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# Assessment of The Composting Process and Compost's Utilizations

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### Abstract

Recently, several studies have affirmed the deleterious effects of conventional agriculture on environmental safety and quality of products. Organic farming was selected as the most promising alternative. This agricultural system is based on the adoption of biological techniques as composting. This process can be taking either in aerobic and anaerobic conditions added to the use of earthworms or vermicomposting. The process is realizing in mesophilic, thermophilic, cooling and maturation phases. It finishes by the production of compost having enhancements on the physical, chemical and biological properties of soil. Moreover, it stimulates the plant's growth and enhances the quality of products when used as amendment or substrate. However, these advantageous are impeded unless it presents some criteria related to its maturity and stability.

### Keywords

Organic agriculture; Composting; Compost; Quality's standards

## Introduction

The green revolution, based on the use of agrochemicals, has induced a prominent increment of the agricultural production [1] but at expense of environment [2] by inducing pollution and altering the ecological symmetry [3,4]. This detrimental effect in conjunction with the high concerning of consumers about the food safety has rekindled the adoption of organic farming [2] especially that it highlights safer products. This privileged quality is attributed to limitation of use of synthetic additives (fertilizers, pesticides), plant growth regulators (hormones, livestock, antibiocids, foods and additives genetically modified organisms), human sewage sludge and monomaterials (Stuzel 2006) adding to relying on organic management practices such as crop rotation, tillage, mulching, weed control, biological pest control, green manures and recycling the plant derived wastes [2,4,5]. Recycling of wastes instead burning or dumping them is preferred namely with the steady increase of wastes production and disposal [6]. Composting is recognized as the most attractive technique of organic waste treatment [7,8,9,10].

## Composting's Definition

Traditionally, composting is an agricultural practice adopting long process open methods as heap and pit structures [8,11]. In modern era, composting was firstly developed by Albert Howard who settled the Indore method [12] used further for developing small scale aerobic composting techniques [8] (Table 1). Recently, faster and more developed methods were investigated [13]: windrow system, vessel and boxes.

### Chemical definition of composting

Chemically, composting is a self-heating, aerobic and natural process of organic matter's degradation [14,15,16,17]. These compounds are, predominantly, in nature of carbohydrates (e.g. cellulose), proteins, lipids and lignin. It is discriminated from natural rotting or putrefaction through the aerated conditions [17] and the human involvement [16]. It can be impeded in anaerobic conditions and produces intermediate compounds (methane, organic acids, hydrogen sulphide) with lesser weed seeds and pathogens' damaging than aerobic one [8]. Furthermore, it can be of vermicomposting type using earthworms in organic wastes' conversion [11].

**Aerobic composting:** Aerobic composting produces well-stabilized, hygienic, rich on humic-like substances and free of pathogens and viable weed seeds compost [9,18,19] indicated four mechanisms of humification:

Mechanism 1: It is strictly chemical and well known as the Maillard reaction. The products of the microbiological metabolism (namely the carbohydrates) are condensed, without enzymatic degradation, and combined with amino compounds leading to the production of melanoid substances. These substances are easily polymerized into humus.

Mechanism 2: It is characterized by the production of polyphenols from the non-lignin substances. The polyphenols undergo enzymatic oxidation inducing the production of quinons which are transferred to humic substances by polymerization.

Mechanism 3: With this procedure, microbial degradation of lignin's products (acids and phenolic aldehyds) is converted into quinons by enzymatic reactions. Further, quinons are polymerized into humic substances.

Mechanism 4: It is recognized as the ligno-proteic theory developed by Waksman (1936). The process consists in the combination of modified lignin with proteic substances (amino compounds) produced by microorganisms following the further reaction:

(Modified ligning)-CHO + $RNH_2$ (modified lignin)-CH=NR + $H_2O$

The modified lignin is obtained by loss of the methoxyl groups (OCH3), production of ortho-hydroxyphenols and oxidation of lateral aliphatic groups leading to the formation of free carboxylic groupments (-COOH) [20].

Stenvenson (1982) distinguished that the ligno-proteic mechanism is dominated in humid soils and the marsh while the polyphenolic mechanism characterizes the forest soils.

**Vermicomposting:** It is an enzymatic degradation through the digestive system of earthworms into vermicast [8]. These invertebrates are classified into burrowing (*Pertima elongata* and *Pertima asiatica)*

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**Table 1:** Salient features of selected small-scale aerobic composting techniques [8].

