specific compost types, which could be used in multifunctional way due to the nature of mature compost or the composting process.

Keywords

Heating energy production, biogas production, water treatment, microbiological treatment system

1. Introduction

Composting is a microbiological process that depends on the optimum activity of mixed populations of mesophilic and thermophilic bacteria's and ultimately provides a substance that can be used for soil improvement or fertilization [1]. Compost can be considered as an organic fertilizer which is made from solid and liquid organic materials of animal or vegetable origin, in directed degradation processes [2]. To successfully complete the process, mixed "vaccine" with the composted materials containing microorganisms (various bacteria or fungi). The degradation process has the role of anaerobic and aerobic microbe populations. Biodegradation of organic matter of compost is carried out by these microorganisms (Table 1) [2]. At the end of the composting process, mature compost production ended. That means the particles (with a size smaller than 25 mm) contains at least of 90% by weight of the mature compost. [3].

Due to various physical, chemical and microbiological characteristics, the composting process produce mature compost. These indicators are paramount importance for the process. Sometimes these are not most ideal, so regulation required [4]. More parameters could be change easily (such as temperature, water contaminant, diversity of microbiological species) [5]. These physical and chemical parameters have priorities during the composting process [6]:

Table 1. The main bacterial and fungus species of composting processes (Source: De Corato et al., 2018, [3])

Bacterial species	Fungus species
Aerobacter (aerogenes)	Thermomyces lanuginosus
Pseudomonad sp.	Thermoascus aurantiacus
Flavobacterium sp.	Mucor pusillus
Micrococcus sp.	Mucor miehei
Sarcina sp.	Humicola insolens
Cellumonas folia	Talaromyces duponti
Mycococcus virescens	Chaetomium thermophile
M. fulvus	Sporotrichium thermophilum
Thibacillus thiooxidans	Myriococcum albomyces
Thermomonospora fusca	Saccharomyces sp.

1. Physical parameters:
 – Temperature (15-70°C)
 – Respiration coefficient (CO_2/O_2 proportion)
 – Temperature–oxygen consumption (linear correlation)
 – Water contaminant and temperature correlation
 – Airways and porosity correlation (inverse correlation)
2. Chemical parameters:
 – Proportion of water and degradable dry matter content (10:15)
 – Amount of ∑ Nitrogen (0,5-2,5 %)
 – Amount of ∑ Organic matters (10-25 %)
 – Proportion of C and N (C/N) (10:30)
 – Water soluble organic matter content (0-120 mg/g)
 – CO_2 production speed (30-100 ml/kg/h)
 – NO_3-N (0-700 ppm), and NH4-N (0-5000 ppm) contents
 – pH value (5,0-8,0)

Maintaining the conditions of composting is the most important key issue. If all the physical, chemical and microbiological parameters are correct, the composting process is shown in the following sematic diagram (Figure 1) [7].

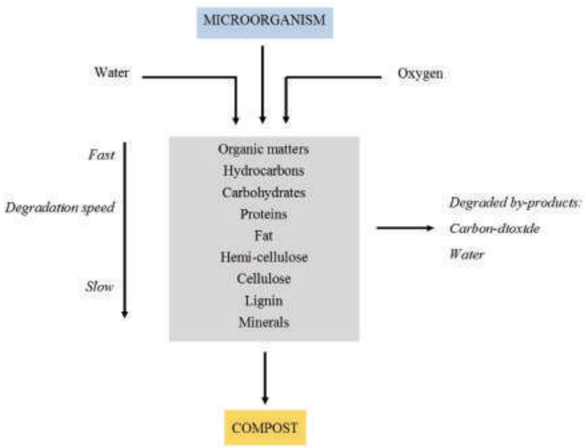

Figure 1. Tha main biochemical processes during composting phases (Based on Wang et al., 2018, [7]; Authors own edition)

