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COMPOSTING HAND BOOK FOR YOUNG FARMERS AND ALL USERS

ÇANAKKALE ONSEKİZ MART ÜNİVERSİTESİ 1992

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COMPOSTING HAND BOOK FOR YOUNG FARMERS AND ALL USERS

THE WEB PAGE OF THE PROJECT

CONTENTS Page

Table List Page

Figure List Page

FOREWORD

This handbook is to determine how to make easily compost with in the scope of sub-work action type KA220-VET-Cooperation partnerships in vocational education and training of the project code 2021-1-TR01-KA220-VET-000024977 " Encouraging young farmers to produce compost for healthy soil and organic food using innovative solutions" supported Europen Union and Turkish National Agency under 2022 program. It has been prepared as a first intellectual output of project titled "COMPOSTER MANUAL”.

Compost is a mixture of organic residues (manure, animal carcasses, straw, etc.) that have been piled, mixed and moistened to undergo thermophilic [high heat, 113 to 160 degrees Fahrenheit (F)] decomposition (SSSA, 1997). Composting is the natural process of 'rotting' or decomposition of organic matter by microorganisms under controlled conditions. Raw organic materials such as crop residues, animal wastes, food garbage, some municipal wastes and suitable industrial wastes, enhance their suitability for application to the soil as a fertilizing resource, after having undergone composting. Compost provides a stable organic matter that improves the physical, chemical, and biological properties of soils, thereby enhancing soil quality and crop production.

With in this scope;

Young farmers, agricultural faculty and vocational school students, non-governmental organizations and their members, people with small gardens in the city and rural areas learn how to make compost;

Ensuring the natural cycle by converting domestic, industrial and agricultural wastes into fertilizers;

Improving the soil with compost and enriching it in terms of organic matter;

In order to facilitate access to sustainable environment and healthy food with organic fertilization, a practical application-oriented compost manual book has been prepared. This handbook has been compiled by the project members to give some basic information about how to make compost. Practical suggestions has been given for preparing a compost heap. Common composting methods have been presented and literature list has been added for supplementary information.

Project Teams

10.01.2022

PROJECT PARTNERS

Çanakkale Onsekiz Mart University (Turkiye)

Çanakkale Onsekiz Mart University (COMU) has 49.791 students, is one of the most competitive universities in Turkey. The reputation and popularity of COMU in Turkey is based on the high quality teaching and learning experience available to students at the university. COMU actively seeks to propose and develop projects within international research programmes. COMU attracted millions of Euros in research grants and contract income from a variety of funders, including the EU, the Turkish Science and Technology Research Council (TUBITAK), the Turkish Ministry of Development, the Turkish Higher Education Council and various NGOs. The Agriculture Faculty initiated its BSc programs in the 1995-1996 academic year. At present, the Faculty of Agriculture is located in its own building on the Terzioglu Campus. Soil Science and Plant Nutrition department has many national and international projects related to soil science, plant nutrition and soil reclamation, conditioners, biochar and composts.

VšĮ "Žiedinė ekonomika" (Lithuania)

VsI "Ziedinė ekonomika" is an environmental NGO, which aims to transform Lithuanian economy to circular. Main areas of work include advocacy of best circular economy practises to national and municipal governments, sustainability and climate change education to youth and circular business practices consulting. In the area of advocacy, concentration is on reusable and recyclable packaging taxation, waste management regulation and incentives, sustainable agriculture policies in direct payments. VsI "Ziedine ekonomika" experts have been involved in several legislation change working groups, including biowaste composting. In the area of youth education, main focus is on sustainable consumption, circular economy models and climate change.

Ezine Gıda İhtisas Organize Sanayi Bölgesi (Turkiye)

Ezine Gıda Specialized Organized Industrial Zone has been established in 2016. In the cooperation communication signed with Çanakkale Onsekiz Mart University, many faculty members from the university work as advisors in this organization. According to the establishment protocol within the Ezine Gıda Specialized Organized Industrial zone, the sector groups of the participants are as follows: Manufacture of food products, processing and storage of meat and production of meat and fish products, processing and storage of vegetables and fruits, manufacture of vegetable and animal oils and fats, manufacture of dairy products, manufacture of ground grain products and starch and starch products, manufacture of bakery and bakery products, other foodstuffs, manufacture of food products and beverages, such as agriculture and food products industry and sub-industry.

Universidad Politecnica De Cartagena (Spain)

The Universidad Politécnica de Cartagena (UPCT) is a public university with long experience and tradition in engineering and economic studies. It places great emphasis on international cooperation and mobility, welcoming approximately 200 foreign students and lecturers. With over 90 R&D groups, this University aims to be not only a place for the dissemination of knowledge but also a source of scientific and technological creation. The Research Groups that participate in this project, have an ample experience in the fields of pig waste management, improvement of soil condition by amendment with pig slurry, efficient techniques for application of organic wastes, composting technologies of organic wastes, prevention, analysis and characterisation of nutrients in water bodies, implementation of innovative and cost-effective technologies for sustainable treatment of pig wastes, prevention of gaseous emissions from pig wastes. These groups have participated in several European and international projects, together with public bodies and private companies.

Isparta Uygulamali Bilimler University (Turkiye)

Agricultural Machinery and Technologies Engineering (AMTE), which is the department of Faculty of Agriculture, Isparta University of Applied Science has missions of conducting both educational program and applied research on agriculture within the sustainability direction prioritized by nationally and globally. The accomplishment of this basic goal is warranted by the scientific track record of the academic stuff and by the possibility of accessing additional top-notch research facilities available in AMTE focusing primarily on providing maximal scientific complementarity to the current professional skills of the researcher in AMTE while maintaining a solid link to their scientific background on agricultural mechanization, specifically agricultural waste management such as composting, biogas technologies, biomass and waste volarization. The priority area of advanced research are waste management in agriculture, composting engineering and technologies, biogas technologies and applications, optimization of composting process, modelling and simulation of composting process, composting technologies in rural areas, composting and compost applications, applications of compost as bio stimulants.

Canakkale Teknoloji Gelistirme Bolgesi A.S. (Turkiye)

Canakkale Teknoloji Gelistirme Bolgesi (CT) was established on 31.05.2012 and started its activities on 06.04.2014. Canakkale Teknopark provides its companies management support, consultancy on technical and administrative issues, and networking services for critical collaborations. In addition, he mentors students on business idea development and business model creation, and organizes various trainings and events under the headings of entrepreneurship, innovation and legislation. In order to transform projects and academic studies developed at Canakkale Onsekiz Mart University into value added products, it provides information and consultancy services on intellectual property rights and guides its entrepreneurs on issues such as corporatization, commercialization and internationalization.

CHAPTER 1

Introduction

Following the industrial revolution in the world, the accelerated agricultural production and the use of intensive agro-chemicals have started to cause negative changes in the natural balance, as well as the degradation of the ecosystem. The increase in the world population requires more food requirements.The reduction in arable land has led to the creation of different alternatives (hybrid seed, GMO and intensive mineral fertilization) for higher production However; unconscious and excessive consumption has begun to cause a large amount of waste. In addition to the wastes generated in rural and urban areas, industrial wastes and agricultural wastes have been started to be stored and disposed of, and important storage and environmental health problems have started to occur. In order to eliminate these problems, organic agriculture has started to be promoted in order to reach safe and healthy food, especially in developed and rich countries, and the recycling of wastes has been focused on. The pandemic in the last three years has once again proven how important healthy and reliable food is. Increasing production costs with the pandemic, especially mineral fertilizer and fertilizer raw material costs, high increases in transportation costs have started to necessitate the creation of alternative resources. In particular, the recycling (composting) of small-scale agricultural enterprises' wastes and other domestic and industrial wastes, their bringing into the economy and the creation of organic fertilizers, the zero waste approach in urban environments has started to come to the fore.

According to worldbank report (2020), around the world, waste generation rates are rising. In 2020, the world was estimated to generate 2.24 billion tonnes of solid waste, amounting to a footprint of 0.79 kilograms per person per day. With rapid population growth and urbanization, annual waste generation is expected to increase by 73% from 2020 levels to 3.88 billion tonnes in 2050
(https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management)
505 kg of municipal waste per capita were generated in the EU in 2020 and 48 % of municipal waste in the EU was recycled (material recycling and composting) in 2020. In January 2022 the European Commission (EC) opened a public consultation to gather feedback on the upcoming amendments to the Waste Framework Directive (WFD). The EC’s Agenda includes the adoption of the amendments in the second quarter of 2023. More specifically, this initiative intends to improve waste management in Europe by reducing waste generation also through re-

use of products or components, reducing mixed waste and increasing preparation for re-use or recycling by improving separate collection.

Waste composition differs across income levels, reflecting varied patterns of consumption. High-income countries generate relatively less food and green waste, at 32 percent of total waste, and generate more dry waste that could be recycled, including plastic, paper, cardboard, metal, and glass, which account for 51 percent of waste. Middle- and low-income countries generate 53% and 57% percent food and green waste, respectively, with the fraction of organic waste increasing as economic development levels decrease.

Globally, most waste is currently dumped or disposed of in some form of a landfill. About 37 % of waste is disposed of in some form of a landfill, 8 % is disposed of in sanitary landfills with landfill gas collection systems. Open dumping accounts for about 31% of waste, 19 % is recovered through recycling and composting, and 11 % is incinerated for final disposal.

According to 2020 data, 32.3 million tons of waste was collected in municipalities of Turkiye (TUIK, 2020). It was determined that 1387 out of 1389 municipalities in total provided waste services. While 69.4% of the 32.3 million tons of waste collected in municipalities where waste service is provided is sent to landfills, 17% to municipal dumps and 13.2% to recycling facilities, 0.4% is burned in the open and buried. It was disposed of by spilling into a stream or land. The average daily amount of waste per person collected in municipalities was calculated as 1.13 kg.

Everyone living in the world has the right to a clean environment and healthy food. Many countries have legal regulations regarding this. For example, in the Turkish constitution in the 56th article;

“Everyone has the right to live in a healthy and balanced environment. It is the duty of the State and citizens to improve the environment protect environmental health and prevent environmental pollution”.

Environmental law of Turkiye

Article 8;

“It is forbidden to directly or indirectly deliver all kinds of waste and residues to the receiving environment, store, transport, remove and engage in similar activities.

Article 11;

Metropolitan municipalities and municipalities are responsible for establishing, having, operating or operating domestic solid waste disposal facilities.

Industrial developments in recent years have brought along the environmental waste problems. The elimination or utilization of environmental wastes (industrial and agricultural) has become inevitable for today's societies. Generally, four different methods are used to evaluate and dispose of solid wastes: landfilling, incineration, composting and recycling (Tchobanoglous et al., 1993). Among these methods, composting has become increasingly important in recent years, as it is a process that accelerates the decomposition and stabilization of organic materials, renders agricultural and industrial wastes environmentally harmless, and provides agricultural use (de Bertoldi and Schnappinger, 2001).

Compost is a mixture of organic residues (manure, animal carcasses, straw, etc.) that have been piled, mixed and moistened to undergo thermophilic [high heat, 113 to 160 degrees Fahrenheit (F)] decomposition (SSSA, 1997).

Composting is the natural process of 'rotting' or decomposition of organic matter by microorganisms under controlled conditions. A mass of rotted organic matter produced from the waste is called as “compost”. Compost has been considered as a valuable soil amendment for centuries. Most people are aware that using composts is an effective way to increase healthy plant production, help save money, reduce the use of chemical fertilizers, and conserve natural resources. Compost provides a stable organic matter that improves the physical, chemical, and biological properties of soils, thereby enhancing soil quality and crop production (https://agritech.tnau.ac.in/org_farm/orgfarm_index.html).

Composting is an effective method for promoting the utilization of organic wastes. However, no organic material can provide the full range of benefits by themselves. In addition to providing essential plant nutrients, some carbonaceous organic materials, such as rice straw, corn stalks, rice hull, sawdust etc. are very useful in improving the physical and biological properties of the soil., Compost is a nutrient-rich fertiliser that helps gardens grow; it's human-made and consists of decomposed material. Additionally, raw organic materials such as crop residues, animal wastes, food garbage, some municipal wastes and suitable industrial wastes, enhance their suitability for application to the soil as a fertilizing resource, after having undergone composting. Composting offers many opportunities for farmers who are not in good economic condition to buy fertilizers and other farm inputs. Compost provide a readily heap source of plant nutrients. It also address the many risks associated with chemical fertilizers that are not only expensive but also harmful to the environment and human health.

Many organic vegetable growers prefer composted manure because composting reduces potential health and environmental risks of raw manure, and the compost contributes to more long-term soil fertility and soil health (Buchanan and Gliesmann, 1991). According to organic standards (USDA, 2017), “composted plant or animal materials must be produced through a process that establishes an initial carbon-to-nitrogen (C: N) ratio between 25:1 and 40:1 and achieves a temperature between 130°F and 168°F” (54.4–75.6°C). The C: N ratio is an important consideration when using various composts; it also is a controlling factor in the composting process itself (Brust, 2019). Composting and utilizing compost are advantageous tools in nutrient management plans that, when managed properly, reduce the potential to pollute and benefit crops. Compost is an organic fertilizer that can be prepared easily on the farm at very low cost. The most important input is the farmer's labour. Most of the compost ingredients can be easily found around the farm.

Composting requires routine introduction of oxygen, which stimulates aerobic microorganisms that feed on the organic components and convert the piled organic material to a fairly stable nutrient-rich soil amendment (Larney and Blackshaw, 2003). Compost can be applied to agricultural fields as a fertilizer, added to improve soil structure, substituted for peat in horticulture and used as a microbial additive to increase enzyme activities (Steger et al., 2007).

The soil benefits greatly from the addition of compost. Fertility, water-holding capacity, bulk density and biological properties are improved (Flavel and Murphy, 2006). Odors are reduced and fly eggs die due to the high temperatures occurring during microbial decomposition (Larney et al., 2006). Certain weed seeds can pass through livestock and grow in manure applied on cropland. Few weed seeds remain viable in properly composted manure, which can reduce the amount of herbicide or tillage needed for weed control. Process that helps degrade organic residue and waste of plant and animal origin to produce soil amendment for agricultural use has been widely known for centuries. Due to the increasing cost of production for organic products, the need for organic fertilizers and compost, which is an important alternative source of rural development, is increasing significantly. Based on this need, the project coordinator developed a strategic partnership project idea by evaluating that composting can be a way of evaluating the contributions to agricultural waste and greenhouse gas emissions in EU program countries. He prepared an evaluation report defining the vital importance of compost in terms of plant nutrients, its benefits for waste recycling, its usability as a natural pesticide, its function to reduce soil erosion and its roles in preventing soil degradation.

