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HOME COMPOSTING - RULES, CONDITIONS, NEW SOLUTIONS

Abstract: The management of composting home bio-waste at the place of their formation leads to several benefits. Among them are: minimising the amount of waste sent to landfills, decreasing the costs associated with transporting them to disposal sites, and reducing the need for new facilities dedicated to this purpose. A further advantage of home composting is the better segregation of waste compared to industrial composting, there is less accidental contamination by plastic, glass, or metal waste, which is a key requirement for a proper biodegradation process. However, despite to many benefits of home composting, the method is still controversial. The first part of the paper briefly characterises the key parameters for an effective home composting process, i.e.: temperature, air porosity, oxygenation, and moisture content. It is also widely considered and discussed the problem of reasons why home composters do not reach the temperature values considered necessary for the sterilisation of waste. Potential needs to reach the same high temperatures in home composting as in industrial composting are also discussed. The next part of the paper presents some technical solutions currently used in home composters to improve the process of biodegradation of waste and to make them easier to use. The final section addresses the quality of home compost and the issues around correctly assessing its maturity and stability.

Keywords: home composting, bio-waste, compost, composter

Introduction

Composting is defined as aerobic decomposition of organic waste, occurring under well-defined conditions, with the participation of various groups of microorganisms [1-3]. It is believed that with the maintenance of proper values of temperature [4], pH, humidity, and C:N ratios in the stored organic matter [5], as well as with a constant oxygen supply [6], it is possible to produce hygienic, stable and mature compost rich in humic substances. The literature agrees that, for the environment, composting is the best way to manage the organic content of municipal waste [7-10]. It should also be emphasised that, with the current state of the environment and the ever-increasing mass of organic waste generated in individual households, this process is becoming particularly important [11] because disposing of bio-waste through this route allows valuable nutrients to be released and returned to depleted farmland soils or areas undergoing reclamation [12-14]; the process also contributes to minimising the discharge of biodegradable waste to landfill and reduces

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soil contamination and groundwater pollution [15, 16]. Although composting, as a method of removing bio-waste fractions from the environment, has been practiced for a long time [6], the actual knowledge and understanding of its principles is based mainly on studies conducted during composting under industrial conditions [1, 6, 17], while detailed recognition of home and backyard composting processes, both from the technical and scientific side, has only recently begun [18]. However, there is no doubt that home-scale composting is an extremely effective way to manage bio-waste. Therefore, the contribution of households to the management of bio-waste, with ever-increasing levels of bio-waste production, is absolutely essential [19] and something that the European Commission has also been calling for a long time [20, 21].

Proper conditions for home composting

Industrial composting and home composting are conditioned by the same types of physicochemical parameters, which include properly selected organic matter, adequate temperature at each stage of the process, pH, humidity, and air/oxygen supply [22, 23] (Table 1). In industrial composting, which occurs in a short period of time with high efficiency, control of these parameters is carried out at each stage of the process [24], however, in the case of home composting such control is not possible. Recent improvements in terms of monitoring and the composting process have been dedicated mainly to industrial purposes, while they have not been applicable to composting under individual household conditions. Thus, as a result, the performance of the two processes is incomparable [6].

Table 1

Range of several important factors of composting [25]

Variable	Ideal range
Temperature [°C]	45 - 60 for thermophilic phase
Moisture [%] by weight	45-60
Oxygen concentration [%]	> 5
C : N ratio [-]	25 : 1 - 30 : 1
pH [-]	5.5 - 8.0

From an environmental perspective, home composting carries great potential - it requires less land for landfill, gives better control of the materials being processed avoiding contamination in the form of glass and plastic, and reduces the need for transportation [7, 26]. However, a major challenge for non-industrial composting is maintaining the required rigour in terms of temperature, moisture, aeration and odour generation.

Temperature, air porosity, oxygenation, humidity

Temperature

There are specified two to four thermal phases in the composting process. The main phase is the thermophilic phase, referred to as the active phase, following by the maturation phase, characterised by falling temperatures [27]. The thermophilic phase is preceded by the mesophilic phase and both of them create the active phase [25]. Zhang et al. [28] additionally indicate a cooling phase after the mesophilic, thermophilic, and ripening phases.