| Method | Salient features | | | | | Duration |
|---|---|---|---|---|---|---|
| | Substrate size reduction | Turnings in intervals (days) | Added aeration provision | Microbial inoculation | Supporting microbial nutrition | |
| **Indore pit** | | +15, +30, +60 | | Inoculum from old pit | | 4 months |
| **Indore heap** | Shredded | +42, +84 | | | | 4 months |
| **Chinese pit** | | +30, +60, +75 | | | Superphosphate | 3 months |
| **Chinese high temperature compost** | Shredded | +15 | Aeration holes in heap through bamboo poles/ maize stalks | | Superphosphate | 2 month |
| **Educator on-farm composting** | | +21 | Lattice of old branches/ poles at heap base | | | 2-3 months in summer; 5-6 months in winter |
| **Berkley rapid composting** | Shredded to small size | Daily or alternate day turning | | | | 2 weeks with daily turning and 3 weeks with alternate day turning |
| **North Dakota State University hot composting** | Shredded | +3 or +4 | 4-5 holes punched in centre of pile | | 0.12 Kg N per 90 cm dry matter | 4-6 weeks |
| **IBS rapid composting** | Shredded | +7, +14, the every 2 weeks | Raised platform ground/ perforated bamboo trunks | *Trichoderma* sp. | | 3-7 weeks |

and non-burrowing (*Eisenia fetida* and *Eudrilus eugenae*) known, respectively, as surface and deep dwelling [21]. Thus, referring to their habitat, they are classified into epigeics (mineral soil surface), anecics (burrows in mineral soil layers) and endogeics (mineral soil horizons). The advocated species for vermicomposting are of epigeic class well known by a great potential of waste decomposition. The common used epigeic species are *E. eugeniae*, *Eisenia foetida*, *Perionyx excavatus* and *Eisenia Andrei* [5,13]. However, it is recommended to combine these microorganisms with anecic ones as *Lampito mauritii* [22].

Vermicomposting can be impeded in pits, concrete tanks, rings, wooden and plastic crates [13]. In addition to its superiority on accomplishment's rate [21], vermicomposting has better performance in terms of nutrients recovery, microbial richness and phytotoxicity [5].

A combination of aerobic and anaerobic decomposition and vermicomposting may be useful for more effective production of high-quality compost: while high temperature ensures better quality through the destruction of pathogens and weed seeds, worms permit turning and maintaining an aerobic condition, thereby reducing the need for investment and labor [24].

**Microbial composting:** Composting is an exothermic reaction [20,17], $\Delta G = -667$ Kcal/mol, of organic matter's decomposition by successive microbial populations [7,4,12,22] that the interfered type depended on mass's temperature [14] . Referring to these last authors, in view of the optimal temperature ranges of their growth activities, microbial groups can be classified in psychrophilic (optimum growth temperature below 20°C), mesophilic (prefer temperatures oscillating between 20 – 40°C; presented by fungi in particular molds and bacteria), thermotolerant and moderately thermophilic (favor temperatures comprising between 40 - 60°C; represented specially by actinomycetes) and thermophilic microorganisms represented solely by thermophilic bacteria that wish temperatures between 60°C and 80°C (Figure 1).

The mass of compost is characterized by microbial diversity which enables it to overcome both environmental and nutritional conditions [14]. The microorganisms occupying a compost pile are classified, predominantly, into bacteria, fungi and actinomycetes which may be facultative or strict aerobic and have individual preferential substrates and environmental conditions for growth [12].

Bacteria: They are typically unicellular with a size of 0.5 to 3 µm conferring them, in addition to their short generations, a prevalence regarding with micro-organisms of greater dimensions such as fungi [17]. This predominance is mainly perceived during the first stage of composting owing to their high capacity to promptly transfer soluble substrates inside their cells [22]. They include a wide range of organisms able to withstand unfavorable environmental conditions in form of spores [14].

Fungi: They form networks of individual cells in strands called filaments. They favor mesophile temperature (5-37°C) excepting some thermophile ones. They have a lignocellulotic degrading capacity like *Phanerochaete chrysosporium,* higher rate of nitrogen and an acid pH. They tend to be present overridingly in the later stages of composting seeing the decay-resistant nature of the materials they decompose (woody substances, waxes, proteins, hemicelluloses, lignin, and pectin) which are not accessible for bacteria.

**Actinomycetes**: They are lesser effective nutrient competitors than bacteria and fungi [17]. Their growth is stimulated by the derived humic acids [3]. They are pervasive, namely, in the later stages of composting for attacking the remaining non decomposed compounds and improving hygienisation [17]. 90% of actinomycetes biomass is represented by *Streptomyces* and *Nocardia*. They are, putatively, responsible of the characteristic earthy smell of the compost given their production of sesquiterpenoid compounds such geosmine. Under drastic conditions, actinomycetes strive and survive as spores [23].

**Physical composting:** Physically, composting is a biodegradation process that depends mainly on temperature, humidity, oxygen content and porosity of the compost's mass. The control of temperature is ultimate for monitoring the composting efficiency [9,18] seeing that it, affects the growth rate, metabolic activity and type of interfering microorganisms' community [4] and influences the physicochemical characteristics of the final product [9]. It was affirmed that a small size of the pile and excessive exposure to cold weather can spike the