The composting process could be divided into four main phases (initial, thermophilic, transformation and maturation phase). The first stage is introductory-initial phase [8]. In this phase, the mesophilic temperature range is typical. It can be traced to growth of microbes, increasing organic acid content and the consequent decrease in pH value. The second (thermophilic) phase begins with a steady increasing temperature [9]. The most important at this stage the temperature of compost rises above 50°C, and could reach up to 70-75°C value. Another important feature of this thermophilic phase is the partial decomposition of cellulose and hemicellulose matters [10]. The pH value rises and reaches the alkaline range. The thermophilic phase takes 2-5 weeks. As a result of continuous degradation, reduced the amount of nutrient and temperature [10][11]. At this time, the third (transformation) phase begins, which occurs in the mesophilic temperature range at 40-45°C value. At this stage, the lignin compounds are broken down. As a result of a further decrease in temperature, the fourth (maturing) phase begins. This pahse is the final composting process. Humic substances formed into hymen fractions and humic acids [12].

Most of the compostable substances should be suitable for biodegradations. This can be achieved by mixing different materials (e.g. microbial culture, semi-finished or finished compost). The degradable material must meet the following conditions [12], [13]:

- Humidity (40-60 %)
- Countinously oxygen demand
- Contains soluble salts (pl. $FeCl_3$, Al) at a lower concentration
- C/N ratio
- Degradable organic matter content
- pH value (optimal: 6,0-7,5)
- Lower concentration of heavy metals

High heavy metal content has negative effect on microorganisms because it stops their physiological processes and changes their metabolic processes. In summary, it can be concluded that the composting raw materials made from several compounds, and all of them are important role during the composting process or at the end of the composting process. The main compounds mentioned are: starch, lignin, fructan, cellulose, chitin, proteins, xylan, pectin and mannan [14].

Proper aeration of compost is one of the most important parameters for the success of composting process. Approximately about 0,6 m^3 to 2,0 m^3 of air is needed for about 1 kg of dry matter [15]. The oxygen content in the system is necessary not only for the degradation of organic matter, also for drying because the moisture contents of materials approximately 55-70% [16]. One of the most widespread variants of composting technologies is the 'free-air prismatic method'. The essence of the method is to provide continuous air supply with easily degradable organic material (e.g. straw) or regular rotation. It is a general fact that the continuous flow of air ensured by the difference in temperature between compost and environment [17]. In the order of process phases, aerobic and anaerobic conditions changes. The strong anaerobic conditions and the reduction of the amount of easily degradable organic matter can be deduced from the changes of compost temperature. The ratio of aeration should be changed in the following cases in compost: aeration is essential to regulate moisture removal or to provide aerobic and anaerobic conditions. When monitoring the aeration process, it is important to ensure that oxidative and reductive phases are in composting [18].

When composting, the heat energy released during the oxidation of organic matter ensures the energy demand of the process, in which case the compost temperature may reach 70-75°C [18]. The organic matter content of compost determine by the input material flow in first composting phase. Table 2 shows the values of the input indicators (flows) measured in different compost types [15].

Table 2. The values of nutritional indicators inhabiting of each solid compost types (Source: Pergola et al., 2017, [15])

	Solid compost types		
	Sheep manure	Mixed compost	Average compost
Moisture content %	70	65	60
Dry matter content %	30	35	40
C %	12	15	22
N %	0,66	0,5	0,7
C/N ratio	16,3	22	31
pH	7,8	7,3	6,9
$\sum P_2O_5$	0,28	1,3	1,8
$\sum K_2O$	0,8	0,9	1,1

The following composting techniques could be differentiate in the way of oxygen input flows [19]:

- Prismatic systems
- Mechanical or air-ventilated systems
- Bunker type composting method
- Reactor type composting method

Based on these, the most applied technologies are the follows [19]:

- Rotating prismatic technique (open prismatic mode, most commonly used in Hungary)
- Air conditioned prismatic version (passive or ventilated type)
- Bunker type composting
- Reactor type method (vertical, rotary or oven version)

During the controlled composting method, the microbiological properties of mature compost are artificially modified [20]. This has the advantage of providing biologically/biochemically controlled, stable safe composting conditions, obtaining unrestricted marketing and competitive compost with fertilizers, which is competitive with artificial soil improvers in terms of active ingredient content [21].

2. Methodology

The concept of multi-function composting technique

The main importance of our conception is the multi-functional composting method. During the normal composting process, alternative utilizations linked to the system, or a special compost type is produced, which has concrete input and output material flows, with special setting parameters. We would like to present few special (multi-function) compost types and related utilizations in the following.