Basically, the mesophilic phase occurs at a moderate temperature, during which microorganisms consume amino acids contained in organic waste. The result is their rapid microbial growth, accompanied by an increase in temperature in the heap. At this stage, plant cell wall elements, including cellulose and hemicellulose, decompose into humus and CO_2. When mesophilic microorganisms are destroyed and replaced by thermophilic microorganisms, at 70 °C, natural pathogens are also eliminated [8]. According to Salama et al. [29], effective disinfection of landfilled waste can already occur at lower temperatures. These authors believe that the range of 50 °C - 55 °C is sufficient for both decomposition of organic raw materials and maximum disinfection. Rich and Bharti [30], on the other hand, point to a range of 40 °C - 65 °C as an optimal temperatures for the composting process. However, in the older literature, temperatures between 45 °C and 55 °C were indicated as improving the rate of degradation, and between 35 °C and 40 °C as increasing microbial diversity [31, 32]. Temperature close to 60 °C was accepted as the optimal temperature for the composting process, and this temperature is simultaneously consistent with maximising respiration rates and CO_2 release rates [31]. Moreover, analysing the effect of temperatures on the rate of oxygen uptake, the proper growth rate, and enzymatic activity of microorganisms, temperature of 54 °C was considered the optimal [33]. Other studies have indicated that effective composting can be carried out at mesophilic temperatures lower than 45 °C [34]. Liang et al. [35] showed that maximum O_2 uptake was recorded at 43 °C, regardless of composting processes in the temperature range of 22 °C - 57 °C. Mesophilic composting is described as more effective in reducing compost mass due to higher microbial activity. However, higher temperature is much more effective in eliminating pathogenic contaminants during composting [36]. The duration of exposure of the stored waste to a given temperature is also not insignificant. It is believed that high temperature and a sufficiently long time of its exposure in the pile can contribute to the complete elimination of pathogens [12] and seeds of weeds. According to Chan et al. [37], the thermophilic phase that lasts a week should lead to the complete elimination of pathogens. The discussed already above temperature conditions in composting process, clearly show that there is no unanimity in the literature on the optimal temperature required for the proper course of composting. Epstein [1] points out another aspect of this issue, that different raw materials decompose faster at different temperatures. Moreover, from the point of view of microbial activity, too high temperatures in the compost pile can lead to the destruction of the thermophilic microbial population. Sudharsan and Kalamdhad [38] considered that temperatures higher than 65 °C can inactivate fungi, actinomycetes and most of the bacteria necessary for the composting process. However, there is no doubt that organic matter contaminated with pathogenic organisms, presents a health risk to both humans and animals [22,39]. As Zhen et al. [32] proved the number of microbes was all positively correlated with the temperature, their density increases with the temperature increase and finally decreases after reaching the peak at the highest temperature. For this reason, backyard composting products are still considered risky, as it is difficult or even impossible, to achieve the temperatures required to disinfect organic materials in open compost piles or commercial small bins (typical volume of 40 L to 500 L). The problem of achieving properly high temperatures during home composting is due that new batches of fresh bio-waste are constantly being delivered and combined with previous portions of waste batches. Another reason comes from the fact that the amount of waste matter in composting piles is usually insufficient to retain the metabolic heat normally generated during the active phase. Thus, there is rising a question, if the temperature profile typical for the industrial composting can be considered to applied in home composting process.

Colón et al. [40] in a study on home composting observed that in a 500 dm^3 composter, where typical residential bio-waste was stored, the average temperature value during the study period was 37.4 ºC. This result did not correspond to the temperature range required to sanitise the stored compost waste. They pointed out that such temperature was due to the different values of external temperatures as well as the low thermal insulation of the composter. However, their analyses did not detect the presence of *Salmonella* sp. in the final product, and the amount of *Escherichia coli* was less than 10 CFU/g. This results allowed to treat the produced compost as hygienic and safe due to the effect of the relatively long residence time of waste in home composters and the natural elimination of pathogens.