Agricultural practices such as excessive use of fertilizers and chemicals have been causing soil degradation, salinity, health effects, reduction in soil biodiversity, atmospheric and water pollution, and climate change.Maintaining soil organic matter and ensuring the cycling of nutrients is crucial to the success of soil management and agricultural productivity strategies. These practices include the application of organic and inorganic fertilizers combined with knowledge of how to adapt these practices to local conditions, aiming to maximize agronomic use efficiency of the applied nutrients and thus crop productivity. Beside conventional agriculture, organic production has also experienced rapid growth in the recent years. The ultimate goal of the project is to contribute to the improvement of soil health and organic production by teaching composting. In accordance with the selection of project priorities, thanks to the cooperation between universities, compost production guidelines will be prepared, marketing and promotion strategie

Additionally with this Project, long-term cooperation and partnership relations among Turkey, Lithuania and Spain in composting sector will be established. The best practices on compost production conformant to EU quality and standards and setting up healthy information exchange, to design training programmes on sustainable compost production methods and putting these methods into practice will be developed. Farmers will be trained, pilot exercises will be organized, and some innovative composting methods will be implemented.

Composter project has different target groups, such as organic waste producers, local farmers and farmers' associations, private consumers, environmental groups and organizations, Agricultural Faculty and Vocational School students, policy makers (local authorities and municipalities) and environmental NGO's.

The Project's Objectives were:

To contribute to the improvement of soil health as well as organic production through teaching composting process,

To establish long-term cooperation and partnership relations among Turkiye, Lithuania and Spain in composting sector,

To develop the best practices on compost production conformant to EU quality and standards and setting up healthy information exchange, To design training programme on sustainable compost production methods and putting these methods into practice,

To train farmers, organize pilot exercises, and to implement some innovative composting methods,

To contribute to environment protection and climate change mitigation,

To increase awareness of compost in the urban and rural area and agricultural faculty and vocational school students in Turkey and EU.

With this project, these outcomes are targeted;

Zero waste (evaluating organic farm and agricultural wastes)

Economical benefit (re-use of materials and promote circular economy)

Sustainable agriculture (compost production will help to develop sustainable agricultural systems with efficient use of resources)

Prevent soil and environmental pollution (using organic compost for plant production will be resulted in decrease chemical inputs to soil)

Climate change and soil healty (increasing soil carbon, promotes soil health and reduces climate change through carbon sequestrations in soils)

Project website was prepared for the dissemination of information about compost and other news related to project. The website address is, www.composterasmus.org

CHAPTER 2

Compost types

2.1 Farmyard manure

Farm manure consists of the decomposed mixture of solid and liquid feces of dairy and beef cattle, horses, sheep and goats, and the bedding material laid on the floor in the barns (Figure 1). It is defined as the product obtained as a result of the treatment (maturation / composting and removal of moisture / reduction) of animal feces on the floors with or without a substrate, and liquid farm manure is defined as "liquid product obtained by dissolving solid farm manure in water" (Kacar, 2013; Roman et al., 2015).

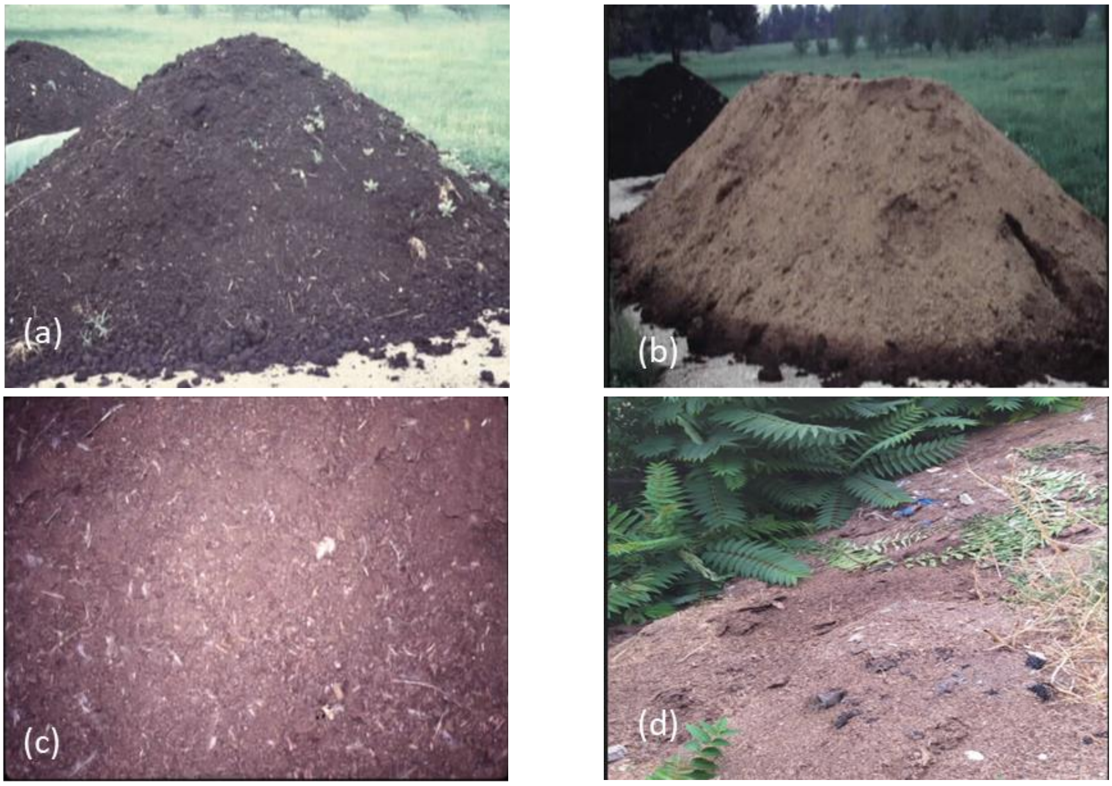


Figure 1. Cattle manure (a), hog manure (b), poultry manure, and horse manure (d)

The effect of farm manure is not unidirectional like chemical fertilizers. On the one hand, farm manure provides the soil with the necessary nutrients for the plant; on the other hand, it makes the structure of the soil suitable for agriculture. It increases the water holding capacity of the soil. It positively and significantly affects the water permeability of the soil. It prevents the independent flow of water from the soil surface, its evaporation, and the transport of arable land (erosion). Farm yard manure ensures that the soil is cultivated easily. In sandy soils, farm manure allows soil particles to bind to each other, while in heavy clay soils; it loosens the bond and increases porosity. It has a suitable effect on soil aeration. It makes the soils dark and increases the holding capacity (Soyergin, 2003; Kacar, 2013).

Many factors affect the content of farm manure. These are the breed and age of the animals, the amount and nutritional value of the feed fed, the work done by the animals, the type of bedding used and the bedding ratio, the condition of the barn, and the storing technique of the manure. Table 1 shows that the solid and liquid feces of animals have significant differences in terms of the plant nutrients they contain. On the other hand, in terms of P_2O_5, solid feces is richer than urine.

Table 1. Composition of animal manure in farm (Kacar, 1997)

	Composition of manure (%)							
	Water		N		P_2O_5		K_2O	
	Solid	liquid	Solid	liquid	Solid	liquid	Solid	liquid
Horse	75	90	0.55	1.35	0.30	Trace amount	0.40	1.25
Dairy Cow	85	92	0.40	1.00	0.20	Trace amount	0.10	1.35
Sheep	60	85	0.75	1.35	0.50	0.05	0.45	2.10
Pig	80	97	0.55	0.40	0.50	0.10	0.40	0.45

2.2 Green manure

The mixing of some green plants that have not completed their development with the soil is called green manure and the plants used for this work are called green manure plants (Figure 8). Green manure plants have a positive and significant effect on the physical, chemical and biological properties of the soil. Although a wide variety of plants are grown as green manure plants, leguminous plants are always preferred to non-legume plants and these are considered the best green manure plants. Plants that are frequently grown as green manure plants are given in Table 2 (Soyergin, 2003; Kacar, 2013).

It has been known for many years that legume plants used as green manure plants increase the N use efficiency of plants grown after them. With the pressure of the economy and environmental conditions, green manure has come to the agenda again, its effects on soil properties as well as on plant products, and the fact that green manure has an important place in the agroeconomic system (Figure 2) (Kacar, 2013).

Table 2. Green manure plants (Kacar and Katkat 1999)

Leguminous Plants	Non-legume plants
Clover	Oat
Meadow Clover	Barley
Stone Clover	Millet
Soybeans	Buckwheat

Canadian Feed Peas	Wheat
Cowpea Feed	Grass
Red Clover	Sudan grass
Japanese Clover	Mustard
Wild Hairy Vetch	Rape
Austrian Peas Rye	Oat

Figure 2. Green manure plants: a) broad bean, b) Feed peas, c) vetch, d) crops such as oats, broad beans, alfalfa and weeds

In order for a plant to be a green manure plant suitable for the purpose: a) It must develop rapidly, b) It must form abundant vegetative organs and c) It must be able to develop well even in poor soils. The rapid development of the plant allows more use of that plant both in crop rotation and in soil improvement. The fact that the plant has more vegetative organs allows more plant organs to be mixed with the soil, and it causes the plant to complete its decay in the soil in a shorter time due to its high water content. It is indisputable that the organic matter requirements of poor soils are higher than that of rich soils. In case other conditions are similar;

as a green manure plant, it should be preferred to grow leguminous plants over non-legume plants. It is possible to give more nitrogen to the soil as well as to give more organic matter with leguminous plants (Kacar, 2013).

2.3 Compost

Composting is a biological process in which organic materials such as animal manure, leaves, paper and food waste are converted into an earthy structure called compost by microorganisms. Composting is actually a natural process in nature, wherever plants grow. When plants shed their leaves or any of their residues fall into the soil, these plant residues are decomposed by microorganisms in nature and converted into humus form. In other words, microorganisms decompose organic material into more stable organic end products, converting it into carbon dioxide, water, heat and humus. In fact, this is nutrient recycling in the ecosystem. Composting was created by examining and imitating this natural phenomenon well. In other words, this natural decomposition was promoted and accelerated by the creation of ideal conditions. Compost may be defined as the stabilized and sanitized product of composting, compatible and beneficial to plant growth (Figure 3) (Insam and Bertoldi, 2007). Compost is a useful natural product from less useful, and often wasted, organic ingredients (Rynk et al., 2022). It changes the soil, improving the physical, chemical and biological properties, resulting in increased crop productivity and increased environmental quality (Brown and Cotton, 2011). The compost formed as a result of this process can be used as a soil conditioner, organic fertilizer or for the control of soil-borne microorganisms (Keener et al., 2000).

Composting and the use of compost have the benefits of facilitating manure processing and preventing environmental pollution. In composting, heat is produced which removes moisture and destroys sources of pathogens and weeds. If the process is managed correctly, there will be minimal odor. Compost is different from the raw materials from which it is obtained. It does not create odor, is easy to process and can be stored for a long time. Also, compost is used in a variety of ways. For this reason, compost attracts the attention of farmers.

Figure 3. Compost made of rose oil processing solid waste, separated dairy manure, poultry manure with straw (Ekinci et al., 2021).

2.4 Vermicompost

Vermicomposting is the process of composting using earthworms. It is an oxidative process (with air) that results in stabilization of organic matter. Like mature compost, the final product is organic matter, but worms perform this process with the help of microorganisms (Lazcano, 2008). The earthworms consume local microbes and organic particles. Castings are the digested particles that they expel. Vermicompost or vermicast is the name for the end product, which is a mixture of castings and other feedstocks that have been digested (Sherman, 2018). During this process, when vermicompost is applied to the soil, insoluble minerals are made soluble and presented to plants. Similarly, other complex organic compounds, such as cellulose, are reduced to simple compounds in part by bacteria in the digestive tract of the worm, increasing the availability of nitrogen. Eisenia foetida, sometimes known as the California red earthworm, is the most popular species of earthworm used to make vermicompost even though it is native to Europe (Figure 4). The odor of the species' exudates, which are probably an anti-predator adaption, gives it the name foetida. Because it consumes food equal to its own weight in food every 24 hours, this species of earthworm is particularly competent in how it feeds. To produce earthworm biomass (growth and new earthworms) and manure, earthworms consume fresh or in various stages of decomposition vegetable, animal, or mixed organic matter. To survive, this species needs high levels of organic matter as well as specific climatic factors, such as low light levels, pH values between 6.5 and 7.5, and ideal temperatures between 19 and 25°C. The probability of an earthworm surviving relies on how much organic matter is present in the medium; this probability diminishes as the proportion of organic matter rises (Roman et al., 2015).

Figure 4. California red earthworm (Eisenia foetida)

A container or bed (Figure 5), the material to be composted, the broodstock, and conducive environmental conditions are required for the production of vermicompost. For growing earthworms, there are a variety of choices, sizes, and container types. The containers, which are often constructed of wood, should be open to facilitate feeding and visibility. Earthworms typically delve 40 cm or less into the substrate in search of food (Schuldt et al., 2007), hence the bed should be 1 m wide and 50–60 cm deep; the length depends on the available space. In times of frost or winter, the bed has to be shielded from the rain, sunshine, and severe temperatures. Paper and unpainted cardboard, fruits and vegetables, eggshells, grass clippings, straw, agricultural waste, coffee pulp, and cereal grains are some examples of acceptable materials. Additionally, biosolids from domestic waste water treatment facilities may be used (Lotzof, 2012).

Figure 5. Vermicomposting bed

2.5 Bokashi compost

Bokashi composting is an anaerobic fermentation process in which microorganisms break down sugary food components such as glucose into organic acids, alcohols, and is completely different from conventional composting. It is a type of compost formed by the fermentation of organic matter by the soil biota in an acidic environment through microorganisms anaerobically in order to quickly assimilate it into the soil (Footer, 2013). Figure 6 shows the steps of bokashi composting.

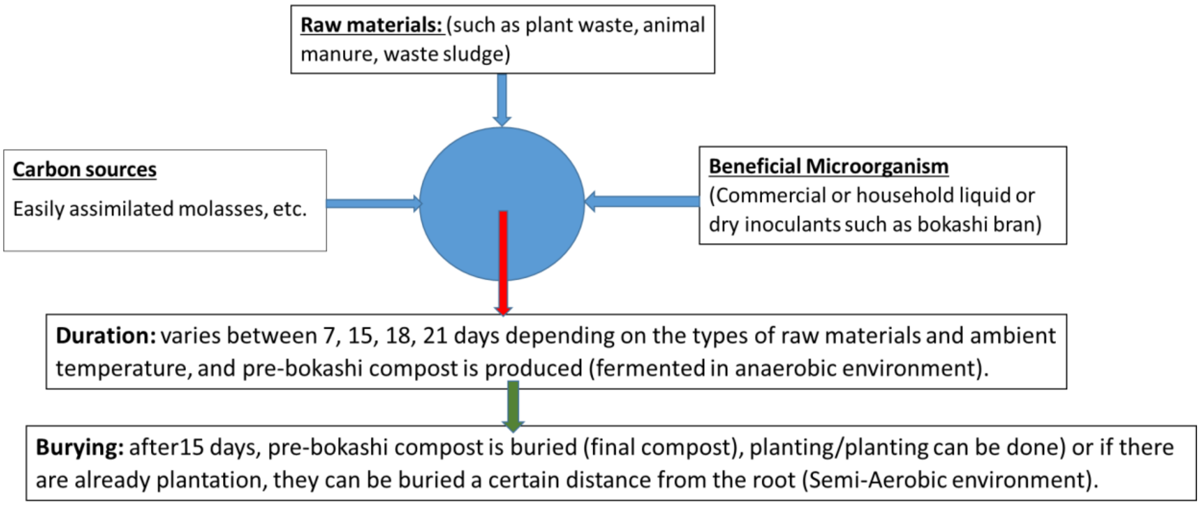


Figure 6. Bokashi composting (Madelaine Quiroz ve Cecilia Céspedes, 2019; Footer, 2013)

By using a specially selected group of microorganisms (Figure 7) by fermenting food wastes anaerobically with bokashi, harmful bacteria are neutralized and the formation of undesirable by-products can be avoided by ensuring the proliferation of beneficial bacteria. When composting using bokashi is planned (Figure 8), it is necessary to introduce beneficial microorganisms to the food waste to initiate the fermentation process. Bokashi compost can be made using commercially grown Effective Microorganism (EM) cultures or bokashi bran or home grown lactic acid bacteria (LAB) serum (Higa, 1991; Higa and Wididana, 1991; Footer, 2013). EM contains selected microorganisms such as lactic acid bacteria (Lactobacillus plantarum, L. casei and Streptococcus lactis), yeast (Saccharomyces spp), photosynthetic bacteria (Rhodopseudomonas plastris and Rhodobacter sphacrodes), and actinomycetes (Strptomyces spp.) in a liquid medium with a pH value of 3.5. They coexist harmoniously in a dry environment such as bokashi or bokashi bran (Higa, 1991).