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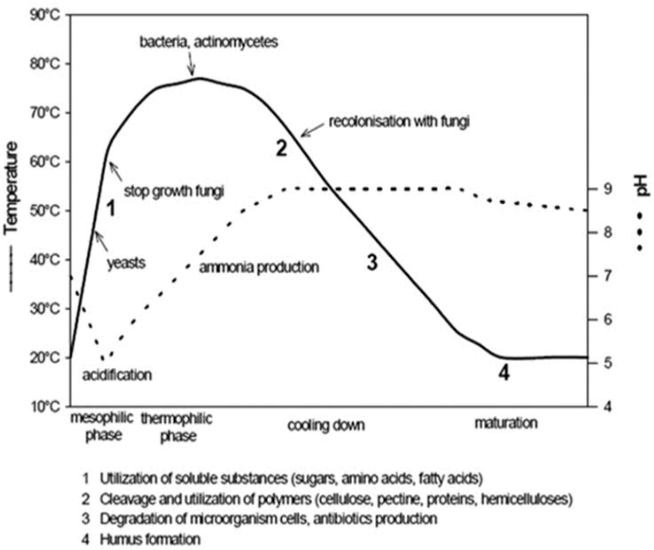


**Figure 1:** Schematic description of the composting process [4].

temperature increment [14]. The temperature curtailment reflects a deficiency in oxygen and moisture. The recorded temperature at any point of a compost heap results from the rate of heat evolution and transfer [15]. Heat evolution is affected by the chemical composition of starting material, the moisture content and the turning frequency hence heat transfer is influenced by the distribution of heat within the composting mass and its removal. This transfer can be realized by radiation, conduction, convection, evaporative cooling and / or sensible heating.

In addition to temperature, moisture affects considerably the composting process especially that most of the decomposition is impeded in thin liquid films on the surface of particles [12] . The advisable moisture during the composting process depends on the wastes to be composted, but generally the initial mixture should be at 50 - 60 % [18,24] and the final output should have a value of 30% [8]). Broadly, pertinent moisture content should enable the achievement of a balance between organic matter decomposition and air renovation in the feedstock mass [12]. In practice, a lack of humidity slows the process by disrupting the microbial activity and produces fungal pathogens such as *Aspergillus fumigates* and white, a resistant form of actinomycetes, whilst a too wet pile induces anaerobic conditions and entails, thus, additional turnings [14,16,25]. Moisture adjustment can be fulfilled by aeration and water addition occurred during turning operation [12].

The content on oxygen is a requisite factor in composting process too. It depended on its porosity and the microbial activity. The supply in oxygen can be realized by regular turnings or injection by forced ventilation [25]. Low levels of oxygen slow composting rate and favor anaerobic metabolism inducing nuisance odors and polluting gases. Aerobic metabolism requires 5-10% of oxygen (v/v) in the free air space of the pile. In order to accomplish the oxygen and water requirement for the microbial population, a compromise should be achieved between the free air space and the moisture content for each particular mixture [20]. In conjunction to these factors, performance of composting process is affected significantly by porosity of the materials. Bernal et al. [17] considered that a porosity greater than 50% induces a temperature's reduction (energy loss exceeds heat produced) whilst a value lesser than 35% leads to anaerobic conditions and odor generation. Broadly, porosity is improved by a more uniform mix of material.

It is noteworthy that these physical parameters depend on the type of composting system [20]. Indeed, it was affirmed that porosity is low in heaps and pits [24,26], moisture is lower in windrow shape than in concave, high porosity and appropriate temperature are impeded with turning windrows [14] while vessel system permits keeping of oxygen out of the system and capture of the released biogas [12].

## Phases of Compost

The composting process can be devised into four successive phases:

### Mesophilic phase

This phase lasts 1 to 3 days (Figure 1). Initial fresh materials with a low molecular weight, simple chemical structure and water solubility pass straightforwardly through the cells walls of the mesophilic bacteria and /or thermotolerant fungi and bacteria [18] inducing a prompt increase of the temperature owing to energy of the organic combinations. The pH typically decreases as organic acids are produced [22].

### Thermophilic phase

This phase is characterized by a noticeable increment of temperature in the center of the pile (Figure 1) consequently to vigorous degradation of organic matter's complex (fats, cellulose, hemicelluloses and some lignin) by thermophilic microorganisms represented namely by fungi and numerous thermophile bacteria, especially the genre *Bacillus* [22]

In addition to temperature increment, alkalinity of the medium, release of $CO_2$ in significant quantity and an obvious dryness of the compost pile subsequent to enormous water evaporation are often noted [22]. Moreover, pathogens were destroyed, actinomycetes in particular streptomycetes strive, larvae were killed and most weed seeds were cracked: it is the sanitation of the compost [17].

These two phases can be assimilated in one phase known as active or degradation phase [9,22].

### Cooling phase

It is recognized as the curing phase too. It starts when turning no longer reheats the pile [8]. This phase is characterized by a conspicuous decline of the temperature to this of ambient air (Figure 1) due to the reduction of microbial activity concomitantly with the depletion of degradable organic matter: sugars, cellulose and hemicelluloses [9,18]. Microorganisms are dominated by mesophilic ones originating from surviving spores [22]. A big diversity of bacterial taxonomy and metabolism was enunciated and several mesophilic and thermotolerant actinomycetes, yeasts and fungi reappear (Figure 1). Commonly, curing period lasts 30 days and insures enduring against the risks of immature compost's application [8,16,17,23].