Tatàno et al. [18] measured the temperature for a period of 8 months in two experimental composters, which were a part of a local backyard composting project in the province of Pesaro-Urbino (central Italy). One of them was used by residents of a multi-family building, while the second one - by a staff of a local university cafeteria. They showed that the average temperature in the composter used by residents of a multi-family building was 38 °C. They stored in it, except the household waste, also garden residues. A similar composter, in which was stored waste from the university cafeteria, achieved an average temperature of 58 °C. The authors of the article do not give a specific explanation for such a wide temperature range for both composters. They emphasised that the presumed reason of observed differences probably resulted from the different moisture content, limiting the temperature regime. However, the large discrepancy they observed for the average temperature values in both composters, confirms that the composting process under non-industrial conditions is unpredictable and requires a separate approach. Vázquez and Soto [21] suggested that the temperature in such type of composting process may remain only a few degrees higher than the ambient temperature and that it may vary seasonally and by region.

Arrigoni et al. [41] pointed out that small-scale composting usually begins with the introduction of a batch of organic waste through the top opening of the composter and ends at the bottom of it. The bottom part of the composter usually possess a special door, which gives the opportunity to collect the mature compost. This means that the transformation of organic matter takes place according to the order in which the waste portions are incorporated into the container. They measured temperatures at four different heights of the compost pile in the container starting from the base 20 cm, next 20 cm - 40 cm, followed 40 cm - 60 cm, and 60 cm - 80 cm. In each zone temperatures were various, and the required sanitising temperatures were observed only in the intermediate layers, namely in 30 cm - 60 cm. According to them, the observed result was influenced by the frequency of waste addition, the amount and variety of waste, and the design of the container in which composting was carried out. It was found that, if walls of a composter are thin - the heat losses would be higher. Thus, the methodology for studying the composting process in a small scale, should be modified and more detailed. These authors believe that the requirements for temperature values, which in home composting are various at different heights of the pile, should change. It is also worth remembering that with new portions of waste constantly added to a composter, new pathogens may be introduced into those layers that previously had the temperatures required to sanitise them [41].

Changes in the temperature values in the composted pile are dependent on moisture content and the supply of oxygen. At the same time, moisture content and access to oxygen depend on the size and air porosity of the stored waste [42].

Porosity, oxygenation, moisture content

The presence in the pile of free spaces between the composted raw materials guarantees the free flow of air and the supply of oxygen to the microorganisms leading to decomposition (Fig. 1). If the oxygen concentration is maintained at 15 % - 20 %, the composting process is considered to occur with high efficiency [43]. If its concentration drops below 5 %, aerobic microorganisms lose access to oxygen and the decomposition of substances takes place under anaerobic conditions [1].

Anaerobic composting have been studied as a suitable alternative to aerobic composting processes due to the minimised loss of nitrogen [44, 45]. However, aerobic composting has significant advantages over anaerobic composting, as rising temperatures play a key role in eliminating weeds' seeds and pathogens. Also important is the shorter decomposition time of organic matter [46] compared to anaerobic composting. The level of emissions of unpleasant gases i.e., ammonia and methane [42], the latter of which belongs to the group of greenhouse gases [47] is also lower in aerobic composting compared to anaerobic composting.

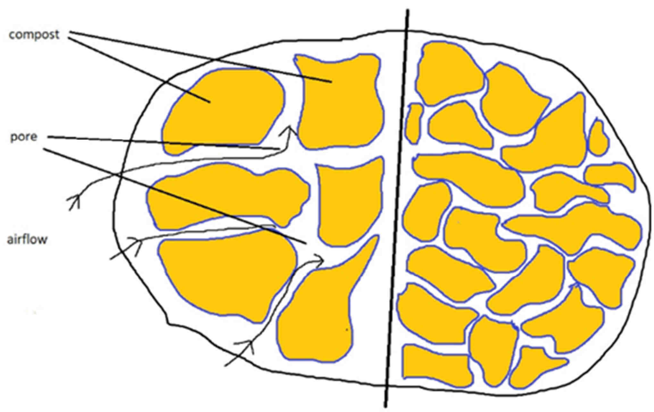

Fig. 1. Air flow in the compost pile depending on the size of composted waste (own elaboration based on [40])