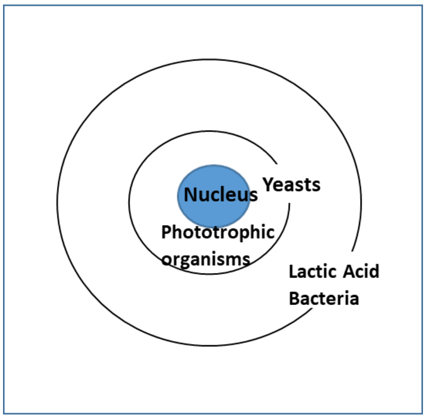


Figure 7. The lactic acid bacteria are seen as providing literally a safe environment or "housing" for the other two groups of organisms (Pinto, 2013)

Bokashi compost production patterns are also changing in different parts of the world. However, usually EM, wheat or rice bran is combined with molasses and water (thus creating bokashi bran) and added to food waste in a sealed container, left to ferment for two weeks (pre-composting) (Christel, 2017).

Figure 8. Bokashi composting in container

Two weeks after anaerobic fermentation, the fermented organic waste can be mixed directly into garden soil or potting soil and applied. In traditional composting, organic matter is broken down in an oxidation process. In traditional composting, organic matter is broken down in an oxidation process. Therefore, it is necessary to periodically turn the pile to deliver oxygen.

It can take up to a year for a passively aerated compost pile to become fully finished compost. At the same time, if anaerobic conditions occur in composting, bad odors occur. Since traditional compost piles are often exposed to the open air, extra water must be added throughout the process to maintain the proper moisture level. The bokashi composting system is closed and organic matter usually has at least 30 percent moisture. Therefore, no extra water needs to be added regardless of the size of the system. When the Bokashi leachate is drained from the container, some water is removed, but not enough to require the addition of extra water. Bokashi composting is much faster than traditional composting. With bokashi, the residues reach the stage to be buried in the ground within 30 days. During these 30 days, it is often just necessary to wait as the process requires very little work (Footer, 2012). In Table 3, chemical properties of traditional compost, (farm) bokashi compost, commercial production bokashi compost, worm compost were compared.

Table 3. Comparison of traditional compost, (farm) bokashi compost, commercial production bokashi compost, vermicompost (Cerrato et al., 2007)

	C	**N**	**P**	**K**	**Ca**	**Mg**	**Fe**	**Cu**	**Zn**	**Mn**	**C/N**
	(%)						**(mg kg^{-1})**				
Traditional compost	40	2.0	0.5	2.1	1.5	0.5	9200	26	177	557	20
Farm bokashi compost	40	1.6	0.4	2.2	1.0	0.7	15175	32	108	500	25
Commercial production bokashi compost	50	1.6	0.2	2.7	0.7	0.4	6750	19	58	288	32
Vermicompost	33	1.7	0.3	0.2	3.6	0.4	21080	49	244	610	19

CHAPTER 3

Compost Feedstocks

Feedstocks are biologically degradable organic raw ingredients for compost production. Different feedstocks have different amounts of carbon, nitrogen, and other nutrients. Feedstocks should be organic, economic (free or very cheap), and locally available. It should be noted that feedstock's properties affect the final compost quality. For instance, feedstocks with high electrical conductivity (EC) values tend to produce compost with high EC. Therefore, it is better to avoid feedstocks with high salt content in composting. Additionally, feedstock type determines the decomposition rate of organic material.

Compost is considered finished when the raw feedstock is no longer actively decomposing and is biologically and chemically stable. Feedstock for composting can be generated from yard waste (YW), biosolids, municipal soil waste (MSW), animal manures (poultry, dairy, horse, swine, and cattle with and without bedding), and other biodegradable waste by-products from urban or agricultural areas (Ozores-Hampton et al., 2011). It is often necessary to combine several ingredients to achieve the desired quality of compost. The mixture of ingredients and their relative proportions are called "recipes". In general, manure and bedding materials and crop residues are the main ingredients for composting recipes on farms.

Table 4. Optimal feedstock characteristics for composting (Rynk et al. 2021)

Parameters	Acceptable range	Ideal range
Moisture content	40-65%	50-60%
C:N ratio of feedstocks	20:1-60:1	25-40:1
Feedstock particle size	<5cm	
Bulk density	<0.7 g/cm3	0.4-0.6 g/cm3
pH	5.5-9.0	6.5-8.0

3.1 Carbon-rich rich feedstocks

Carbon-rich organic materials are called browns because most of them are brownish in color. Plant wastes that are dry, fibrous, bulky, and resistant to decay are categorized as brown. Brown ingredients help the aeration of composting piles.

3.1.1 Dry leaves

One of the most readily available sources for compost is leaves from deciduous trees. Pine needles can also be used however resinous coating on pine needles can take a while to break down, so use them in limited quantity.

Dry leaves are brown ingredients that are ready to be used in the compost mix. Leaves can be composted with any method. Leaf mold compost is a cold composting process since it was not turned during the composting process. It decomposes more slowly and contains a higher fungal-to-bacterial ratio than traditional composting systems. Leaves are easily degraded by fungi, but also bacteria and actinomycetes (Insam and de Bertoldi). Richardwille et al (2022) reported that by amending soils with leaf mold compost, increased the survival of beneficial microbial inoculants which help plants withstand attack by pathogens that cause crop diseases. Wet materials such as food scraps and kitchen wastes can also be mixed with dry leaves. Lignin-rich ingredients do not decompose quickly. To enhance the decomposition, they are mixed with lime in a ratio of 5 kg of lime per 1000 kg of waste to produce compost. Liming weakens the lignin structure, enhances the humification process, and improves humus quality (Hubbe et al. 2010).

3.1.2 Woody plant trimmings

Shrubs, trees, palm fronds, pruning wastes, dead perennial stems, brussels sprout stalks, and dried cornstalks; dried sunflower stalks all fit into this category. Break, chop, and shred this material as much as possible to speed decomposition. At first break thin branches or cut, them into smaller pieces with hand pruners and loppers (Cronnel and NGA, 2010). Much of the C in woody feedstocks is lignin and it degrades slowly. High proportions of lignin cause less availability of carbon to microorganisms. Therefore lignin-rich feedstocks can be used as amendments and bulking agents in a compost pile.

İşler et al (2022) produced vineyard pruning waste compost with neutral pH and low C:N ratio (11.72) and amendment of soils with this compost increased soil carbon content and soil aggregate stability. Olive leaves and pruning wastes are good sources for composting. Olive leaves and branches are composed mainly of lignocellulosic material. It can be used safely in composting ingredients.

3.1.3 Paper products

Paper is made from wood and contains very little nitrogen, and it is not very rich in nutrients. Paper reduces the moisture content of compost piles and helps aeration. Paper products include newsprint, cardboard, napkins, and tissue. The size of paper feedstocks should be reduced before incorporation into the compost pile.

Ahmed et al (2018) investigated the biodegradability of newsprint without ink, newsprint with ink, recycled paper, and glossy paper. They reported that the biodegradation of newsprint without ink and with ink took 18 and 21 days respectively in compost. However, the biodegradability of glossy paper and recycled paper took 14 days and 16 days that were shorter than newsprint paper.

3.1.4 Straw

Straw is an agricultural waste and its application to the field was common practice, but the stalks can cause problems for field operations. Most of the agricultural crop residues are clean feedstocks that decompose well and cause little odor risk. Straw is beneficial to increase soil organic carbon. It has a high humus production potential that was calculated with 100 kg C t^{-1} straw (Joschko et al, 2012). Straw material of either wheat or corn has a high C/N ratio of between 70 and 100.

Rice straw is another alternative feedstock for composting. According to FAO (2020), the global paddy rice production was 756.7 million Mt. As rice generates about one Mt of straw per each Mt of grain, a large amount of residue is accumulated annually (Nakhshiniev et al. 2014). Due to their high C/N ratios, it is suggested to combine straws with manure or other nitrogen-rich compounds for quick composting. When using a feedstock with a C/N ratio above 30/1 in composting, the decomposition process will be slow since there will not be enough nitrogen for microorganisms.

Figure 9. Rice straw (1-2 cm length)

3.1.5 **Sawdust**

Because sawdust has an extremely high C: N ratio it should be used sparingly in the compost pile. In general saw, dust is used as bulking agent in composting process. Additionally, it is critical in holding the leachate and for maintaining the aerobic condition in the compost pile (Sharma et al. 2018). Sawdust will dry out compost, so add enough water to keep the composting pile moist. It is suggested to mix sawdust with N-rich feedstocks. Hatten et al. (2009) reported that sawdust amended with chicken litter and then composted reduces the leaching potential of N and K compared to chicken litter alone, thus helping to prevent contamination of the environment.

3.1.6 Olive Pomace

Olive cultivation and olive oil production is a very common practice in Mediterranean countries. The extraction of olive oil generates high quantities of liquid and dry wastes that can create problems for the environment due to their high phytotoxicity. Olive pomace contains a significant amount of salt, phenolic compounds, organic acids, and fatty acids, it can have negative effects on plant germination when used in large doses (Linares et al., 2003). For this reason, it is suggested to make compost for agricultural use. Chowdhury et al (2015) reported that water-soluble phenols of olive mill waste decreased by around 90% during the composting process. They also reported that mature olive pomace compost (102 days) did not appear to have any genotoxic and cytotoxic effects therefore it could be safely used in agricultural cultivations. Olive pomace is one of the potential economic feedstocks for composting. Approximately 50-60% of olive by volume is “solid” waste. Olive pomace can be combined with manure, cereal or rice straw, pruning wastes, fish waste, and other feedstocks to produce compost. Considering its high organic matter (>90%) and plant nutrient contents, olive pomace compost can also be used to treat degraded and eroded soils. Applications of olive pomace on sandy soil increased soil aggregate stability from 18.2% to 80.6% in 2 months (Kavdir and Killi 2008). The application of olive pomace compost increased soil organic carbon contents significantly for loam, sandy loam, and clay soils (İşler et al, 2022).

Figure 10. Pirina

3.2 Nitrogen-rich rich feedstocks

Nitrogen-rich compost feedstocks are called greens because of their greenish color. Himes (2018) reported that fresh residue contains <45% carbon and less than 35% of the carbon will be converted to humus. During the conversion, microorganisms require nitrogen and other nutrients for metabolism and reproduction. During composting, most nitrogen is immobilized by microorganisms, and some N is lost as ammonia.

Table 5. Approximate C/N ratios of nitrogen-rich ingredients for composting (a)

Nitrogen-Rich Ingredients	Carbon to Nitrogen Ratio*
Chicken manure	10:1
Coffee grounds	20:1
Grass clippings	10-25:1
Kitchen scraps	10-50:1
Fish waste	4:1*

*İlay et al. 2019

3.2.1 Food processing waste and kitchen food waste

According to FAO roughly 1.3 billion tons of food were lost or wasted globally (Gustavsson et al.2011). The food waste generation rate is around 88 million tons per year in European Union (Stenmarck et al. 2016). Composting is an eco-friendly alternative for food waste management and a wide variety of by-products from food processing make good feedstocks for composting. Some examples of food processing by-products that can be composted include fruit and vegetable waste, hull, bran, meal or cake from oil extraction, bagasse (sugar processing), cottonseed meal (cotton processing), peels of apples, banana, oranges, tomatoes, and potatoes, spent grains, nut hulls (almond, peanut, walnut), olive mill pomace, spent coffee grounds, seafood processing waste.

The main by-products after oil are extracted from seeds are oil cake and meal. In Europe, the majority of meals are produced from rape (13,5 million tons), soya (12,5 million tons), and sunflower (4,8 million tons) and a total of 32 million tons of these by-products are produced in the EU per year (FEDIOL, 2019)

The production of one ton of crude palm oil generates 1425 kg of empty fruit bunch and 300 kg of palm kernel shell. Approximately 74 tons of dry oil palm trunk per hectare are generated while 23 % of the empty fruit bunch byproduct comes from the processing of fresh fruit bunch (FFB) in the palm oil mill (Chin et al. 2013).

FEDIOL Statistics. Available Online: https://www.fediol.eu/web/2019/1011306087/list1187970188/f1.html (accessed on 30/06/2022)

3.2.2 Yard trimmings

It is a green waste that include deciduous leaves, grass clippings, pine needles, unused fruits and vegetables, shrubs, tree branches, garden vegetation and other plant materials that are generated from maintenance of yards, gardens, parks, and other public and private landscapes. Yard trimmings may contain pesticides, weed seeds, and other contaminants that should be considered before composting. In large-scale production, the dry leaves can be stored during the winter and they are mixed with clipped grass in the spring and summer. The major cost of yard trimming arises from the collection and transportation of wastes, which is 67% in the USA (Ligon and Garland, 1998). Yard trimmings provide microorganisms, contain nitrogen, and improve the aeration of compost piles (Lopez et al. 2010).

3.3 Manure

Manure composting is one of the most popular forms of manure management. Composting of manure recycles manure as a stabilized and sanitized end-product for agriculture, reducing greenhouse gas (GHG) emissions and the volume of waste derived from intensive animal production (Bernal et al, 2009). Fresh manure applications to the field cause odor, and it contains concentrated nitrogen that may hinder plant growth or prevent seed germination.

The composting animal manures eliminate pathogens and weeds, reduce the volume and moisture of wastes, reduce odors, and produce good quality organic soil conditioners (Bernal et al, 2009). On the other hand, cost and large area requirements can be a negative side of manure composting compared to direct use of manure. Chicken, cow, duck, geese, goat, horse, lama, rabbit, sheep, and turkey manures are safe to add to compost. Manure contains very small amounts of macronutrients (nitrogen, phosphorus, and potassium) that all plants require, as well as essential micronutrients (trace elements), such as boron, iron, and zinc.

Using animal manures alone may be not adequate for good quality compost. In general, manures have high density and moisture content, low porosity, low C/N ratio, and in some cases high pH values. Therefore, other bulking agents should be used in manure composting. The addition of a bulking for manure composting optimizes air space, moisture content, C/N ratio, particle density, and pH (Petric et al. 2009). There are many bulking agents such as barley, rice, wheat and oats straw, olive pomace, wood shavings, sawdust, and pruning wastes.