Analysis of selected compost types and their utilizations

The scope of specific compost type's use described below and the related possibilities were analysed. We did not focus on traditional agricultural utilization for soil improvement, so the focus on composting and utilization of mature compost (wastewater sludge composting - sludge reduction process, biogas production - combined heat energy production and utilization, and special water treatment with compost adsorption).

3. Results and discussions

Special waste management with wastewater sludge composting

The amount of primary and secondary sludge, which generated during wastewater treatment, could be reduced in several possible ways. On each wastewater treatment plant, a part of produced sludge recirculation realized, which means that only excess sludge should remove from the system [22]. However, this should be dewatered for proper storage and further treatments as it has a high water content (~ 98%, which means it is practically liquid sludge). Dewatering is achieved by centrifugation, drying or gravity compression [23]. This is followed by the anaerobic sludge stabilization phase, which is a basic condition for further utilization [24].

Sewage sludge composting is an appropriate method for further treatment and use of excess sludge formed during water purification. Wastewater sludge composting may only take place after dewatering because the high water content of wastewater sludge would blocking the formation of mature compost [23][25]. It is important to note that wastewater sludge composition is special because after the biological phase of wastewater treatment the sludge from the system contains diverse microorganisms with high number and species [3],[25]. This is useful in the composting process so there is no need to microbiological vaccines to produce the mature compost in appropriate quality. Regarding the quality of compost, it is an important requirement that all ingredients should be below the pollution limits (listed by No. CLXXXV/2012. Law about waste management, and No. 50/2001. (IV. 3.) Government decree about the rules of use and placement of wastewater sludge) (the concentration values presented by Table 3.). Untreated or semi-treated wastewater sludge, non-ripe compost or municipal liquid waste can not be used in agriculture production processes [26].

Table 3. Limited concentrations of toxic elements in wastewater sludge composts (in unit of mg/kg dry matter) (Source: No. 50/2001 (IV. 3.) Government decree)

Toxic contaminants	Limited conc. (mg/kg d.m.)
As (*arsenic*)	25
Cd (*cadmium*)	5
Co (*cobalt*)	50
Σ Cr (*Σ chromium*)	350
Cr VI (*chromium – isotope VI*)	1
Cu (*copper*)	750
Hg (*mercury*)	5
Mo (*molybdenum*)	10
Ni (*nickel*)	100
Pb (*lead*)	400
Se (*selenium*)	50
Zn (*zinc*)	2000
Σ PAH (*Polycyclic aromatic hydrocarbons*)	5
Σ PCB (*Polycyclic biphenyls*)	0,5
TPH (*Total petroleum hydrocarbons*)	1000

Sludge composts can be considered as special compost varieties because they could be used for agricultural production to improve soil parameters, better yields and significantly improve the composition and activity of soil microbiological community [20][27]. The compost components of wastewater sludge complies with the active substance content of the fertilizers, while being environmentally friendly and economical as the compost raw material is accessible to any wastewater treatment plant [28].

The wastewater sludge composting process can be studied from a circularly economic point of view also. The fermentation residue can be transformed into suitable materials for agricultural use by appropriate biological procedures, with a cycle time of 60 up to 90 days. This enables the utilization of wastewater sludge, the raw materials can be returned to the biochemical circulation through the soil, and the costs of dumping and storing wastewater sludges as waste could be reduced also [29]. This is the basic condition of biological directed composting technique using. That means we could control the flora of the compost microorganisms of the wastewater sludge and influence its species and numbers [30]. The communities originally present in wastewater sludge, the species associated with lignocelluloses (mushrooms, molds, polyphagous parasites), and the spores in the air blast ventilation. Their proportions should be properly adjusted, as spores (e.g. beetroot) and mold species can also cause damage to compost soil remediation [31].

Biogas and combined heating energy production

The biogas production associated with composting is typically carried out in wastewater treatment plants, but there are also known residential and biogas production. The latter is only tangentially concerned, because the gas thus produced cannot be regarded as biogas in the conventional sense, as it does not meet biogas requirements for supply to the natural gas pipeline system either in terms of composition or in terms of quality. Typically, communal biogas is a small-scale home-use gas that can be used to heat a farm or a garden house [32].