Correct air porosity of the stored materials determines the proper transport of oxygen, as well as the drainage of water and heat from the compost pile generated as the decomposition processes. To determine the air porosity of composted materials, it is necessary to calculate the ratio of the volume of the air-filled pores to the total volume of the material. This parameter is determined by laboratory methods, including the pycnometric method or saturation of the material with water method [48]. In both of these methods, it is necessary to perform mathematical calculations, which complicates the task for the potential user of a home composter. The value of air porosity can also be determined theoretically using the parameter of bulk density, which is the ratio of the total mass of composted raw materials to their volume [49]. When the bulk density of a compost increases - its air porosity decreases. It is reported in the literature that a porosity range maintained at 35 % - 50 % of the volume of composted material will maintain a balance between the appropriate amount of oxygen and moisture in the compost pile. This provides a favourable surface for the biodegradation carried out by microorganisms. As reported by Assandri et al. [50], porosity above 50 % prevents increasing the temperature inside the compost, because energy loss exceeds heat production; whereas, porosity below 50 % can lead to anaerobic conditions and generate unpleasant odours.

When the moisture level in the compost increases, this leads to filling the air gaps with water, and the number of air-filled pores decreases. A similar effect occurs when very small particles of organic matter are present in the compost. Their presence in the compost pile causes compaction of the composted mass, and consequently, a decrease in the amount of oxygen occurs (Fig. 1, right side of the diagram), as well as the moisture level decreases. On the other hand, small particles of composted materials provide a large effective surface area for decomposing microorganisms [3]. According to Coker [42], aerobic composting is most efficient (in terms of its duration) with a particle size of 50 mm to 200 mm; smaller sizes stimulate decomposition under anaerobic conditions. Hajji and Rhachi [51] showed that digestion efficiency (as measured by biogas production rate and volume) is greatest at particle sizes ranging from ~0.4 inches (10 mm) to ~1.2 inches (30 mm).

An uncomplicated way to maintain optimal porosity conditions is to use filling agents, such as wood chips [27, 52] or other fine materials. The principle of alternate placement various materials in backyard composting works well-structure-forming and provides looseness as well as aeration of the compost pile. This means mixing "green" waste mainly consisting of wet kitchen residues and mown grass with "brown materials" such as tree or shrub branches. An additional advantage of such an arrangement is the ability to maintain relatively correct C : N ratios in the compost [53], as it is assumed that the "brown" layers are characterised by a large amount of carbon while the "green" layers have a large amount of nitrogen.

Another way to aid good aeration of the compost pile is to flip it regularly [27]. Weekly flipping has been found to effectively accelerate the decomposition of stored organic matter [54]. Awasthi et al. [55] proved that flipping the compost pile three times per week is more beneficial to bacterial succession than taking this action daily. However, achieving adequate porosity and thus oxygenation of the composted pile, according to these authors, does not seem to be as much challenging for potential users of a home composters, as achieving and maintaining the high temperatures required to sanitise the stored raw materials.

Likewise, maintaining the right moisture level does not seem to be difficult. The amount of water in the compost pile should be systematically controlled, since it is the environment in which microorganisms move and live, chemical reactions take place, and nutrients are transferred [56]. It is also important to adjust the moisture level according to the composition of the degraded waste [57].

When the moisture content of the waste is in the range of 45 % to 60 %, composting is considered to proceed with good efficiency. Makan et al. [58] showed that, if the initial moisture content of the compost pile is at 85 % then the process will be inhibited due to the existence of anaerobic conditions. Krysztoforski [53] suggests that home-produced compost should be regularly monitored for the degree of hydration, and if necessary, regularly sprinkled with water.

Examples of solutions for backyard and residential composters

There is no doubt, that the traditional method of backyard composting, e.g. piling a simple compost pile in the backyard or garden, involves the need for adequate outdoor space, which can be difficult or even impossible to achieve in urban areas with dense housing [59]. The location of the composter is also regulated by relevant legal provisions, according to which, for example, in Poland, a small composter of up to 10 m^3 must be located over 7.5 m apart from the property boundary and 15 m from the neighbour's house, while a larger one with a capacity of 10 m^3 - 50 m^3 should be at least 30 m apart from the neighbour's buildings [60]. Thus, a small composter, in the form of a lockable container with a capacity adapted to the needs of an individual household, seems to be an attractive alternative.