Table 6. Approximate C/N ratios of carbon and nitrogen-rich ingredients for composting (b)

Carbon-Rich Ingredients	**Carbon to Nitrogen Ratio***
Corn stalks	60:1
Dry leaves	40–80:1
Newspaper	150–200:1
Pine needles	60–110:1
Straw	50–150:1
Woody plant trimmings	200–1300:1
Olive pomace	30-45*
Green walnut husk	41*
Nitrogen-Rich Ingredients	**Carbon to Nitrogen Ratio***
Chicken manure	10:1
Coffee grounds	20:1
Grass clippings	10-25:1
Kitchen scraps	10-50:1

**Kavdir et al. 2018; Kavdir et al (2019), Killi and Kavdır, 2013

Table 7. The effect of compost feedstock types on soil properties

Feedstock types	Application rates	Soil Type	Effects	Reference
MSW	0,60,120 t/acre		Increased SHC, WAS, AWC, and decreased BD	Albaladejo et al., 2008
PMBS	0, 22.3, 44.6 and 66.9 t/ha		Increased WIR, SHC, AS, and AWC decreased BD	Price and Voroney, 2007
Animal manure	0 and 30		Increased aggregate stability and BD	Gülser et al., 2015a
MSW+YT	15, 30, and 45 t t/ha	Loam	Increased Zn and Cd concentrations	Baldantoni et al. 2010
	0, 50, and 100 t/ha	Clay loam	Increased SOM, pH	Giannakis, and Kourgialas, 2014
MWC	0, 40, 80, 120, 160 and 200 t/ha	Clay Loam	Increased SOM, EC, CEC, AS, Ksat and reduced BD	Yuksel and Kavdir, 2020
Olive pomace (OP)+FYMC	0, 4, 8 and 10% (pot)	Sand and Loam	Increased CEC, EC, AS, and reduced C/N	Killi and Kavdır, 2013
OPC	0, 3%, and 6%	clay, loam, and sandy loam	Increased AS TC decreased MWD	İşler et al. (2022)
Vineyard pruning waste	0, 3%, and 6%	clay, loam, and sandy loam	Increased AS TC decreased MWD	İşler et al. (2022)
OPC	30 kg/tree	-	Increased available P and K	Proietti, et al (2015)
Sewage sludge compost (SSC)	48 t/ha	Silt Loam	Increased DOM and heavy metal leaching	Fang, W., Wei, Y., & Liu, J. (2016

YT: Yard trimmings; GWC: Green waste compost; OPC: Olive pomace compost

3.4 Materials to avoid when composting

Tobacco (contains toxic substances), detergents, antibiotics, drugs. Weeds that have gone to seed. Physical contaminants such as rocks, bottles, labels, cardboards. Non-degradable materials such as plastics, microplastics and metals. Pesticide residues from grass weeds, greenhouse and crop remaining, heavy metals.

Meat

The use of meat waste for home-scale composting is regulated in many countries. In Europe, it is regulated according to Animal By-Products Regulation (Regulation EC 1069/2009). While few European countries prohibit the inclusion of meat waste in a home composting, most countries do not regulate the utilization of meat waste when it is composted on at home scale (Storino et al. 2016)

Walnut husk

Black walnut trees (*Juglans nigra*) produce a chemical called juglone that inhibits the growth of some plant species in the surrounding area, although other plant species are tolerant of juglone. Composting black walnut leaves in an actively managed compost pile is safe because the juglone breaks down and loses toxicity within 2 to 4 weeks (Cronnel and NGA, 2010).

CHAPTER 4

Compost Equipments

4.1 Introduction

Choosing the right equipment for composting process is very important. It depends on composting method, type of feedstock, capacity, climate etc. Farmers usually already have equipment, so selecting equipment which could complement would be able to save capital costs and thus reduce whole process costs. The overview of equipment will be focused on options to select equipment as an addition to the tractor or telescopic handler and as a stand-alone for larger operations.

Most of the equipment used in composting would be involved in moving, mixing or other operations with materials. All composting process could be divided into steps (Figure 11).

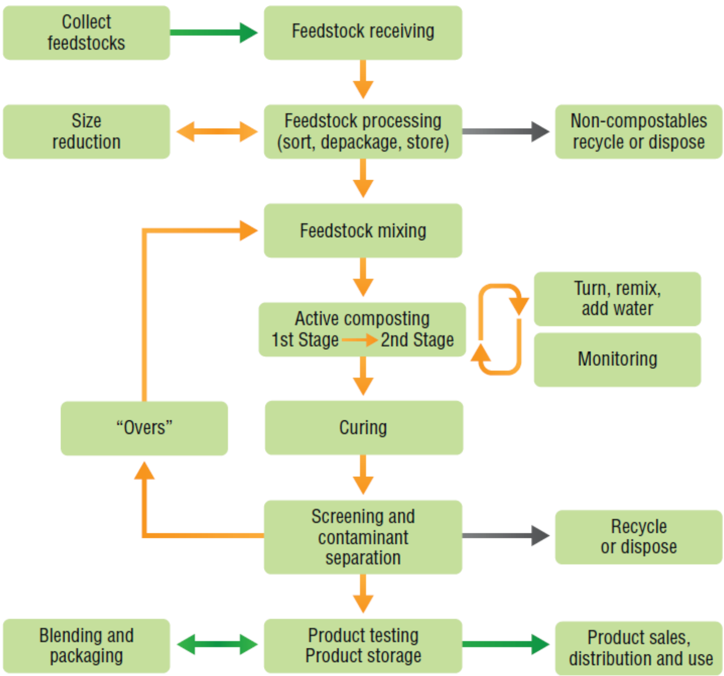


Figure 11. Flowchart of typical composting process *(Source: The Composting Handbook)*

First, the feedstock is received and handled. Then it is being processes if required by reducing size or removing contaminants. Afterwards feedstock is mixed for composting. Depending on the process, it might require several more turnings or few mixings. To ensure that composting is within the optimal conditions it might needed to be covered or watered. After the material is cured, it is screened to a finished compost, "overs" that are returned to the process and impurities. Finished compost is then used pure or in mixture with soil and other additives.

4.2 Composting site

The composting site (example in Figure 12) should match the planned quantities feedstock and method of composting.

Figure 12. Composting site

It should be made flat so that the equipment be able to move and operate without any difficulties. Also, it should be made so that no underground water be able to get into it and water runoff to the nature would be minimized or prevented. For that a uniform asphalt or concrete surface with 1-2 % gradient can be used together with run-off water collection and storage if there are neighbors nearby it is worth considering dominant wind position and select site accordingly.

4.3 Material handling at site

Composting operations are usually associated with significant quantities of waste or compost. To make those materials move heavy machinery is needed. Options depend on feedstock, quantities and available equipment at hand. Feedstock and compost handling can be done using any machinery, which is able to mount a bucket, most commong: wheel loader, telescopic handler and tractor (Figure 13).

Figure 13. Feedstock and compost moving equipment

Front-end loaders are used for various operations such as transporting feedstocks, building windrows, turning and agitating piles, transporting compost, loading vessels. They come in a wide variety of sizes, maneuverability and capabilities. Main productivity feature is the amount of materials front end loader is able to fit in it’s bucket and the height it can lift it. To have an efficiently operating compost site, it should be designed with the size and turning capabilities of front-end loaders in mind.

Figure 14. Roll-out bucket

Additional buckets are used to increase the capabilities of front-end loaders:

1) Roll-out buckets (Figure 14.)

These can be fitted on larger front-end loader and allows higher effective dumping height.

2) Grapple buckets (Figure 15.)

These can be used to pick up hay bales, branches and other looser material. It is also possible to use fork lifter and excavator, but they are not efficient for material movement.

Figure 15 Grapple bucket (*Source: norcar.com)*

4.4 Feedstock preparation

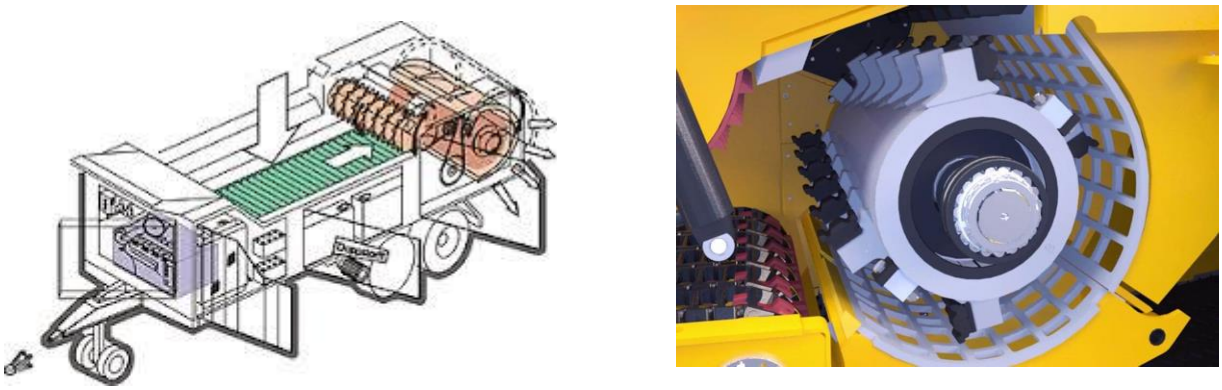
For composting process to be optimal it needs to be prepared – having the right size of particle size, moisture content, porosity carbon and nitrogen balance. Main feedstock preparation for composting operations are size reduction and homogenious mixture.

4.4.1 Size reduction

Most common types of equipment used for used for size reduction are grinders, shredders and chippers. All of them use physical force to breaking feedstock particles appart. Depending on feedstock and what it is being mixed with the usual size for composting is between 25 to 160 mm.

4.4.1.1 Grinders

Grinders reduce material with hammermill that apply combined tensile, comprehensive and shear forces. Feedstock is being reduced in size until it can pass through discharge gate or screen. The output of grinders have uneven particle size and greatet surface area that is very beneficial for composting process. It is best suited for woody biomass.



Source: Doppstadt *Source: CBI*

Figure 16. Grinder and hammermill

4.4.1.2 Shredders

In the waste management, industry shredders are typicaly described as a low speed, high torque machine that tears materials appart. Shredders are more versitily and are able to operate with solid and flexible feedstock. The output of shredders tend to have elongated shape. In composting, shredders are usually used for pre-shredding of large wood pieces.

Figure 17. One shaft and two shaft mobile shredder (*source: Komlech*)

4.4.1.3 Chippers

Chippers usually cut materials into uniform shape and size pieces. Typically they are used only for woody biomass that is being incerted into the cutting chamber one by one. Chippers produce chips or mulch.

Figure 18. Tractor mounted chipper (*Source: John Deer)*

Smaller grinders and chippers are made with PTO shaft for connection with more powerful tractors. Additionally magnets can be installed at the back of grinder or shredder to collect ferrous materials.

4.5 Material mixing

If composting is being done in static piles, then material mixing is needed to achieve efficient process. Mixing should be done to achieve parameters that are optimal for composting. It is possible to mix using just front-end loader, but the process is not efficient. Few other options could be used instead: mixing bucket (Figure 19) or vertical/horizontal mixing machine (Figure 20). Mixing buckets are used in farms with relatively low quantities of compostable feedstock. Vertical and horizontal mixing machines can be stand alone and with PTO shaft and are able to mix large quantities of feedstock.

Figure 19. One shaft and two shaft mobile shredder (*Source: Emily)*

Figure 20. One shaft and two shaft mobile shredder (*Source: Foresin*)

4.6 Material turning

Windrow turning composting is one of the most popular composting methods. To do it efficiently a windrow turner (Figure 21) is needed. Every time a turner is going through windrow it homogenises and aerates the material. The most popular turner type is the drum turner, which goes over the windrow and has a drum which agitates and reshapes the windrow. Windrow turners can be self-propelled and PTO powered.

Source: Eggersmann Source: Compost-Systems

Figure 21. Self-propelled and PTO powered windrow turners

There are few other types of windrow turners: auger, elevating face, trapezoid and front bucket (Figure 22, 23)

Source: Reotemp instruments

Figure 22. Front bucket turner

Source: Brown Bear

Figure 23. Temperature and oxygen probe

4.7 Monitoring

Composting is a continues process that have a changing parameters. Most important for microorganisms are temperature, oxygen level and moisture level. Temperature and oxygen levels can be fastly and efficiently measured using probes (Figure 24.). Temperature and oxygen should be as determined level. If the results are not reached, feedstock selection was not correct or it has not been well mixed. Moisture level can be measured by hand (Figure 25).

Figure 25. Moisture measurement

Source: Reotemp Compost

Figure 24. Temperature and oxygen probe

4.8 Moisture control

Moisture in composting is a very important parameter, because if the material is too wet or too dry microbial activity associated with composting slow down or stop activity. Depending on the feedstock and climatic conditions, few strategies to control moisture can be applied:

1. Roofed composting site or compost cover (Figure 26.) prevent outside moisture of getting into the pile. Compost cover can be put on using front-end loader or turner with rolling mechanism. Additionally, compost cover, depending on the parameters, can reduce some amount of odours.

Source: Sevier Solid Waste *Source: Compost Systems*

Figure 26. Roofed composting site and compost cover system

2. Irrigating piles according to needs can be done to maintain efficient composting process. Water tanks can be used separately or together with windrow turner (Figure 27).

Figure 27. Compost irrigation equipment (*Source: Compost Systems)*

4.9 Screening compost

Ready made compost depending on feedstock and application is either suitable for use or is screening. If compost was made all from easy degrading plant based materials such as leaves without any contaminants it could be used in agriculture directly. Screening allows achieving needed compost size and removing oversize organic particles (that can be returned to composting process such as large pieces of wood) and impurities. The screening size for compost starts with 8 mm (for substrate production) and up to 40 mm (for agriculture). The most common sieving types are trommel, disc and star.

4.9.1 Trommel screens

In biowaste management, trommel screens are most popular, because they are efficient and easy to maintain. Ready made compost is ebing sieved in the rotating cyclindrical drum usually made out of wire mesh. Depending on the parameters it can separate at least two fractions. There are mobile and static trommel screens (Figure 28). Rotating brushes keep trommel screen from clogging.

Source: Komptech

Source: Menart

Figure 28. Mobile and static trommel screens

4.9.2 Disc and star screens

These type of screens (Figure 29) are of a similar design, except for rotating part, which is in one case disc like and in other star like. Screening is done when compost goes through rotating elements and the undersize elements fall through and oversize elements stay over. Advantages of disc and start screens are that they can deal with high level of moisture in the compost without clogging and have a relatively large screening surface. Both types of screens can be either static or mobile.

Source: Komptech

Source: Komptech

Figure 29. Disc and star screens

Additionally for smaller composting operations that have a more powerful front-end loader with hydraulic connection it is possible to use screening bucket (Figure 30).

Figure 30. Screening bucket *Source: ALLU*

4.10 Making compost substrate

Sometimes compost is used in mixture with other materials (i.e. soil, sand, peat, zeolite etc.). They are primarily destined for landscaping, commercial and residential uses. Compost blends with biochar and mineral additives (gypsiu, sulfur etc.) are used for agriculture applications. Specific rates of additives are calculated according to soil conditions and crops at the receiving farm. Compost substrates are made using mixing or turning equipment.