The final stage of this phase marks the stability of compost [9]. These three phases can be combined in the biooxidative one [18].

### Maturation phase

The needed period for maturation of the compost depends on initial materials: lignocellulotic wastes (manure) can be swiftly composted (above 6 weeks) whereas lignic wastes (green wastes) require, at least, six months being ready for use after their composting. Furthermore, external factors like oxygen supply, moisture content, active turning and outside temperature affect strikingly the taken time for the maturation phase [17]. During this phase, macroorganisms such as lombrics, several insects, mites, gastropods and myriapods interfere. Microorganisms namely fungi ensure the humification process [17,23,22].

## Advantageous of Composting

The use of compost has assumed significant relevance in agriculture owing to its numerous advantageous [27]. Indeed, it ensures:

The waste management: Composting permits the wastes' reinsertion into economic and environmental innovation [6,8]. It is considered as a promising alternative to sanitary landfill input, dumping and incineration [7,4,12,22,28,29]. Likewise, it constitutes an appropriate solution for shrinking biodegradable residues' volumes [9,16,30] and a safe option for sustainable solid waste management [5] combining the recovery of valuable resources with environmental protection [18].

Enhancement of the soil's fertility: Application of compost is considered as a common provider of organic matter in soil given its both amendment and fertilizer roles [8,11,13,21]. Indeed, it replenishes this content in a cheap cost [29] and permits more sustainable building of the soil fertility and tilth [16,26,31] than the chemical fertilizers. This effect was noted, too, with the compost tea [32].

Improvement of the physical properties: Ozores-Hampton [14] indicated that compost's application improves soil's physical properties such as porosity and CEC, fights against degradation of the soil surface [22] by mitigating runoff and erosion's processes [1,14,26,28], reduces intensity of sand flux whereby increases the soil's strength and roughness, enhances water retention [29] and reduces the density affording opportunity for deeper root penetration [16]. Protection against soil-borne diseases [1,7,13] specified that the main plant diseases suppressed by composts are 'wilt' caused by *Fusarium* spp.; 'damping off' caused by *Fusarium, Pythium, Rhizoctonia* and *Sclerotium* spp.; 'stem and root rot' caused by *Fusarium, Rhizoctonia, Pythium, Phytopthora, Sclerotium* and *Aphanomyces* spp. This suppression varies considerably with the compost inclusion's rate, feedstock materials [11], the degree of organic matter's decomposition [16,32] and population size [33]. Martin and Brathwaite [11] reported that the suppressive effect of compost is, in nature, biological rather than chemical or physical seeing that the water extracts of several composts are suppressive of soil-borne pathogens while they don't contain antibiotics or siderophores. These authors have identified four mechanisms of the attack:

Antibiosis: It corresponds to an association between two organisms where the production of antibiotics (specific and/or non-toxic specific metabolites) by one organism has a direct effect on the other one. It is the case of bacteria and fungi against *F. oxysporum*, *Enterobacter* which produces chitinolytic enzymes against *Rhizoctonia solani* and *Gliocladium virens* which affects *P. ultimum by gliotoxin;*

Competition: It occurs when a non-pathogen enters in competence with a plant pathogen for a resource lending to disease control. The attack of *Pythium spp* by lessening of the availability of iron *via* the production of low molecular weight ferric-specific ligands remarked in iron limiting conditions exemplifies this process;

These two mechanisms seem being more efficient against pathogens with propagules of 200 mm diameter including *Phytophthora* and *Pythium spp;*

Parasitism: This attacking mechanism is impeded in four successive stages: chemotrophic growth, recognition, attachment and degradation of the host cell walls through the production of lytic enzymes. These steps, namely the last one, are influenced by the presence of glucose and other soluble nutrients that repress the production of lytic enzymes used to kill pathogens. This mechanism is prominent with propagules of 200 mm diameter;

Numerous studies displayed that microbiostasis (antibiosis and/or competition for nutrients) and hyperparasitism are the main adopted mechanisms.

Induced systemic resistance impeded by numerous beneficial microorganisms namely *Trichoderma spp.*

The aforementioned mechanisms can be categorized into general and specific [2,11]. General suppression is a quantitative mechanism not straightforwardly transferable from one medium to another as competition [11]. However, the specific mechanism refers to the elimination of pathogens by hyperparasitism (colonization resulting in cell lysis and death) and systemic resistance [4,32]. The parasitism of *Trichoderma* spp., versus propagules (sclerotia) of *Rhizoctonia* species exemplifies this mechanism [16]. Martin and Brathwaite [11] indicated that the general suppression was more dominant than the specific one.

In addition to biological protection, compost has a chemical suppressive action [33]. This property is ensured by some compounds as polyphenols, fulvic and humic substances, alcalinization effect owing to the sensibility of several agents such as clubroot to basic pH or through released toxic substances such as waxy substances produced by the decomposition of lignin.