Knowing that proper composting depends on basic parameters such as temperature, oxygen supply, humidity and aeration, manufacturers of the composters designed for the collection of bio-waste in backyard and residential settings, are trying to provide in them the ability to monitor at least one of the parameters. Mahapatra et al. [59] suggested that a composting bin should ensure the maintenance of a mesophilic phase followed by a thermophilic and a maturation phase. In addition, it should be equipped with adequate aeration, mixing, and a chamber for collecting excess water (leachate). Their review of the small composters currently available on the market shows that manufacturers are trying to introduce simple solutions that optimise the entire process. The composting bins usually are lightweight and easy to assemble. The vast majority of them are made of plastic (e.g. *Eco bin*, *Eco Stack*, *Thermo King*) or recycled plastic (e.g. *The Envirocycle*, *Exaco Juwel Austrian Compost bini Tumbleweed compost tumbler*), some also have double walls, (e.g. *Back porch compost tumbler*), or are insulated with foam *(Home compost bin*- SCB 100). They are also usually closed with a top flap, which helps to keep in the heat released during composting. Aeration is usually carried out through vents located on the side walls (e.g. *Eco Stack composting bin*, *Exaco Juwel Austrian Compost bin*, *Home compost bin*-SCB 100), this ensures an adequate supply of oxygen and the maintenance of proper moisture levels (*Back porch compost tumbler*) without the need for frequent mixing of composted materials. Ventilation holes can also be placed at the bottom of the composter, which allows air to flow through it just like in an oven, from the bottom to the top (*Humus composter*). In addition, such composters may have a faucet for removing excess leachate that is generated in the process (*Home compost bin-SCB 100*, *The hungry bin*) [61].

The decomposition processes are often aided by various organisms deliberately added to composted raw materials [59]. An example is the preparation Magic Microbes Bokashi Bran (MM), formulated in granules enriched with microorganisms called by producers "magic microbes" [62]. They are made of a dry mass of bran and molasses, inoculated with beneficial microorganisms, which are a selected mixture of bacteria, yeasts and fungi that work together, speeding up composting, eliminating pathogens and preventing rotting and unpleasant odours. The MM preparation is especially designed for composting in the *Eko bin* composter, but it may be used to enrich household kitchen waste collected in any type of composters. Numerous invertebrate organisms also play a key role in bin composting, including *EkoStack*, *The hungry bin* or in a rotating composter *The Envirocycle*.

Interesting solutions for eliminating bio-waste at source of their obtainment, and in smaller spaces (e.g. apartments, offices etc.) are Japanese composting techniques based on anaerobic decomposition processes of organic matter [63, 64]. Examples of these are

Takakura composting boxes (TCBs), which involve adding of food scraps to a "*Takakura container*" lined with a 40 cm × 25 cm × 70 cm cotton bag. Decomposition of the shredded food waste takes place in it with the help of microorganisms. Jiménez-Antillón et al. [63] shown that after only about six weeks and without nuisance leachate, food waste is transformed into good-quality compost with macro- and micronutrient composition comparable to composts obtained by other techniques.

Another method, still not very common in Europe [64], is the Bokashi method, or the Japanese method of "fermenting organic matter". Bio-waste, mainly food waste, processed according to this method is decomposed by lactic acid fermentation (LAF) under anaerobic conditions. Once the shredded organic waste is placed in a special garbage can, it is inoculated with a mixture of microorganisms (EM) consisting of cultures of naturally occurring microorganisms such as purple sulphur-free bacteria (PNSB), lactic acid bacilli (LAB), yeast and actinomycetes that thrive in an anaerobic, acidic environment [64]. The fermentation process usually takes 2 to 3 weeks, during which acidic (pH = 3.5) and anaerobic conditions suppress potential pathogens accidentally introduced with composted raw materials [65]. It is crucial to drain excess moisture from the garbage can and maintain a temperature in a range of >18 °C - 20 °C to obtain optimal fermentation conditions [64]. The result of this decomposition is two fractions - a solid part, which is odourless organic compost, and a liquid fraction, so-called "Bokashi tea". Both fractions are high-quality fertilisers [59] that can be directly applied to the soil [64].