4.11 Bagging

When making substantial amounts of compost and compost substrate it is possible to tap into the retail market. This would mean using bags that can vary from a few litres up to 50 litres.

Compost sold in small volumes is usually more expensive than sold in bulk and has a higher margin for farmers. For that customers expect higher quality with lower moisture content (around 40 %) and no odours. Holes in bags to allow air to circulate prevents from forming anaerobic conditions.

Bags can be filled manually, semi-automated and fully automated (Figure 31) with bagging equipment (usually housed indoors to prevent unnecessary moisture getting in).

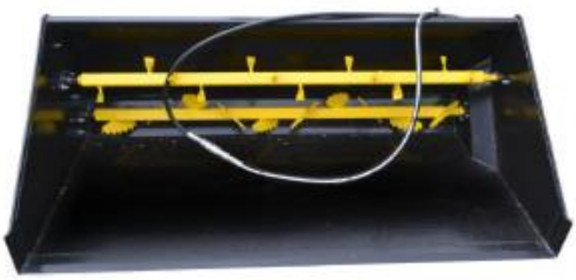
Source: Option Srl.

Source: Amadas Ind.

Figure 31. Semi-automated and automated bagging equipment

4.12 Spreading

Most of the produced compost is used in agriculture. To ensure even and efficient spreading of compost manure spreading devices (Figure 32.) can be used. Depending on the quantity of compost, either bucket or trailer is used.



Source: idealattachements.com

Source: Tebbe

Figure 32. Compost spreading

CHAPTER 5

Composting Process and Curing

5.1 Composting process

Industrial developments in recent years have brought along the environmental waste problems. The elimination or utilization of environmental wastes (industrial and agricultural) has become inevitable for today's societies. Generally, four different methods are used to evaluate and dispose of solid wastes: landfilling, incineration, composting and recycling (Tchobanoglous et al., 1993). Among these methods, composting has become increasingly important in recent years, as it is a process that accelerates the decomposition and stabilization of organic materials, renders agricultural and industrial wastes environmentally harmless, and also provides agricultural use (de Bertoldi and Schnappinger, 2001).

Composting; aerobic, that is, oxygen-requiring, and under controlled conditions is called the decomposition of organic substances. During the composting process, the microorganism uses oxygen while feeding on the organic material. During active composting, significant heat, carbon dioxide (CO_2) and water vapor (H_2O) are produced. The amount of carbon dioxide (CO_2) and water vapor (H_2O) production can be up to half the starting material weight (Epstein, 1997). The sequence of operations in composting is as follows: the microorganism uses O_2 for the biochemical reaction to take place, and as a result, it produces heat energy. The heat energy produced evaporates the water in the environment and allows the compost material to dry slowly (Finstein et al., 1986). With proper control of the composting process, pathogenic microorganisms are destroyed and the mass and volume of organic wastes are reduced (Rynk, 1992). With an effective composting process (by controlling physical, biological and chemical factors at the same time), bad odor and dust in the system can be prevented (Miller, 1993). A simplified composting process is shown in Figure 33.

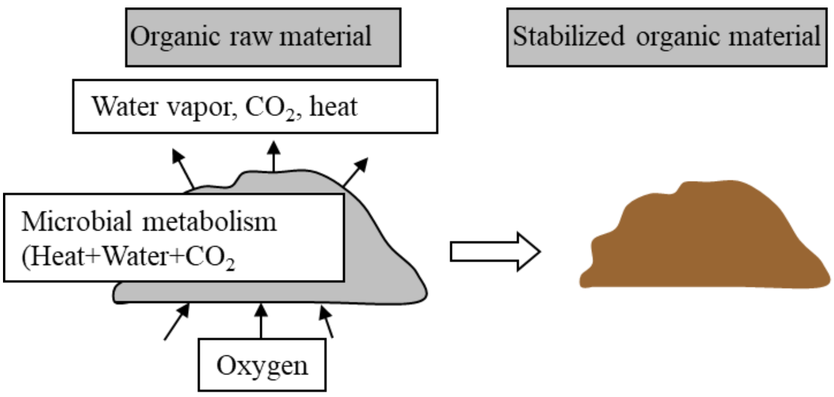


Figure 33. Composting process (Keener et al., 2000).

Composting is considered an efficient and economical method for disposing of organic wastes, which can reduce the harmful substances in composting material and producing valuable organic fertilizers and soil conditioner for agricultural applications. There are three main applications of composting: agricultural production, mushroom cultivation and disposal of organic solid waste. Regardless of the purpose of composting, it is based on a common ecology (Miller, 1993). However, the compost resulting from each application has different characteristics due to the materials used, the system and the system management. Today, although the focus is not on how composting is done, but where the compost will be used (Rynk, 1992), it has been stated that it is not possible for mature compost to have the desired properties without a good composting process management (Keener et al., 2000).

The quality of the compost basically depends on the material used, the processing and composting system (de Bertoldi and Schnappinger, 2001). Many commercial compost plants were closed because these key factors were not fully understood. Since composting is a physical, biological and chemical process, there are many factors that affect compost production. Particularly among these factors, nutrients, moisture, pH, temperature, particle size and porosity are of great importance in making composting easy, economical and odorless.

In Figure 34, the material flow in conventional composting systems is given. In order to prepare a mixture by considering factors such as C/N ratio, moisture, pH, the primary material, amendments, recycled compost material are mixed and then piled or filled into the reactor to start composting. Depending on the compost system used, it is mixed daily, every 3 or 4 days, or in weekly and monthly periods. If little or no heat output is observed from the compost formed, the material is stabilized and the maturation stage is started.

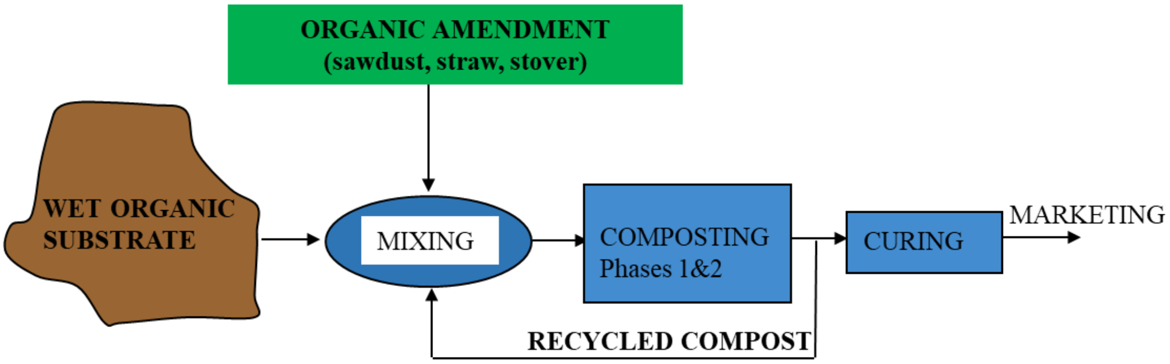


Figure 34. Material flow in conventional composting (Keener et al., 2000).

The main product is called compost, which may be defined as the stabilized and sanitized product of composting, compatible and beneficial to plant growth (Figure 35) (Insam and Bertoldi, 2007). Compost is a useful natural product from less useful, and often wasted, organic ingredients (Rynk et al., 2022). It changes the soil, improving the physical, chemical and biological properties, resulting in increased crop productivity and increased environmental quality (Brown and Cotton, 2011). The compost formed as a result of this process can be used as a soil conditioner, organic fertilizer or for the control of soil-borne microorganisms (Keener et al., 2000).

Figure 35. Stabilized and sanitized compost

The composting process is carried out using different organic materials (animal manure, leaves, straw, grass waste, food waste, etc.). These wastes have values and uses. They contain energy, mineral matter, organic matter, nutrients, and microorganisms that provide benefits to the soil, products, landscape, animals, people, atmosphere and environment. With the composting process, the nature of these resources is preserved while converting them into soil-improving products. The value of composted products usually exceeds the value of the original raw materials (Rynk et al., 2022).

The composting process under controlled conditions consists of two main stages: **composting and maturation** (Chen and Inbar, 1993). These stages are shown in Figure 36. The composting stage consists of 3 sub-stages. Different communities of microorganisms become dominant in different stages of composting.

1) Initial phase: This phase lasts 1-3 days. At the initial phase, mesophilic microorganisms are active in the decomposition process. Mesophilic microorganisms degrade soluble, readily biodegradable compounds. Due to the heat generated as a result of decomposition, the temperature of the compost rises rapidly. Compounds such as simple sugar, starch and protein are decomposed by mesophilic microorganisms. The temperature rises very quickly.

2) High decomposition phase: This phase lasts 10-100 days. When the temperature reaches about 40°C, mesophilic microorganisms become less competitive and heat-loving thermophilic microorganisms replace them. Fats, hemicellulose, cellulose, and some lignins are decomposed by thermophilic microorganisms. The temperature rises above 40 °C and at this stage pathogenic microorganisms are destroyed. Oxygen consumption and CO_2 production peak. If the composting process is not well controlled, large amounts of NH_3-N gas and other gases are produced. Many microorganisms, including human and plant pathogens, are destroyed at temperatures of 55°C and above. Above 65°C, decomposition is extremely limited. For this reason, aeration and mixing processes are performed to reduce the temperature. During the thermophilic phase, high temperature accelerates the decomposition of proteins, fats and complex carbohydrates (such as cellulose and hemicellulose).

3) Stabilization phase: This phase also takes 10-100 days. Hemicellulose, cellulose, and some lignins continue to decompose and the temperature drops. With the depletion of high-energy compounds, the temperature of the compost decreases and mesophilic microorganisms come into play again. They take part in the last phase, that is, in the maturation of organic matter (Chen and Inbar, 1993). In the maturation stage, mesophilic microorganisms form colonies again. The maturation stage lasts at least 1 month, usually 3-6 months (Chen and Inbar, 1993). The duration of any one step varies depending on the organic material to be composted, the C/N ratio, particle size, mixing frequency and many other factors.

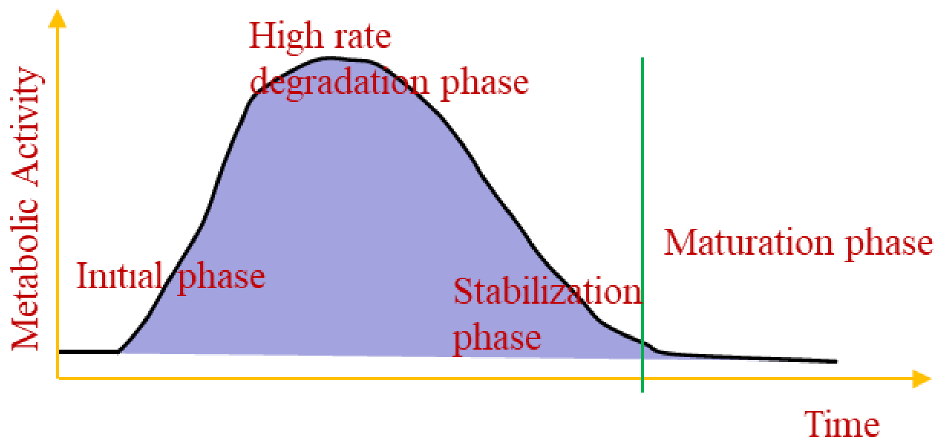


Figure 36. Stages of the composting process (Keener et al., 2000).

In the maturation phase, mesophilic microorganisms form colonies again. The maturation phase lasts at least 1 month, usually 3-6 months (Chen and Inbar, 1993). The duration of any one step will vary depending on the organic material to be composted, the C/N ratio, particle size, mixing frequency and many other factors.

5.1.1 Factors that affects composting process

The composting process takes place faster when the conditions that enable the growth and functioning of the microorganism are provided (Table 8).

Table 8. Favorable conditions for composting (Rynk et al., 2022).

Conditions	Reasonable range[a]	Preferred range
Moisture	%40-%65	%50-%60
C/N ratio	20:1-60:1[b]	25:1-30:1
Oxygen concentration	>%5	>%10
Temperature[c]	45-70°C	55-65°C
pH	5.5-9.0	6.5-8.0
Particle size	3-50mm	Depends on feedstocks and use for compost
Bulk density	<700 kg/m^3	400-600 kg/m^3

[a]:Generally for rapid composting. Composting can still be successful outside of these ranges.
[b] :Some feedstocks can be composted successfully even at C:N ratios greater than 60:1, although the composting is slow and the time period is long.
[c] : Temperatures as low as below 45°C are conducive to rapid composting, but sanitization specifications require temperatures to be held at 55°C or above for a period of time (e.g., three days)

5.1.2 Nutrients

Carbon (C), nitrogen (N), phosphorus (P), potassium (K) are essential nutrients for microorganisms working in the composting process. Organic materials such as animal manure, plant waste and food waste contain enormous amounts of nutrients (Rynk, 1992). One of the most important factors for successful composting is the C/N ratio (Poincelot, 1977). In general, biological organisms (including humans) need 15-30 carbons per nitrogen. Therefore, it is important for microorganisms to provide carbon and nitrogen in certain proportions. The ratio of carbon to nitrogen is called the C/N ratio. Microorganisms use carbon for both energy and growth and use nitrogen to create protein (Poincelot, 1977; Haug, 1993). Generally, the ideal C/N ratio for composting is 25-30:1, although initial C/N ratios from 20:1 to 40:1 are within acceptable limits for good composting (Keener et al., 2000). Excessive or insufficient amount of carbon or nitrogen affects the composting process. At low C/N ratio values (less than 20:1), since the available carbon and nitrogen are used by the microorganism without all stabilization, ammonia gas is formed and an undesirable bad odor occurs (Ekinci et al., 2000). When the C/N ratio is higher than 40:1, the decomposition process slows down (Rynk, 1992; Haug, 1993; Ekinci et al., 2002).

Although the C/N ratio is an important parameter in determining the mix for compost, the rate of decomposition of carbon compounds must also be considered. For example, carbons in straw are easier to use than carbon in woody materials. This is because the carbon compounds in the woody material are bound by the organic compound - lignin, which is resistant to biodegradation. Similarly, the carbon in the simple sugars of the fruit residues decomposes faster than the cellulose-carbon in the straw. If the carbon is difficult to decompose, the composting process can be slow. Since the decomposition process takes place on the compost particle, the decomposition rate can be increased by decreasing the particle size (which increases the surface area), as long as porosity is not a problem in the compost matrix. If desired, the carbon content can be adjusted to a high rate to compensate for the poor decomposition rate, despite a longer composting time (Rynk, 1992).

5.1.3 Aeration and Oxygen Concentration (O_2)

In aerobic composting, air is provided for three main purposes: (1) to meet the oxygen required for the decomposition of organic materials, (2) to remove the water in the compost matrix while composting continues, (3) the heat energy generated as a result of decomposition increases the temperature in the environment. If the heat energy is not removed from the environment, the decomposition first slows down and then stops. To prevent this, excessive heat in the environment should be removed by aeration (Rynk, 1992; Haug, 1993; Ekinci; 2001). The aeration method differs depending on the composting system used, organic material and economic factors. According to the information obtained in line with the calculations, the amount of air required to remove heat is 10 times higher than the amount of aeration required providing oxygen (Haug, 1993). Therefore, it is the compost temperature that determines the amount and frequency of aeration (Keener et al., 1993). The aeration rate required to remove moisture from the material is higher than the aeration rate required to provide oxygen to the environment, but less than the aeration rate required to remove the heat generated in the environment (Haug, 1993).