The protection of plants against diseases is recorded with the vermicast [13] by suppressing, repelling or killing them through pesticidal action [1]. Furthermore, current reports have proved this activity with the compost tea in control of telluric agents [3,18,34] and foliar pathogens [34]. Indeed, Zhang et al. [32] reported its efficiency in treating powdery mildew and downy mildew of grape caused respectively by *Uncinula necator* and *Plasmopara viticola*, grey mold of strawberries and late blight of potato. As the same, the suppression of bacterial spot of tomato, microdochium (foliar fungus) on turf's leaves and *Phytophthora infestans* in potatoes by foliar sprays of compost's extract.

- Sanitation of toxic substances [1] and remediation of contaminated soils *via* heat's production, the long term treatment duration and the development of a saprophyte flora competing with pathogen population [22]

- Substitution of peat: Compost is suggested to be a feasible substitute for peat based on its better performances regarding the plant morphology, biomass, and yield [11,35]

- Stimulation of the plant's growth by dint of humic substances that can affect it directly (stimulation of proteins' synthesis, hormonal effect such as this of gibberellins, auxins and cytokinins, increment of photosynthetic activity) or indirectly (solubilization of oligo-elements, reduction of compounds' toxicity, stimulation of microbial activity) [1,8,13,19,21]. Sinha et al. [1] indicated that the promotion of growth by vermicompost is of 5 - 7 times over other bulky organic

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fertilizers and 20 - 40 % higher than chemical fertilizers. Moreover, it was proved that the foliar application of humic and fulvic acids in combination with others nutrients enhances the vegetative growth of plants.

## Standardization of the Compost's use

Feedstock, composting system and management have been reported to affect significantly the compost's quality [11]. The aforementioned advantageous of compost's application depend on its quality which is closely correlated to both stability and maturity [36]. Seeing diversity of compost' feedstock and composting technology, it may be advisable to adopt a combination of methods evaluating compost's maturity and stability that differ in simplicity, duration and approaches [16,30]. These methods are broadly classified into physical, chemical and biological groups [18]. Although these wide approach, there is still a controversy to the reliable parameters that can be used for defining maturity and /or stability of the compost [16,30].

### Evaluation of compost's stability

Compost's stability is defined as the level of organic matter's decomposition [4]. Francou [19] estimated this in relation to the content on organic carbon (Table 2). Ozores-Hampton et al. [15] considered that it represents the degree of nitrogen and $CO_2$ consumption to support biological activity [18,19,22]. This activity generates anaerobic conditions [23]. Leads to the production of harmful compounds such as hydrogen sulfide and nitrite [17] and permits the release of water vapor which induces the plant stunting and leaves' yellowing. This activity can be assessed by determining the microorganisms' respiration (measurement of $O_2$ consumption, $CO_2$ production, self-heating capacity) that is inversely correlated to stabilization (Table 3). Yoshida et al. [26] reported that oxygen's deficiency stimulates the growth of anaerobic microorganisms, slows the composting process and produces odors. Graves and Hattemer [13] provided a minimum oxygen concentration of 5 percent for maintaining aerobic conditions.

Furthermore, compost's stability can be forecasted *via* malodors, the nutrient availability, the available carbon or other energy sources, color, heavy metal dissolution, the environmental health risks [37] and the content on organic volatile acids such as acetic and butyric ones [14]. Indeed, these acids are mainly produced subsequently to incomplete oxidation due to low $O_2$ diffusion rate relative to respiration one. These last authors affirmed that presence of these acids is indicative of anaerobic fermentation thus instability and are inducers of odors. However, their absence does not necessarily indicate stable compost. USDA (2000) noted the relationship volatile acids/ stability (Table 4). The C/N ratio is commonly adopted as an indicator of compost's stability: Dayegamiye et al. [25] enuciated that stabilization of compost is reflected by a C/N ratio less than 30 whereas Zbytniewski and Buszewski [38] reported that it is achieved with a ratio of 15. Albrecht [22] reported that stable compost is characterized by a C/N ratio limited between 10 and 15.

The redox potential is putatively an indicator of compost's stability: during incubation's period, stable material shows stable redox potential's value whereas lesser stable one displayed a reduction of this parameter [15]. Khiyami et al. [20] indicated that stable composts are characterized by alkaline pH. Albrecht [1] thank that conversion of lignin to humic acid is in "the heart" of the compost's stabilization. Thus, humification indices such as humification index, humification ratio and humification percentage, are considered as reliable parameters in evaluating compost's stability [6] even their absolute values vary greatly among feedstock of composts.

### Evaluation of compost's maturity

Compost's maturity estimates the degree of completeness of composting [7,9] and its readiness for employment [39] seeing that immature compost induces problems during storage (establishing anaerobic conditions), marketing and use [7]. Thus, it ascertains its phytotoxic behavior [14,40,18,19] which is strongly related to the composting method: indeed, phytotoxins disappeared faster in piles than in windrows [41].