Another method of managing bio-waste is vermicomposting. This process usually requires less space than traditional garden composting [66, 67]. The vermicomposting process is actually based on the combined activity of microorganisms and earthworms [68], in which earthworms play a key role. As a result of their activity, the amount of oxygen in the composted pile increases, as well as the effective surface area for microorganisms also increases, this intensifies their enzymatic activity making the composting process of organic waste more efficiently [69]. Of course, earthworms also are able to digest the waste materials resulting in coprolites (vermicast) [70], and the vermicompost obtained at the end of the process is rich nutrients available to plants [68]. Vermicompost can be obtained by using various vermicultures, the most popular of which are *Eisenia fetida*, *Eudrilus eugeniae* and *Perionyx excavatus* [71, 72]. The temperature regime during the vermicomposting process is always within the mesophilic range, however, that does not ensure the removal of pathogenic microorganisms, although studies show that the final product is hygienic [27]. According to Samal et al. [73] the reduction of pathogens (including *Salmonella* spp. and *E. coli*) here may be mainly due to the action of the earthworms' intestinal enzymes. The stomach and intestines of these organisms act as a "bioreactor." Earthworms ingest food residues, remove harmful microorganisms and excrete the organic matter mixed with minerals and beneficial microorganisms as "vermicast" on the external compost layer surface. Moreover, earthworms secrete coelomic fluids from their body cavity (*coelomas*), which antibacterial properties allow to destroy all pathogens present in the environment [74]. Nevertheless, the implementation of this process on an industrial scale is blocked due to this process does not reach high temperatures [66].

The demand for home composters that offer the possibility of quick, odourless and unattended management of bio-waste is still growing. Especially since the traditional method of composting carried out in open compost piles is not suitable for numerous urban users, presumably due to lack of space and time [25]. Commercially available garbage cans or boxes designed for small-scale composting meet these expectations to some extent. For example, the duration of composting in some of them is considerably shorter than using the traditional method, such as in the *Termo-King*, in which the process duration is about 3 months; in the *Back porch compost tumbler* lasts about 1-2 months, and in the *Bokashi* or *Eco bin* using the Bokashi technique - only 2-3 weeks [59]. Considering, how quickly new portions of bio-waste are currently produced, this time seems to allow for continuity in the delivery of new portions of raw materials for composting with the receipt of finished compost.

However, the disadvantage of some of the containers characterised above is that they still require access to a small outdoor space, possibly a terrace or balcony [59]. The fact that the basic parameters that determine the occurrence of the composting process are not monitored in them is the one more of the disadvantages [6]. Manufacturers of automated electric composters, equipped with a bio-waste shredder, automatic turning and sensors to ensure optimal conditions for the process try to find solutions to resolve these problems. The compact size of such composters also allows to set them up indoors, such as on a kitchen counter [25]. The principle of the electric composter, also known as a food recycler, is based on replicating selected phases of natural composting, with heavily reduced duration. According to manufacturers [75], the decomposition time of all the raw materials in it is just 5 h to 48 h. The electric composter basically applies three stages of composting, namely (1) drying stage, (2) grinding stage and (3) cooling stage. In the first stage, which mimics both the mesophilic and thermophilic phases, drying of raw materials takes place at an average temperature of 70 ºC, which is adequate to eliminate pathogens and seeds of weeds. This is followed by grinding and crushing of the dry material. The process is intended to increase the contact surface with microorganisms. In the last stage, the cooling phase, additional aeration is applied to shorten the time to return the decomposing materials to room temperature. The resulting product differs from the traditional compost, which is characterised by a large number of microorganisms and a certain degree of moisture. The difference means that the product is dry and sterile. For this reason, it cannot be used as a topsoil, but can be a good addition to enrich soil with missing organic components. Electric composters make possible to manage bio-waste such as food scraps (including meat and dairy) and other waste generated during food preparation. However, big sized waste e.g. horticultural are too big to use in this type of the device. Therefore, electric composters seem to have the potential to be an excellent complement to the traditional manual composting technique.