In aerobic composting, microorganisms consume O_2 and produce CO_2. In early stages of composting, the easily decomposable part of the raw material is used by the microorganism. Therefore, oxygen demand and heat production are greatest in the early stages of composting and then decrease as composting progresses. If the amount of oxygen in the environment is limited, the composting process slows down (Miller, 1993). In the compost matrix, a minimum 5% oxygen concentration is required for aerobic composting (Rynk, 1992; Harper et al., 1992). If the oxygen concentration is not sufficient for microorganism activities, the composting process takes place under anaerobic conditions. Anaerobic composting involves different microorganisms and biochemical reactions. It has been stated that anaerobic composting has less energy release and higher odor potential than aerobic composting, it is slower and less effective (Haug, 1993). Anaerobic composting involves different microorganisms and biochemical reactions. It has been stated that anaerobic composting is slower and less effective as it has less energy release and higher odor potential than aerobic composting (Haug, 1993). Anaerobic composting produces intermediates such as methane (CH_4), organic acid, hydrogen sulfide (H_2S) and other compounds. Many of these compounds have a very pungent odor and pose health hazards. Ensuring aerobic conditions in the environment is very important in terms of preventing the sharp odor that occurs in the anaerobic environment (Rynk, 1992).

5.1.4 pH

One of the parameters that must be controlled in order to carry out the composting process properly is the pH of the environment (Ekinci et al., 2000). Although the preferred medium pH is 6.5-8.0 (Rynk, 1992), these limits are wider due to the natural buffering capacity of the compost medium (Haug, 1993). Composting can be done effectively when the pH is between 5.5 and 9.0. However, when the ambient pH is neutral (pH=7), the process efficiency is higher than when the ambient pH is 5.5-9.0. pH is considered as a very important parameter in the use of materials with high nitrogen content in composting (Elwell et al., 1998). When pH=8.5, it accelerates the conversion of nitrogen to ammonia gas. Lowering the pH below 8.0 reduces ammonia gas losses (Ekinci et al., 2000). Increasing the compost pH with lime, ash and other additives is not always necessary and is not recommended because it increases ammonia gas losses. If such additives are to be used, they should be used in small amounts and mixed very well (Rynk, 1992). The composting process changes the structure of the compost material as well as its pH. For example, while ammonia gas consisting of nitrogenous compounds raises the pH, the organic acid produced in the environment in the early stages of the compost lowers the pH. Regardless of the pH of the starting material, the pH of the finished compost is close to neutral (Haug, 1993).

5.1.5 Moisture

Moisture is necessary to support the metabolic activities of the microorganism. Water provides the environment for chemical reactions, transports nutrients and enables microorganisms to move. In theory, biological activities are optimal when the moisture content in the material is at the saturated (100%) point (Gouleke, 1977). However, in these conditions, since the oxygen uptake of the microorganism becomes difficult and anaerobic conditions occur, the moisture content should be between 45%-65% (Rynk, 1992; Keener et al., 2000; Ekinci et al., 2004). Biological activities cease when the moisture content of the material falls below 15% (Rynk, 1992). As the moisture content of the composting process approaches 40%, microorganisms resume their activities slowly. When the moisture content is above 65%, the air in the pore of the compost material is replaced by water. This event limits the movement of air and leads to anaerobic conditions. The initial moisture content should be well above 40 as the composting process progresses. For most compost mixes, very dry materials are mixed with very wet materials to achieve a moisture content of 50-60%. During the composting process, the moisture content decreases by evaporation from the compost pile and the addition of water by rain and snowfall increases. Generally, moisture content tends to decrease because the amount of water evaporated is greater than the amount of water added (Rynk, 1992).

5.1.6 Structure of organic material

Plant cell walls are composed of three compounds: cellulose, lignin, and hemicellulose. Lignin is particularly difficult to degrade and complicates the bioavailability of other cell wall components. In addition, different plant materials have very different decompositions from each other (Richard, 2001). Cellulose needs to be broken down by enzymatic reactions. It is formed by branching polymers of hemicellulose, glucose, mannose, galactose, arabinose and xylose. Lignin is a complex polymer composed of phenylpropane units. In particular, fungi degrade lignin by enzymatic reactions.

5.1.7 Temperature

Temperature, which is one of the basic parameters of composting, determines which microorganisms will be dominant in the compost environment. At the beginning of composting, the temperature of the compost mass is equal to the temperature of the outside air, but as the microorganism multiplies in the compost environment, the temperature increases. When the temperature rises above 40 °C, the mesophilic phase (10-40 °C) is replaced by the thermophilic phase (40-70 °C) (Poincelot, 1977). Although mesophilic temperatures provide effective composting, many experts recommend maintaining a compost temperature between 43 °C and 65 °C. It is more preferred because more pathogens, weed seeds and fly larvae are killed in thermophilic temperatures. Legal practices say that the temperature must be 55 °C to kill human pathogens (Rynk, 1992; Keener et al., 2000). This temperature also means the destruction of plant pathogens. The critical temperature required to kill most weed seeds is 63 °C. As a result of the decomposition of organic wastes by microorganisms, a large amount of heat energy is released. The insulating property of the compost material leads to heat accumulation, which causes an increase in temperature (Finstein et al., 1986). Air movement carries out water vapor and other gases, and the compost material is constantly losing heat. Mixing or aeration of the compost pile accelerates heat loss and is used to keep the temperature at certain values. Cold air and small compost piles accelerate heat loss (Fernandes and Sartaj 1997).

Because of the accumulation of heat in the compost, it raises the temperature of the compost well above 60 °C. The microorganism looses its activity due to high temperature and slows down the composting process. The temperature can reach up to 72 °C due to the heat produced due to the activity of the microorganism and the insulating property of the compost material (Keener et al., 1997). At this point, most microorganisms either die or remain in the environment inactive. As a result, the composting process stops and cannot perform its functions until the necessary environment for the microorganism to survive is created. To prevent this phenomenon, the compost temperature should be constantly monitored. If the compost temperature approaches 60 °C, heat losses must be accelerated by either aeration or mixing. If microorganisms lose their viability due to heat, it is recommended to mix the compost pile with microorganisms from another active compost pile (Rynk, 1992).

5.1.8 Porosity, structure, texture and particle size

Porosity, structure and texture are related to particle size and shape, which are the physical properties of the material. These physical properties affect the aeration process applied in the composting process. These physical properties can be changed depending on the material selected and the crushing or mixing process. Particle size is calculated based on the size of the material and the air gap. The presence of larger particles and more uniform particles increases the porosity (Rynk, 1992). Structure is defined as the durability of particles (a measure of the compost material's resistance to settling or compaction over time). A good structure prevents the loss of porosity in the wet compost pile over time.

Texture is a property used to describe the material surface available for the activities of aerobic microorganisms. Aerobic decomposition of organic substances occurs on the surface of the material particles. This is because oxygen moves faster through air spaces and more slowly through liquids and solid parts of particles. Populations of aerobic microorganisms are concentrated in the liquid layer surrounding the particle surface. Since the microorganisms cannot enter the particle center, no decomposition process occurs and they only use the available oxygen on the particle surface. Since the surface area is greater for small particles, the rate of decomposition increases with increasing surface area. However, small particles reduce the effective porosity. The composting process gives good results when the particle sizes are between 0.3-5 cm (Rynk, 1992).

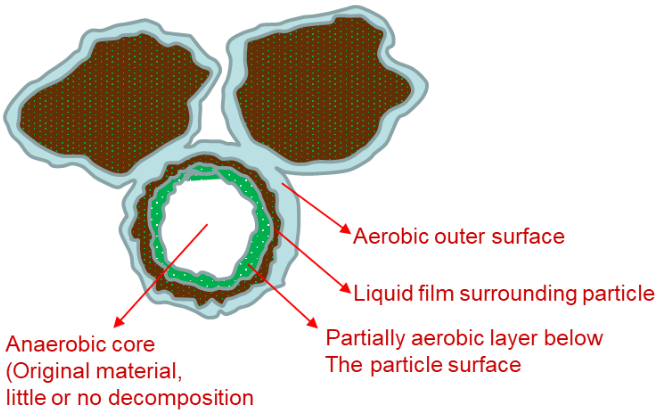


Figure 37. Decomposition of solid particles

5.2 Curing

The curing phase, in which the compost matures, is vitally crucial and is one of the important stages of composting, which is not always emphasized. Curing phase is essential to achieving a stable compost product that can be stored and used without phytotoxic effects (Epstein, 2011; Oshins et al., 2022). Aeration during curing should be considered because of the more rapid reduction in respiration rates (Haug, 1993). The curing phase takes place at low temperatures. Compared to the active phase, less metabolic energy is produced, less oxygen is consumed and less moisture evaporation is observed. There is no certain point for the start and end of the curing phase (Figure 38). On the other hand, the curing phase starts at the point where reheating is not observed after mixing the heaps. In the forced aerated static pile method, it starts after the pile temperature shows a steady decline and approaches mesophilic levels (40 °C). If there is enough moisture in the pile, air is no longer required for cooling (Oshins et al., 2022).

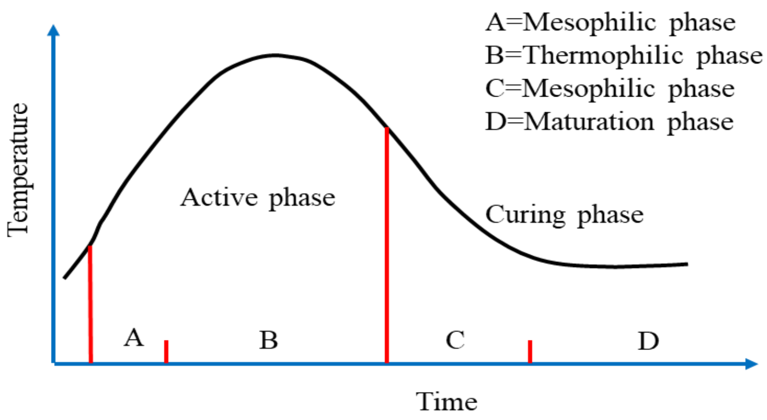


Figure 38. Temperature changes in an average compost pile (Briški and Domanovac, 2017)

In the curing phase, decomposition resistant compounds, organic acids, and large particles from the active phase continue to decompose. Fungi and actinomycetes that can degrade some cellulosic compounds are active only in the mesophilic temperature regime of the curing phase. In this phase, the C/N ratio decreases, the exchange capacity increases, and the concentration of humic components increases. Some desired changes occur only at low temperatures. For example, (1) nitrification is the conversion of ammonium to nitrate nitrogen. Nitrification becomes noticeable only in the curing phase. (2) Another change is the recolonization of soil organisms, which gives the compost its disease suppressing properties (Oshins et al., 2022). One of the key objectives of the curing stage would seem to be the reestablishment of a diversified microbial community. As a result of their capacity to prevent bacterial infections from regrowing, the diverse flora would also seem to be a significant benefit of compost products (Haug, 1993). (3) The development of humus-like compounds occurs more easily under the specified conditions (Oshins et al., 2022).

A composting process with a short active phase or a compost obtained from a poorly managed composting process ensures the safe use of compost by increasing the duration of the curing phase and prevents the use of immature compost from damaging the plant. Some phytotoxic intermediates produced during thermophilic decomposition are completely decomposed during curing phase (Oshins et al., 2022). One problem associated with immature compost is continued decomposition. The continued decomposition of an immature compost in soil can induce anaerobic conditions as the microbial biomass utilizes oxygen in the soil pores to break down the material (Mathur, 1993). Immature compost continues to consume oxygen, thereby reducing oxygen availability to plant roots. Compost that has not fully matured keeps consuming oxygen, which lowers the amount of oxygen available to plant roots (van der Wurff et al., 2016; Oshins et al., 2022). When immature compost is utilized for certain horticultural or agricultural uses, it may also include high quantities of organic acids (Haug 1993) and ammonium, a high C/N ratio, and other qualities that might be harmful. The intended level of compost maturity should, in theory, dictate the length of curing. The consensus advises allowing at least one month for curing (Oshins et al., 2022).

Adequate aeration is still required during curing because it maintains the aerobic breakdown process (Haug 1993; Epstein, 2011; Oshins et al., 2022). Due to the more rapid reduction in respiration rates, aeration should be taken into account during curing (Haug, 1993). The size and moisture content of the curing piles are constrained by the ongoing demand for oxygen. Because the oxygen demand during curing is far lower than during the thermophilic phase, curing piles can be substantially bigger than their predecessors without going into anaerobic conditions. If anaerobic conditions do arise in the curing piles, the anaerobic products that are produced can degrade quickly when the cured compost is exposed to air (Oshins et al., 2022).

Curing can be a crucial component of the main composting process rather than being a separate step. Separating the curing step from the active composting stage has benefits, though. The production of heat and the need for oxygen both significantly decrease as compost ages. Typically, this enables a lower level of management. It is feasible to shorten the amount of time required for management of process monitoring and control by isolating the curing stage (Stoffella and Kahn, 2001). Pre-screening or post-screening curing are both possible. The bulking agent is eliminated if curing is conducted following screening. As a result, there is less bulking agent degradation and greater recovery. Curing requires less room. The best aeration technique in these circumstances is forced. More space is required for curing if the compost is screened after curing. Convective air may be sufficient for oxygen while forced air may not be required if the bulking agent is still present in the compost. The bulking agent will degrade, lowering its capacity for recycling (Epstein, 2011).

Temperature alone is not sufficient to determine whether the composting process is finished since temperature drop may only indicate the transition from the thermophilic phase to curing. Stability and maturity are two words used to describe the state of completion of a compost. In the curing phase, compost can become stable and mature. The intended use for the compost is important since while some applications require a more finished compost; others can use immature compost (Oshins et al., 2022). While compost maturity is related to phytotoxicity, stability is generally related to the microbial activity of the compost (Iannotti et al., 1993). However, both stability and maturity are often evaluated together, as phytotoxic compounds are produced by microorganisms in unstable composts (Zucconi et al., 1981). Stability refers to a particular stage or decomposition while maturity is the degree or level of completion of composting (Bernal et al., 2009). The microbial community uses less oxygen and produces less carbon dioxide when a product is stable. The product won't be offensive and will have an earthy smell. Low fatty acid content and the inability of the product to inhibit plant growth define a mature product (Epstein, 2011).

CHAPTER 6

Characteristics and Quality of Compost

6.1 The common parameters to characterize the compost are pH, carbon, nitrogen, sulfur, NH4/NO3 content, organic matter, moisture, electrical conductivity, and heavy metals content.