Maturity can be estimated *via* intensity of the microbial activity using the Dewar self-heating test based on the concept that this activity induces a significant heat' production. USDA (2000) indicated the level of compost's maturity accordingly to this test (Table 3). Brinton et al. [23] considered that the Dewar test is limited seeing that it mostly distinguishes only very mature from very immature. Brinton et al. [23] specified the use of compost regarding it maturity's level (Table 5). The continual microorganisms' activity after compost's application immobilizes native and added nitrogen [40] and induces anaerobic conditions in the root system where recorded an increment of temperature [15]. Besides, it produces ammonia, ethylene oxide and lower molecular weight fatty acids [16,22] acetic, propionic, isobutyric, butyric and isovaleric acids [15] which inhibit seeds' germination [36].

In addition to this test, microbial activity can be estimated using the Solvita test based on carbon mineralization (respiration) and ammonia gas emission [23]. Francou [19] indicated that an index of 1 to 8 characterized mature compost.

**Table 2:** Evaluation of stability/ maturity of compost referring to the content of organic carbon in relation to the total one 108 days after composting at 28°C [19].

| Degree of stability of compost | C-$CO_2$ 108 days after composting (%) | Degree of maturity of compost |
|---|---|---|
| Very stable | [0; 10] | Very high |
| Stable | [10; 15] | High |
| Relatively stable | [15; 20] | Average |
| Unstable | [20;30] | Slight |
| Very unstable | >30 | Very slight |

**Table 3:** Dewar self-heating test and $CO_2$ loss for determining the compost stability/maturity (USDA 2000).

| Eating rise over ambient | $CO_2$ loss (mg C $g^{-1}$ C $d^{-1}$) | Rating | Description of stability |
|---|---|---|---|
| **0-10** | 0-2 | V | Completely stable, can be stored |
| **10-20** | 2-8 | IV | Maturing compost, can be stored |
| **20-30** | 8-15 | III | Material still composting, don't store |
| **30-40** | 15-25 | II | Immature, active composting |
| **40-50** | >25 | I | Fresh, very active composting |

**Table 4:** Volatile organic acids as indicator of stability (USDA 2000).

| Volatil organic rating | Level of volatile organic acids dry basis (ppm) |
|---|---|
| Very low | <200 |
| Medium-low | 200-400 |
| Medium | 1,000-4,000 |
| High | 4,000-10,000 |
| Very high | >10,000 |

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**Table 5:** Dewar self-heating increments, rating and description of stability/maturity classification [23].

| Heat rise (°C) | Official class of stability | Description of group (Brinton et al., 2001) | | |
|---|---|---|---|---|
| | | **Descriptors of group** | **Compost use** | **Major group** |
| 0-10 | V | Very stable, well-aged | Potting mixes, seedling starters | Finished compost |
| 10-20 | IV | Moderately stable; curing | Gardening, greenhouse cultivation | |
| 20-30 | III | Material still decomposing; active | Grapes, fruit, apple | Active compost |
| 30-40 | II | Immature, young or very active | Field cultivation, greenhouse hotbeds | |
| 40-50 | I | Fresh, raw, just mixed ingredients | | Fresh compost |

**Table 6:** Phytotoxicity limits as indication of stability [23].

| Percent inhibition | Classification of toxicity |
|---|---|
| 81-100 | Extremely toxic |
| 61-80 | Highly toxic |
| 41-60 | Toxic |
| 21-40 | Moderately toxic |
| 0-20 | Slightly to non toxic |

Commonly, mature compost is distinguished by a pH of 8 [18,22] while acid pH characterizes immature one. The C/N ratio is largely used as an indicator of compost's maturity even there is no general consensus about a specific value [2]: indeed, the interval indicating compost's maturity ranges between 25 and 35 for Ryckeboer et al. [35] yet it oscillates between 25 and 40 for Baldwin and Greenfield [15] and Naidu et al. [3] Raj and Antil [36] have reported that a C/N ratio lesser than 20 and even 15 characterizes mature compost whilst Zbytniewski and Buszewski [38] have reported that maturity is achieved with a ratio lower than 12. Conversely, Komilis and Tziouvaras [18] adopted that a C/N ratio of 10 classified composts as mature. However, this parameter can be misleading particularly when the compost contains higher level $NH^+$ - N.

Mature compost is characterized by total nitrogen content of 1 to 4 % of dry mass [20]. A low degree of released carbon dioxide reflects advanced humification [15]. Indeed, Francou [19] indicated that the proportion of organic carbon in mineralized compost for 108 days is of 0 to 10 % for very mature compost hence of 10 to 15 % for mature one (Table 2).

The increasing level of humic acid, HA, produced by polymerization and/or degradation of fulvic acid, FA, is strictly concomitant with the compost's maturity [17,41,42]. Indeed, $H_A/F_A$ ratio inferior to 1 characterizes immature compost yet values higher than 1.9 specify mature one [33] without exceeding the limit of 3 [1]. Besides, it was suggested that a $C_{HA}/C_{FA}$ ratio limited between 1.7 and 3 pertains mature compost [12]. Spectroscopic analyzes of humic substances indicate that mature composts are characterized by a low $A_{472}/A_{664,}$ recognized by $Q_4/Q_6$, [1,43]. Higher index of decomposition of chlorophyllous compounds, predictable by the absorbance in 667 nm, implicates that decomposition of these compounds is incomplete thereof a lack of maturity [44].