A review conducted by Azis et al. [25] of patents on various composting techniques, both small and large scale, shows that over the period 2000-2021, 457 different patents were developed worldwide, and many of them came from 5 countries - China, South Korea, the United States, Japan and Canada (a total of 391 patents). Classifying them according to technology (manual, semi-automatic and fully automatic), composting category (aerobic, anaerobic and category "undefined"), system size (small and large, where small means a home composter that can handle a relatively small amount of kitchen and garden waste), type of waste (food waste, animal manure, garden waste, agricultural waste and general organic waste) showed the domination of patents for fully automated composters (60 %), for processes that run under aerobic conditions (86 %), for large-scale processes (73 %) and those that process general organic waste (58 % of patents). Thus, from a patent perspective, it can be seen that there is a worldwide growing interest in small-scale composting of food and kitchen waste, as is indicated by 64 patents in this area. Nevertheless, there are still much larger number of patents for improvements the industrial-sized systems, which confirms the dominance of this type of composting.

Quality of home-made compost

The quality of home-made compost is a problematic and widely discussed. According to some authors, it is a risky product [6], since the lack of high temperatures in the course of home composting does not allow to eliminate pathogens and weeds' seeds from it [41, 76, 77]. Also, the assessment of compost maturity and stability by compost producers based on an organoleptic method may be incorrect [78]. Bernal et al. [11] emphasise that even though colour (dark brown), odour (fresh earth), or moisture content are good indicators of the overall degree of decomposition of composted raw materials, the maturity of compost cannot be inferred from them. In contrast, Kohli et al. [78] paid attention to the problem of trace metals and non-metal elements (TMM), the content of which in home composts is not controlled, and whose dosage in garden soils is often excessive. However, according to other authors the quality of compost obtained from home systems is similar to, or even better, than that obtained from industrial systems [79, 80]. It is due that home composting involves a good waste segregation, which means that there is no contamination in the initial mixture for composting. During source segregation, bio-waste, including fruits, vegetables, food scraps, fallen leaves, grass clippings, cut wood, weeds and paper do not come into prolonged contact with foreign materials [70, 78]. A study conducted by Vázquez and Soto [21] on the quality of home-made composts in 90 composters showed a very low proportion of unsuitable materials in them, averaging 0.27 % ± 0.44 % of dry matter; in addition, these authors observed a low C : N ratio reaching 10-15, and a low content of heavy metals (94 % of the samples met the required standards). In terms of nutrients content, these composts had a high average content of N - 2.1 %, P - 0.6 %, K - 2.5 %, Mg - 0.7 % and Ca - 3.7 % in dry matter.

Interesting observation in terms of the TMM content in home-made composts were made by Kohli et al. [78]. They stated that in home-made composts the amount of TMM was high, particularly in the case of Pb, however, it was observed only for composts that were made from green waste coming from gardens created, for example, on post-industrial brownfield sites. On the other hand, when such waste was mixed with food or other kitchen waste, the TMM content dropped significantly.

There is also a lot of controversy regarding the quality of home-made compost if it is produced with animal kitchen waste, such as meat or fish trimmings and pet faeces [78]. Typically, recommendations for raw materials that can be disposed of through home composting explicitly state that cooked and uncooked meat should not be disposed of through this route [59]. Small-scale composting of this form of bio-waste is possible in vermicomposters or *Bokashi* garbage cans [70, 81]. The reason not using the animal origin bio-waste in home composters is the possibility of attracting insects and the emission of gases such as ammonia [78] contributing to odour emissions [28]. Whereas, Storino et al. [80] showed that the addition of meat waste to composted raw materials led to an increase in temperature, which resulted in faster compost maturity and a higher humus amount compared to compost obtained from vegetable waste alone. In addition, phytotoxicity, salinity, the presence of viable seeds, pH or heavy metal content were not increased in the final product.