The untreated biogas contains the highest proportion of methane (about 40-45%), which is an energetically usable part of the generated biogas. In addition, large amounts of carbon dioxide (roughly 20%) are generated, which cause problems with the input of biogas into the natural gas pipeline system and energy loss [32].

Figure 2 shows the economic-social and environmental impact of biogas production. The resulting biogas is suitable for many utilizations. Primarily due to methane content, direct energy use can be considered, but indirect use and impact can also be reflected in the socio-economic and natural environment [33]. With regard to the social segment, it can be stated that direct use of untreated biogas can be used directly for communal use, but due to the relative high carbon content the calorific value will be reduced and the risk of accidents will increase. Definitely recommended that whole of the produced biogas must be cleaned before using [32][33].

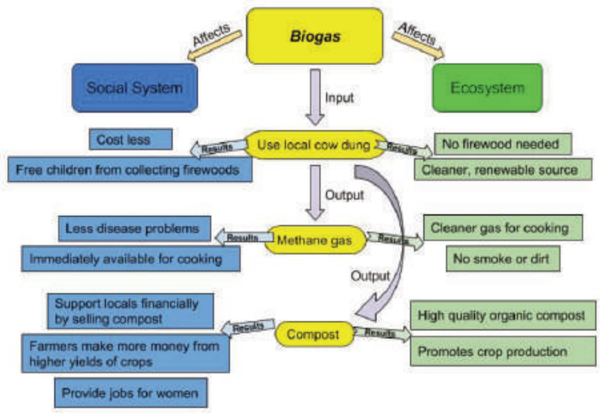

Figure 2. Impacts of biogas production on the social-economic and ecosystem fields
Source: Meng et al., 2018 [33]

In the maturation phase of the composting process, when the compost temperature reaches 70oC, a recoverable amount of heat is generated. For plants with open prism composting technology, composting parameters can be monitored by regular control measurements to determine the maximum temperature value. This can be inferred from the achievement of the mature compost phase, which can be defined by a parameter decrease following the maximum temperature reach [33], [34].

Waste recycling in the form of innovative organic fertilizers and composts - The practical implementation of the circular economic approach

The proportion of bio-chemical recyclable waste in Europe increasing. However, in spite of high organic matter content, the ratio of recycled waste is still below the desired level (at least 65% would be the ideal rate for recycling and a 10% reduction in the amount of waste to be deposited in landfills) [35].

The European Commission declared the "Manure regulation" in 2016, which will increase the proportion of recycled waste amount (No. 2016/157. COM decree) [15]. The Regulation will apply to organic fertilizers, so composts and various fermentation residues (e.g. biogas for plant residues). The organic fertilizer using could increase by re-utilizing (composting) bio-waste [35].

Under the Regulation, it has made it possible to utilize secondary raw materials in order to realize more efficient raw material use, and the regulation increases resource efficiency and reduces import dependence on organic (organic matter-bound) phosphorus.

The indirect effect of the Regulation is that contributes to the classification of organic fertilizers (composts) under a single system of limit values since uniformity of phosphorus, nitrogen and cadmium limits can be effectively influenced by soil composition and the mobility factor for each element [15][26][34][35].

The transition from fertilizer production to the production of organic manures provides a conceptual framework for understanding the parts of bio-waste management in the circular economic concept. This economic strategy can be reconciled with the idea that a product with added value after the biological treatment of wastes can be produced, and thus some degree of modification of waste streams is possible [35].

4. Conclusions

Multifunctional composting has become a common practice today. During the composting process, or after the phase of the mature compost, alternative utilization options seems to be available based on the quality properties of the compost. Combined thermal energy production and biogas production are the most commonly used multifunctional utilizations today. Sludge, as special liquid medium, are suitable for producing compost so that biochemical materials can be returned to the material flow, reducing the volume of waste production. The circular economic concept also appears in composting. The modification of the waste flow with a quantitative reduction has become available with the realization of the economic competitive advantage based on the biodegradation of waste.

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