## Biological parameters

In addition to chemical and physical analyzes, biological tests are adopted to complement them [45,46] seeing that toxic substances don't present a permanent state [45]. Moreover, toxins are produced solely in certain stages of decomposition and tend to be swiftly inactivated and plants' sensitivity to toxins tends to be transient [25]. Plant tests used in quality standards are categorized into: germination tests; growth tests (assessment of both top and root growth), combination of germination/ growth and other biological methods like enzyme activities [18]. The most adopted germination test is this of Zucconi et al. [43]. It is, commonly, carried out on garden cress seeds incubated on various concentrations of compost's extracts. Many species including cabbage, lettuce, carrot, cucumber, tomato and oats are recommended for this test too. However, due to the selective toxicity of different composting materials towards species, it will be necessary to select species that are sensitive to the specific composting materials before this test can be used for the evaluation of compost's stability [44].

It is noteworthy that the germination index, GI, has been proven to be the most adequate parameter in estimation of the phytotoxic risks [44]. Referring to this parameter, compost presents higher phytotoxicity when GI is lower than 50 %, the phytotoxic potential is moderate in case of GI values limited between 50 and 80 % whereas values over 80 % reflect that the material does not show phytotoxic risks [41]. Brinton [23] specified the level of toxicity referring to the inhibition of germination (Table 6). Exceptions can be found by values of GI over 100 which indicate the presence of nutrients or germination promoters [43]. Nonetheless, a widely accepted threshold germination index, above which maturity can be ascertained, does not appear to exist in the literature [19].

## References

1. Sinha RK, Hahn G, Singh PK, Suhane RK, Anthonyreddy A (2011) Organic farming by vermiculture: producing safe, nutritive and protective foods by earthworms. American Journal of Experimental Agriculture 1: 363-399
2. Narayanan S (2005) Organic farming in india: relevance, problems and constraints. National Bank for Agriculture and Rural Development 38: 1-79.
3. Naidu Y, Meon S, Kadir J, Siddiqui Y (2010) Microbial starter for the enhancement of biological activity of compost tea. Int J Agric Biol 12: 51-56.
4. Beffa T (2002) The composting biotechnology: A microbial aerobic solid substrate fermentation complex process. The composting process and management. Madep, USA.
5. Singh D, Suthar S (2012) Vermicomposting of herbal pharmaceutical industry waste: earthworm growth, plant-available nutrient and microbial quality of end materials. Bioresource technology 112: 179-185.
6. Loukil F, Rouached L (2012) Modeling packaging waste policy instruments and recycling in the MENA region. Resources, Conservation and Recycling 69: 141-152.
7. Butler T, Sikora L, Steinhilber P, Douglass L (2001) Compost age and sample storage effects on maturity indicators of biosolids compost. J Environ Qual 30: 2141-2148.
8. Misra R, Roy R, Hiraoka H (2003) On-farm composting methods: food and agriculture organization of the United nations (FAO).
9. Khiyami M, Masmali I, Abu-khuraiba M (2008) Composting a mixture of date palm wastes, date palm pits, shrimp, and crab shell wastes in vessel system. Saudi Journal of Biological Sciences 15: 199-205.
10. Jindo K, Suto K, Matsumoto K, García C, Sonoki T, et al. (2012) Chemical and biochemical characterisation of biochar-blended composts prepared from poultry manure. Bioresource technology 110: 396-404.
11. Martin C, Brathwaite R (2012) Compost and compost tea: Principles and prospects as substrates and soil-borne disease management strategies in soil-less vegetable production. Biological Agriculture & Horticulture 28: 1-33.