Undoubtedly, the first step of waste administration at home is its initial segregation and disposing of bio-waste in some containers and bags with a typical total capacity of 10 L to 30 L [82]. However, the bags used for this purpose are usually made of plastic (low-density polyethylene). This material do not decompose in composting processes, and also hinder the subsequent disposal and degradation of the bio-waste stored in them. The vast majority of petroleum-based plastics are resistant to microorganisms, which lack enzymes capable of degrading most synthetic polymers. In addition, their hydrophobic nature inhibits enzyme activity and significantly hinders the pre-treatment and final processes of bio-waste utilisation [83]. Therefore, it is recommended to use compostable bags for their collection in residential settings, however, it is not a synonymous to biodegradable [84]. Formally, they can be also disposed through composting. Using this type of bags for segregation and storing bio-waste makes it easy to close the circulation of resources in the household and realise the goals of a closed-loop economy. In this way, the bio-waste is processed into fertiliser, which may be used in private gardens [9].

Currently, many companies offer such products, such as BioBag® [83, 85]. BioBag® bags are available in various sizes (e.g. (8, 10, 30) dm^3 and more), and are made from thermoplastic starch (TPS) or other plant-originating materials [86]. Their physical and mechanical properties are similar to conventional plastics, but their recognition as compostable and biodegradable (iz.com/), seems to allow for the deposition in them household bio-waste (including meal leftovers, tea bags, coffee grounds or egg shells) in a hygienic manner [87]. It is also recommended that the collection of bio-waste in compostable bags should be carried out in specially invented containers allowing to ventilate the garbage [81]. This allows for adequate aeration and evaporation of water from the stored waste. According to Puyuelo et al. [83] this provides the reduction of biowaste weight and volume up to 5 %. The continuous exchange of air between the waste and the environment also reduces the emission of unpleasant odours.

Development of multifunctional bio-degradable and recyclable coatings and packages are highly demanded, however, their proper degradation and/or reuse should be carefully studied [26]. One of the materials used for collection and composting together with biowaste is a patented plant-based bio-plastic known as Mater-Bi® plastic. According to the manufacturer’s assertion it meets several European and international standards for being composted [88].

Weinstein et al. [89] tested the degradation of various bio-based plastics, including BioBag® shopping bags made from Mater-Bi® plastic. They showed that after 32 weeks of storing them in an intertidal salt marsh in the Ashley River led to their physical degradation leading to plastic crumbling. Microscopic observations using scanning electron microscopy (SEM) showed that only microcracks were present in other samples of tested materials such as PLA cups, extruded polystyrene (bioPS) sheets, biodegradable high-density polyethylene (bioHDPE) bags and conventional plastics, recycled polyethylene terephthalate [rPET] cups, and HDPE bags. It is noteworthy, that after just 4 weeks, these authors observed the presence of biofilm on all plastics, which mostly increased their weight and decreased their UV permeability. In addition, starting from a fourth week, all plastics produced microplastic particles, and BioBag® bags produced the majority of microplastic particles due to their highest degradation rate. Currently, the literature searching by authors, resulted in no more other research results on the impact of BioBag® (Mater-Bi®) plastics to the environment, including the influence on the quality of home-made composts. This problem undoubtedly requires further detailed study.

Conclusion

To summarise, home composting is undoubtedly an effective method of disposing of organic waste at source. Home composting allows for a reduced use of landfill space without additional investment in transport, a high degree of segregation of the disposed waste and, above all, the use of its fertilising potential.

Scientists confirm that the relatively long retention time of waste in home composters allows for the natural elimination of pathogens and is therefore considered hygienic and safe. It should therefore come as no surprise that the development of techniques to facilitate composting, particularly in domestic conditions, has been an intensive pursued. However, a major challenge in non-industrial composting is maintaining the required conditions in terms of temperature, moisture, aeration and odour generation. It is therefore extremely important to inform composter users about the possibilities and methods for checking the degree of maturity and stability of the compost produced. In this way, mistakes such as the incorrect use of organic fertiliser can be avoided in the future. It seems that full success in home composting can be achieved through the active support of local authorities in financial and educational terms.

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