The main factors to composting control include: (i) environmental parameters (temperature, moisture content, pH, and aeration), (ii) substrate nature parameters (C/N ratio, particle size and nutrient content). The compost quality is an important environmental factor related to the existence of various inorganic and organic pollutants and their stability, nutrient content, physico-chemical and biological parameters (Silva et al., 2007). In order to assess the maturity of compost many research (Bernal et al., 2009; Cestonaro et al., 2021; Illera-Vives et al., 2017; Toledo et al., 2020) are based on chemical characteristics such as pH which the typical

values are 6.5-8.5, this parameter measure the acidity or basicity of the compost. An excessively high value can cause odors and ammonia odors and losses of ammonia.
Electrical conductivity reflects the soluble mineral content of the sample that typically comprises the cations, Na^+, K^+, Ca^{2+} and Mg^{2+} and anions, HCO^{3-}, Cl^- and SO_4^{2-}. Electrical conductivity, µS/cm typical values are 500-4,000, high EC can produce a dehydration effect on plants, especially if compost is used as a substrate in high proportions in pots, planters also it can inhibit seed germination and crop development (Paradelo et al., 2012).

Compost that is intended to be added to the soil must contain a high percentage of organic matter (Gigliotti et al., 2012). Organic matter indicates the percentage of the dry matter that remains after the composting process. Values below 30% usually indicate that the compost is mixed with sand, soil, ash, or another mineral compound, however, it is crucial that this organic matter is stable and mature during the composting process.

Different chemical parameters, in particular the C/N ratio, COD, the ratio NH^{4+}/NO^{3-}, and microbial respiration rates reflect compost stability and maturity (Barrena et al., 2006). The C/N ratio is an indicator commonly used to evaluate the composting process and assess the stability of the compost. This index indicates the stability of organic matter from a microbial perspective and predicts whether compost is stable in the soil. There is no consensus in the literature on the optimal C/N ratio for composting. Some authors (Benny Chefetz et al., 1996; Provenzano et al., 2001) consider values close to 10 to indicate slow microbial activity and lead to material stabilization. According to Tomati (Tomati et al., 2002) the C/N ratio of stabilized compost was between 11 and 22 and referring to (Benny Chefetz et al., 1996) C/N ratio is not a reliable indicator of the maturity of municipal waste composting.
The nitrogen % value normally vary between 1.0-2.5. To produce composts with high nitrogen content (>3%), it is advisable to use a high aeration level and long time and a low particle size, regarding to El Kader (el Kader et al., 2007) there is an important relationship between free air space (related with the particle size) and the ammonium emissions which provoke loss of high contents of nitrogen. Phosphorus values normally vary between 0.40-1.2; while Potassium, % K_2O between 0.50-1.3. The values of mineral nutrients depend to a large extent on the on the starting biowaste (proportion of garden and kitchen waste), also on the composting process (industrial or self-composting) and the screening of the sample.
One of the possible negative effects of the compost, it´s the content of heavy metals, which can be transmitted to the environment, and possibility to be transferred from the soil to the food chain. Therefore, ‘Low metal compost’ is very valuable resource for soil management practices. According to Real Decreto 506/2013, the heavy metals such as cadmium, copper, nickel, zinc,

mercury, chromium, and lead should be presents with low concentration in the compost as showed in Table 9.

Table 9. Compost classification according to the metal content in RD 506/2013

Unit mg/kg	[1]Class A	[2]Class B	[3]Class C
Cadmium	0.7	2	3
Copper	70	300	400
Nickel	25	90	100
Lead	45	150	200
Zinc	200	500	1000
Mercury	0.4	1.5	2.5
Chromium (total)	70	250	300
Chromium (VI)	Not detectable according to official method		

[1]*Class A: Fertilizer products where the heavy metal content does not exceed any of the values in column A.*

[2]*Class B: Fertilizer products where heavy metal content does not exceed any of the values in column B.*

[3]*Class C: Fertilizer products where the heavy metal content does not exceed any of the values in column C.*

The benefits of using compost as an organic soil amendment may be seen in agricultural land, but compost should only be applied to soil after it has been characterized and shown to be safe, laboratory analysis is an important tool in manufacturing compost with qualities that fit its intended uses, such as:

- pH: the pH of any compost should be neutral to slightly acid (6.05–7.5) and must be lowered if it exceeds pH 8.0, Lowering a high pH lowers ammonia volatilization and reduces odors, favoring a balanced microbial population.
- N–P–K: the percentages of finished compost are relatively low, but their benefit lies in the slow release of organically-bound N and P in the soil that plants can use more effectively (Gershuny & Martin, 1992).
- There is no absolute level of organic matter that is ideal in terms of compost quality, but rather the quantities must be viewed in relation to the age of the compost, its nitrogen content, and its intended use.
- Composts may be considered mature when the C/N ratio is approximately 17.
- The components contributing most to salinity are Na, K, Cl, ammonia, nitrate and sulfate. Low values indicate a lack of available salts, while high values indicate a large

amount of soluble salts that may inhibit the biological activity or may be unsuitable for land application if large quantities of the material are used.

- Important factors for plant growth are nutrient elements such as P, Mg, K and Ca. The concentrations of these elements can be expressed as total or available forms.
- Physical properties that must be considered in preparing substrates include total porosity, free air space, water holding capacity, bulk density, compacted bulk density and particle density.
- The humic substances, which constitute a major part of the organic matter of compost, can reduce metal solubility by the formation of stable metal chelates (Ross, 1994).
- Low nitrate concentration may indicate insufficient oxygen, causing gaseous N loss by denitrification or may indicate a high pH, causing inhibition of nitrifying microorganisms.
- Soluble nitrogen may also be present in compost as ammonia, but this is not desirable because it is more volatile and can be lost if the material is surface spread

Increased levels of soil N, P, K, pH, and C levels in the soil can increase crop yield beyond the application years. A study case concluded that soil pH, organic matter, total N, NO3–N, and P levels were still elevated 4 yr after dairy manure application ceased (Mugwira, 1979). Eghball (Eghball et al., 2004) found that the increased plant-available P level in soil following N-based manure or compost application could contribute to crop P uptake for up to 10 yr without any additional P addition.

According to Ginting (Ginting et al., 2003) did not find increased emission of greenhouse gasses (CO2, CH4, and N2O) as a result of residual manure and compost applications that ceased 4 years earlier.

CHAPTER 7

Use of Compost as Soil Conditioner and Plant Growing

7.1 Use of compost as soil conditioner

The main area of compost use in agriculture is mostly related to the soil improvement. Compost application to soil improves soil structure since compost is an organic material, it can be used to maintain and increase soil organic matter content. Many studies have reported improvements in soil physical and chemical properties such as soil aggregation, cationic exchange capacity (CEC), water-holding capacity, aeration, hydraulic conductivity, soil pH and some of them are explained below. Application of compost to soil can reduce soil bulk density, increase aggregate stability, and water-holding capacity (Miller and Miller, 1999).

7.1.1 Soil Bulk density

Compost has low bulk density and higher porosity because of its organic origin (Martin and Stephens, 2001) and addition of compost to soil reduces soil bulk density. Bulk density of soil is calculated by the weight/volume ratio of an undisturbed soil sample after drying at 105 °C until constant weight in the oven. Long term study results revealed that compost addition to soil at the rate of 25 ton/ha/year reduced soil bulk density from 1.41 g/cm^3 to 1.12 g/cm^3 at 0-15 cm soil depth and 1.46 to 1.20 g/cm^3 at 15-30 cm soil depth (Celik et al. 2010). Yuksel and Kavdir (2021) conducted field experiment in Canakkale-Turkiye. Six different compost application rates (0, 40, 80, 120, 160 and 200 t ha^{-1}) have been applied to sunflower plots. Municipal waste compost (MSWC) applications to clay loam soil decreased soil bulk density in both years.

Aggelides and Londra (2000) reported that bulk density and penetration resistance decreased with compost (composed of 62% town wastes, 21% sewage sludge and 17% sawdust) applications and reduction was greater in the loamy soil than in the clay soil. The improvement was proportional to the compost rate.

Table 10: Effects of different compost types on soil bulk density

Type	Soil type	Plant	BD -b* (g cm^{-3})	Application rate	BD-a (g cm^{-3})	Reference
CMC	-	Wheat-corn	1.43	%25 of total fertilizer	1.33	Guo et al.2016
MSWC	SiCL		1.34	25 t ha^{-1} 50 t ha^{-1} 100 t ha^{-1}	1.33 1.28 1.03	Hemmat et al.2010
FC	SL	Fodder beet Forage maize Brussels sprouts Potato	1.40 1.37 1.41 1.42	50 m^3/plot	1.38 1.35 1.38 1.39	D'Hose et al.2012

*BD-b: Soil bulk density before amendment; BD-a: Soil bulk density after amendment; CMC: Cattle manure compost; MSWC: Municipal solid waste compost; FC: Farm compost

7.1.2 Soil organic carbon (SOC)

The chemical structure of organic materials in the soil is controlled by the chemical composition of the C inputs (Baldock et al.1992). Therefore, the types and origin of feedstock of compost important to maintain SOC of soil. In general, application of carbon rich compost to soils maintains and improve soil organic carbon content and soil fertility. Effect of compost on SOC contents depend on compost types, application rates and soil properties. For instance, applications of 120 dry t ha^{-1} garden organics compost improved soil SOC significantly (%2.1) compared to the conventional farmers practice treatment (%1.3) (Eldridgeet al., 2014). Applications of composted cattle manure up to 15 Mg ha^{-1} contributed about 1.35 to 2.02 Mg C ha^{-1} yr^{-1} in the SOC pool after 5 yr, in a sandy-loam Humic Gleysol in Quebec. (Whalen et al., 2008).

Laboratory study shown that the percentage of remaining rice husk derived (RHC) compost varied from 16% to 40% at R5 (80 Mg ha^{-1}) for the topsoil. The application of RHC increased the SOC with increasing application rates and its residual effect lasted about 24 months after application. Decomposition of RHC n the soil was in the order field > greenhouse > laboratory conditions (Anda et al. 2010).

Tautges et al. (2019), observed nine cropping systems in 19-year study and only one system which is, poultry manure compost and winter cover crop fertilization in maize-based systems, showed increases in SOC stocks throughout the 2m depth soil profile. Annual inputs of 9 t/ha of composted poultry manure resulted in the addition of 2.22 Mg ha^{-1} year^{-1} more C to the soil compared to the conventional fertilizers. The greatest increases in SOC were observed in the organic treatment, especially in surface layers, where SOC increased by 4.20 g/kg in the top 15 cm layer ($p < .001$) and 2.59 g kg^{-1} at 15–30

Fish wastes and olive pomace compost applications (9% w/w) to sandy loam soil increased SOC about 68 % compared to control soil. SOC content of soil was 2.94% and increased to 4.96% within two-monts after compost application. Increasing SOC content with the addition of compost also promoted the increase of soil aggregate stability that has been increased from 52% to 85% (Ilay et al. 2019).

Table 11: Effect of composts on SOC

Type	Soil type	Plant	SOC-b (%) control soil	Application rate	SOC-a (%)	Reference
CMC	-	Wheat-corn	0.75	%25 of total fertilizer	1.46	Guo et al.2016
MSWC	SiCL		0.89	25 t ha-1 50 t ha-1 100 t ha-1	1.45 1.72 2.22	Hemmat et al.2010
FC	SL	Fodder beet Forage maize Brussels sprouts Potato	1.13 1.15 1.17 1.09	50 m3/plot	1.30 1.23 1.22 1.29	D'Hose et al.2012

*SOC-b: Soil organic carbon before amendment; SOC-a: Soil organic carbon after amendment; CMC: Cattle manure compost; MSWC: Municipal solid waste compost; FC: Farm compost; SW+FWC: Sea weed+fish waste compost.

7.1.3 Water holding capacity and hydraulic conductivity.

Compost application improved the water retention characteristics of the soil depending on the compost particle size and feedstock type. Compost produced from a combination of plant material, sewage sludge and biochar amendment showed the best result in terms of water holding capacity. Compost amendment both increases water retention and water repellency risk (Glab et al. 2020).

Soil porosity and pore-size distribution determines the water and air movement within soil profile. Macropores in soil regulates water infiltration rate and aeration while micropores control water-holding capacity. Soil that has a balance of macropores and micropores provides optimum conditions for plant growth.

Aggelides et al. (2000) applied compost composed of town wastes, sewage sludge and sawdust at the rates of 75, 150 and 300 m3 ha−1 to loamy and clay soils. Total porosity and saturated hydraulic conductivity increased with compost application to loamy and clay soils. The increase of total porosity was greater in the loamy soil than in the clay soil, and saturated hydraulic conductivity was greater in the clay soil than the loamy soil. Compost applications improved all physical properties. It reduced bulk density and penetration resistance and increased porosity and saturated hydraulic conductivity.

On the other hand, compost chemical properties have a great influence on soil water characteristics. In general incorporation of compost improves soil porosity and soil structure and permeability. However, Hanson et al. (1999) reported that fine soils might be affected by sodium (Na+) induced clay swelling after the application of Na+ rich compost. The results by Colombani, et al (2020) showed that the compost addition modified the physical and hydraulic properties of the soil, because of the elevated sodium content of the used compost, leading to clay's swelling, which negatively affected soil water holding capacity and infiltration rate. In this study compost, application rate was 30t $^{ha-1}$, it contained 450 ppm Na+ and applied to silty clay soil.

Mulching with compost to soil surface, reduces evaporation, reduces topsoil temperatures in hot climates, and provides optimal environment for root development. Le Bissonnais et al.,(2007) reported that soil organic carbon increased the hydraulic conductivity by increasing soil aggregate stability and porosity. Compost improves soil structure which reduces crust formation and increase water infiltration. Addition of compost to soil increases soil porosity, soil water retention capacity (depending on soil texture) and hydraulic conductivity (Hargreaves et al., 2008; Ramos, 2017). On the other hand, sometime compost application causes soil water repellency especially in sandy soils (Scott, 2000). It was observed that water repellency depended on the particle size and compost feedstock. When the size of the compost particles decreased, the water repellency rapidly increased for sandy soils (Glab et al. 2020).

7.1.4 Soil aggregation

Aggregate stability is highly dependent on organic matter contents in coarse textured (sand, sandy loam etc.) since these soils have low amount of clays and oxides. Composting improves soil structure by the binding organic matter and clay particles via cation bridges and by increasing microbial activity (Farrell and Jones, 2009)

Application of different composts improves aggregate stability and related physical properties. Isler et al. (2022) amended different textured soils with olive pomace (OPC) and vineyard pruning waste (VPC) composts. In clay soil, the highest aggregate stability (AS) values of 3% OPC and 6% VPC treatments were recorded on the 210th day of incubation (AS 93%). The highest AS values for 6% OPC and 6% VPC (82.7% and 83.1%) for loam soil. Application of composts to coarse textured soils resulted in higher increases in soil aggregate stability than those in fine textured soils. The highest increase of AS in clay soil was 6.8% while the increase in sandy loam soil was about 41% (İşler et al, 2022).

The amount of large aggregates increased by 4% due to compost application in the sandy soil and 1.6% in the loamy soil (Rivier et al. 2022). They reported that the relative effects of compost application (vermicompost and sewage sludge compost), with respect to macro aggregate stability depends on the soil texture, and stronger effect can be seen on soils with poor structure. The addition of composts increased the aggregate stability of the sandy soil.