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12. Baptista MHDC (2009) Modelling of the kinetics of municipal solid waste composting in full-scale mechanical-biological treatment plants.
13. Graves R, Hattemer G (2000) National engineering handbook. Composting. Part 637.
14. Ozores-Hampton M (1999) Compost as an alternative weed control method. Hort Science 33: 938-940.
15. Baldwin KR, Greenfield JT (2009) Composting on organic farms. North Carolina Cooperative Extension Services: Raleigh, NC, USA.
16. Ryckeboer J, Mergaert J, Vaes K, Klammer S, De Clercq D, et al. (2003) A survey of bacteria and fungi occurring during composting and self-heating processes. Annals of Microbiology 53: 349-410.
17. Bernal MP, Alburquerque J, Moral R (2009) Composting of animal manures and chemical criteria for compost maturity assessment. Bioresource technology 100: 5444-5453.
18. Komilis DP, Tziouvaras IS (2009) A statistical analysis to assess the maturity and stability of six composts. Waste Manag 29: 1504-1513.
19. Francou C (2003) Stabilisation de la matière organique au cours du compostage de déchets urbains: Influence de la nature des déchets et du procédé de compostage-Recherche d'indicateurs pertinents. INAPG (AgroParisTech).
20. Nagavallemma K, Wani S, Lacroix S, Padmaja V, Vineela C, et al. (2004) Vermicomposting: recycling wastes into valuable organic fertilizer. Global Theme on Agroecosystems, India.
21. Gajalakshmi S, Abbasi S (2004) Earthworms and vermicomposting. Indian journal of biotechnology 3: 486-494.
22. Albrecht R (2007) Co-compostage de boues de station d'épuration et de déchets verts: Nouvelle méthodologie du suivi des transformations de la matière organique. Université de droit, d'économie et des sciences-Aix-Marseille III.
23. Brinton W, Evans E, Droffner M, Brinton R (2001) A standardised dewar test for evaluation of compost self-heating. Biocycle Report. Woods End Research Laboratory, USA.
24. Estévez-Schwarz I, Seoane S, Núñez A, López-Mosquera M (2009) Characterization and evaluation of compost utilized as ornamental plant substrate. Compost science & utilization 17: 210-219.
25. N'Dayegamiye A, Turcot M, Laverdière M (2005) Effets d'apports de composts de résidus verts urbains sur les rendements et la nutrition azotée du maïs-grain et sur certaines propriétés du loam argileux de la série Providence. Agrosol. 16: 91-98.
26. Yoshida N, Hoashi J, Morita T, McNiven SJ, Yano K, et al. (2001) Monitoring of the composting process using a mediator-type biochemical oxygen demand sensor. Analyst 126: 1751-1755.
27. Martínez-Blanco J, Muñoz P, Antón A, Rieradevall J (2009) Life cycle assessment of the use of compost from municipal organic waste for fertilization of tomato crops. Resources, Conservation and Recycling 53: 340-351.
28. Mubarak A, Ragab OE, Ali AA, Hamed NE (2009) Short-term studies on use of organic amendments for amelioration of a sandy soil. African Journal of Agricultural Research 4: 621-627.
29. Rajbanshi S, Inubushi K (1997) Chemical and biochemical changes during laboratory-scale composting of allelopathic plant leaves (Eupatorium adenophorum and Lantana camara). Biology and fertility of soils 26: 66-71.
30. Bustamante M, Said-Pullicino D, Paredes C, Cecilia J, Moral R (2010) Influences of winery-distillery waste compost stability and soil type on soil carbon dynamics in amended soils. Waste Management 30: 1966-1975.
31. Gharib FA, Moussa LA, Massoud ON (2008) Effect of compost and bio-fertilizers on growth, yield and essential oil of sweet marjoram (Majorana hortensis) plant. Int J Agric Biol 10: 381-382.
32. Zhang W, Han D, Dick W, Davis K, Hoitink H (1998) Compost and compost water extract-induced systemic acquired resistance in cucumber and Arabidopsis. Phytopathology 88: 450-455.
33. Scheuerell SJ, Mahaffee WF (2004) Compost tea as a container medium drench for suppressing seedling damping-off caused by pythium ultimum. Phytopathology 94: 1156-1163.
34. Perez-Murcia M, Moral R, Moreno-Caselles J, Perez-Espinosa A, Paredes C (2006) Use of composted sewage sludge in growth media for broccoli. Bioresource technology 97: 123-130.
35. Miyittah M, Inubushi K (2003) Reduction of phytotoxicity and maturation of okara compost during decomposition. Technical Bulletin-Faculty of Horticulture Chiba University 7-16.
36. Raj D, Antil R (2011) Evaluation of maturity and stability parameters of composts prepared from agro-industrial wastes. Bioresource technology 102: 2868-2873.
37. Cabañas-Vargas D, Sánchez-Monedero MÁ, Urpilainen S, Kamilaki A, Stentiford E (2005) Assessing the stability and maturity of compost at large-scale plants 25-30.
38. Zbytniewski R, Buszewski B (2005) Characterization of natural organic matter (NOM) derived from sewage sludge compost. Part 1: chemical and spectroscopic properties. Bioresource technology 96: 471-478.
39. Itävaara M, Venelampi O, Vikman M, Kapanen A (2002) Compost maturity-problems associated with testing. Springer, Finland.
40. Bernal M, Paredes C, Sanchez-Monedero M, Cegarra J (1998) Maturity and stability parameters of composts prepared with a wide range of organic wastes. Bioresource technology 63: 91-99.
41. Zucconi F, Pera A, Forte M, De Bertoldi M (1981) Evaluating toxicity of immature compost. Biocycle 22: 54-57.
42. Hsu JH, Lo SL (1999) Chemical and spectroscopic analysis of organic matter transformations during composting of pig manure. Environmental Pollution 104: 189-196.
43. Zucconi F, Monaco A, Forte M, De Bertoldi M (1985) Phytotoxins during the stabilization of organic matter. Composting of agricultural and other wastes/ edited by JKR Gasser.
44. Tam N, Tiquia S (1994) Assessing toxicity of spent pig litter using a seed germination technique. Resources, Conservation and Recycling 11: 261-274.
45. Environmental engineering. Chapter 2–Composting: 16-40.
46. Unit RO (2006) Overview of compost tea use in New South Wales.

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