Annabi et al. (2007) reported that immature and mature composts increased aggregate stability of loam soils. The microbial activity in immature compost can increase soil aggregate stability by increasing the water repellency of soil. The addition of mature composts improved aggregate stability by increasing aggregate cohesion due to the diffusion of organic substances into the aggregates. Killi and Kavdir (2013) applied increasing amounts of olive pomace and olive pomace compost on sandy and loam soils (0, 4, 8 and 10%) and grown tomato (*Solanum lycopersicum*) plant. Soil aggregate stability increased with both amendments however effect of compost on increasing soil aggregate stability was higher in sandy soil than loamy soil.

In some cases, aggregate stability of soil with high clay content that has already stable aggregates decreases with compost application. Rivier et al. (2022) reported that soils that had already stable aggregates do not respond to the addition of small amounts of organic amendments.

Mean weight diameter (MWD) of aggregates have different responses of compost application in the literature. Aggelides and Londra (2000) reported that compost applications improved all physical properties of study soils. Mean weight diameter of the aggregates decreased in both soils, while aggregate stability was increased. Obalum et al. (2019) reported that compost amendment did not increase the MWD of dry and wet sieved aggregates. Application of municipal waste compost at the rate of 16 t ha-1 to soil increased soil AS value from 52.27% to 60.88% in two years of field study (Yuksel and Kavdir, 2020)

7.1.5 Soil pH

Changes in soil pH with compost amendment depend on initial soil pH value and soil characteristics such as soil organic matter content, soil texture, soil cation exchange capacity, soil pH buffering capacity. Therefore, application of high pH compost to a low pH sandy soil can increase soil pH, however the same compost applied to a low pH clay textured soil may result in little or no change in soil pH. Additionally compost pH value and amount applied to soil can also alter soil pH. As soil pH declines, the supply of macro plant nutrients decreases, whereas a few micronutrients become more soluble and toxic to plants. Compost can improve soil pH and soil buffering capacity (Latifah et al. 2018). Compost pH can be adjusted during the composting period by adding either acidifying materials such as elemental sulphur or liming materials.

Compost application has a liming effect since it contains Ca, Mg and K, which release from OM mineralization. The increased soil pH was also directly proportional to the base cations contents of the added organic material (Wong et al. 1998). Erana et al. (2002) conducted a field experiment where Allium cepa L. was grown using five different levels of agro-industrial wastes compost. Compost (pH:7.3) was prepared by co-composting of wastes from vegetables processing plants and their trimmings, slaughter house wastes, bone meal and saw dust. Most of the treatments showed a pH increase after compost amendment. Application of olive pomace compost to sandy and loamy soils resulted in only a slight changes in pH (Killi and Kavdir, 2008).

Only in some few cases, a pH decrease was observed after compost application. Application of cow manure compost at the rates of 6,12,18 and 24 t ha^{-1}, decreased soil salt content and soil pH in saline-alkali soil with pH of 8.25. The pH reduction was caused; possibly, by the organic acids and acid functional group contained in the cow manure compost (Li et al. 2022).

7.1.6 Cation exchange capacity (CEC)

Compost addition to soil increases the cation exchange capacity of soils, especially coarse textured soils. The addition of olive pomace compost to sand and loam textured soils resulted in a general trend towards increased cation exchange capacity. Sandy soils CEC increased from 28 to 40 cmol/kg while loam textured soil CEC increased from 8 to 18 cmol/kg (Killi and Kavdir, 2008).

Cooper et al (2020) reported that the strongest increase in soil CEC in the surface and subsurface soils was for the high application rate ($C_{70}B_{31.5}$ - 70 t ha^{-1} of compost and 31.5 t ha^{-1} of biochar) of the compost-biochar mixture They found a significant increase in CEC in response to compost (control < low-rate < high-rate) application to soil surface. The $C_{70}B_{31.5}$ treatment showed the highest CEC (134 $mmol_c$) and the lowest CEC was found for $C_{20}B_9$ (92 $mmol_c$) in the surface soil.

7.1.7 Soil nutrients

The main purpose of compost amendment is not to supply essential nutrients for plant growth like nitrogen, phosphorus, and potassium, but to contribute to the improvement of the soil health and structure (De Bertoldi et al., 1983). Although amount and solubility of nutrients in compost is not like in chemical fertilizers, compost contains N and P elements necessary for plant growth.

The global demand for for nitrogen fertiliser was estimated to increase from 110.03 to 118.76 t from 2015 to 2020, with an annual growth rate of 1.5 % (FAO, 2017). Replacement with organic amendments, such as compost, manure, or plant residues, as a nutrient source is becoming more attractive.

Pelletized pig manure compost was shown to be an effective slow-release fertilizer for maize. It was suggested that addition of a bulking agent should be added before composting, small diameter pellets should be used and composts should be incorporated into the soil. Smaller diameter compost pellets induced increased plant N concentration and root production (Pampuro et al. 2017).

Sometimes it is necessary to combine compost and chemical fertilizers together. Noor et al (2020) determined that compost use enhanced the effectiveness of chemical fertilizers by increasing crop productivity when both compost and fertilizer were applied rather than either one of the amendments. The highest sesame (Sesamum indicum L.) yield (805.1 kg ha^{-1}) was obtained in integrated fertilizer farming treatments (30 t ha^{-1} compost+ ½ dose chemical fertilizer). Compost application increased field capacity, wilting point, and soil available moisture and reduced bulk density of soil.

The quality as well as the quantity of applied compost is important factor for its agronomic benefits. Compost contains both organic and inorganic N forms. The majority of nitrogen in compost is organic while low amounts of N is inorganic form. During the mineralization of compost both mineralization and immobilization of N take place in the soil. Release of nitrogenous compounds after compost application to soil perform a slow rate of nitrogen mineralization due to its immobilization. Mineralization means that nitrogen is decomposed into inorganic forms such as NH4+ and NO3− that can be used by plants. Immobilization means available nitrogen is taken up by microorganisms and as a result N cannot be accessible by plants (Oscar et al, 2017). If compost has high C:N ratio, a high lignin or a high polyphenol content, N immobilization occurs in the soil. The immobilized nitrogen will be available to plants but mineralization rates considered to be slow (1–3% of total N/year), (Al-Bataina et al., 2016).

In general, the application of organic material with a C/N ratio > 20 - 40 promotes net N immobilization (Vigil and Kissel, 1991). Al-Bataina et al., 2016, studied the effect of grover green waste compost age on the extent and rates of nitrogen release under rainfall simulation studies. The nitrogen release during simulated storms declined in the order 4 week>9 week>0 week. On the other hand, total phosphorous release declined with aging time. Major form of nitrogen released in storms was ammonium (Al-Bataina et al. 2016).

Considering all soil and compost types, a mineralization rate for compost in temperate climates are between 0 % - 20 % for the first year after application (Ozores-Hampton et al.2022). Therefore, amount N derived from compost can be estimated according to climate, soil type and compost N content and compost application rate. Animal manures and biosolid compost contain higher concentrations of P than compost produced from vegetative feedstocks. It was suggested that, P-availability in the first year of application ranges between 30% and 50%, and between 60% and 90% over 2 years (Ozores-Hampton et al.2022).

Some researchers indicated that compost amendment increases plant phosphorus (P) contents. For instance, canola (Brassica napus L.) was grown in pots containing clay loam soil mixed with 0.04 kg of the amendments (composted and non-composted manures). Inorganic P fertilizer (KH_2PO_4) and control soil were included for comparison. Cumulative P uptake was similar for composted (74 mg kg^{-1} soil) and non-composted manures (60 mg kg−1 soil).

Cumulative P uptake was significantly higher for organic amendments than the control (24 mg kg^{-1} soil) and for composted manure than the fertilizer. Total CPU over the 363-d period ranged from 23.8 mg kg−1 soil for the control to 73.9 mg kg^{-1} amended soil for the composted manure treatment (Zvomuya et al. 2006).

7.1.8 Soil-born Pathogens

Plant diseases caused by soil-borne pathogens threatens plant health and productivity. In recent decades, continues tillage, intensive cultivation, mono culture and lack of soil organic matter content promoted these pathogens in agricultural soils (Jambhulkar et al. 2015). Compost addition may suppress diseases if compost contains recalcitrant carbon pool. The compost amendment can enhances fertility and provide the soil of biocontrol-based microbiota (Santos et al., 2011) and increases soil chemical, physical and biological capacity to suppress disease (Stone et al. 2004).

In the review of Bonanomi et al. (2007), it was reported that OM was suppressive in 45% of cases and non-significant in 35% of the cases and OM increased disease 20% of cases. Suppressive effects of organic materials depended on their types. For instance, composts and organic wastes were the most suppressive types in all organic materials. Compost application suppressed diseases more than 50% of cases and increased only <12% cases.

Santos et al (2011) applied tannery sludge compost (TSC) to sandy and clayey soils at rates of 0, 7.5, 15, 30 and 60 Mg ha^{-1}. The application of 7.5 Mg ha^{-1} TSC significantly increased the microbial biomass and activity. There were no negative or positive effects by the application of 7.5 Mg ha^{-1} on soil enzymes. TSC did not negatively affect the soil microorganisms and their activities even at the lowest rate. Soil microbial biomass increased at 15th day of incubation due to readily available C and nutrients contained in the tannery sludge.

Ntougias et al (2008) studied nine different composts produced from the by-products of the olive oil, wine, and Agaricus mushroom agro-industries. All compost amendments showed suppressiveness against *Phytophthora nicotianae* Breda de Haan in tomato, when they were applied directly after curing however, composts were relatively less effective when applied 9 months after curing

Kavdir et al (2019) conducted both pot and field study to investigate nematicidal effects of olive pomace and green walnut husk compost effects on root-knot nematode in Çanakkale-Türkiye and reported that application of olive pomace and green walnut husk compost significantly reduced the root-knot nematodes (*Meloidogyne incog*nita) number in soil as well as gall formation on tomato roots. Additionally compost applications significantly enhanced the tomato growth, increased fresh mass, root length, root surface area and tomato yields. Improvements in soil physical properties with the addition of compost enhance plant root growth and soil health. Soils with poor physical quality (compacted, restricted layer, poor aeration) reduce the rate of root growth and roots can be easily infected (Allmaras et al., 1988).

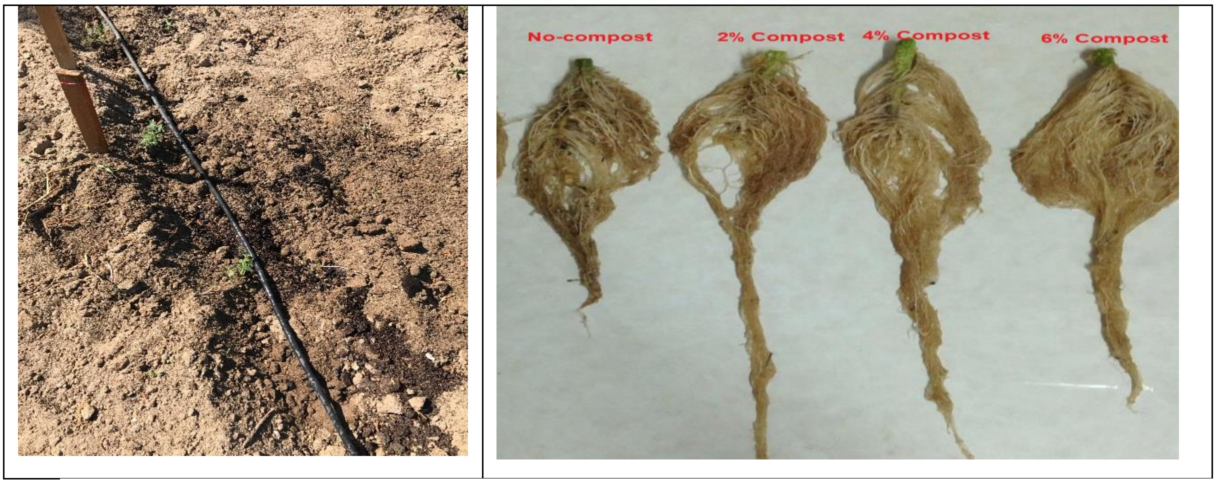


Figure 39. Application of composts to Tomato Field (left), tomato root development in root-knot nematode infected pot vs compost added pots at different rates (Kavdir et al. 2019)

Khumalo et al (2021), investigated the effect of compost amendments on the survival and infectivity of *Heterorhabditis bacteriophora* infective juveniles in loamy and sandy soil under decreasing moisture conditions. They concluded that the use of organic compost in agricultural soils can improve the survival and efficacy of entomopathogenic nematodes (EPNs) which can be used as biocontrol agents in the field.

Table 12. Effects of composts on nematodes

Compost Type	Nem. type	Plant	Nematode-s Per 100ml	Rate	Nematode-cs Per 100ml	Reference
FC		Fodder beet	2630 4329 2203	50 m^3/plot	3355 6777 2633	D'Hose et al.2012

		Forage maize Brussels sprouts Potato	5197		6291	
Yard waste Compost	*Criconemella spp.* *M. incognita* *Paratrichodorus minor*	Maize	91 24 74	269 t/ha	14 12 39	McSorley & Gallaher 1996
Potato waste	Root-knot nematodes Root-lesion nematode	Potato	1410 /kg soil 2,880	16 t/ha	1050 /kg soil 5,250	Kimpinski et al. 2003

CMC: Cattle manure compost; MSWC: Municipal solid waste compost; FC: Farm compost

7.2 Use of compost for plant growing

The effects of compost on plant growth are closely related to species and the amount of compost in the media. Plant responses to the compost treatments are highly dependent on the species, the source, and the quantity of compost utilized, even though much research has focused on the beneficial effects on plant growth of moderate (up to 30%) compost doses in the mixtures. To avoid adverse effects on plants, this compost should not be used for plant growth until it has become well stabilized and mature.

The agronomic utilization of manure compost not only represents a low-cost disposal method, but also a means to recycle nutrients for plant growth and to counteract the decreasing organic matter content of most modern agricultural soils. The application of manure compost has been shown to have a positive effect on crop production (Woodbury, 1992) when nutrient deficiencies have been corrected by compost addition.

Developing inexpensive and nutrient-rich organic media alternatives cannot only eliminate environmental impacts, but also means reducing fertilization rates, irrigation rates, and nursery costs (Wilson et al., 2001). Numerous studies have demonstrated that these organic residues, after proper composting, can be used with very good results as growth media instead of peat (Garcia-Gomez et al., 2002).

Composts obtained from different organic materials have proved to be very promising substitutes for peat (Sánchez-Monedero et al., 2004). In a study case there were conclusions about the use of compost as a substrate for tomato and lettuce seedlings production, being an alternative to peat-based substrates usually used. For tomatoes, the highest growth was achieved when seedlings were grown on 100% composted substrate. While the growth of lettuce seedlings was not affected by the presence of compost on the substrate composition.

The physical properties of the substrates were significantly affected by the percentage of compost present in the mixtures in this study case:

- Compost addition significantly increased pH values of substrates.
- Increasing the percentage of compost in the substrates increased N, Mg^{2+} and Ca^{2+} and decreased K concentration in shoot tissues.

Literature shows great variability between pH values, electrical conductivity, or nutrient contents among these types of compost (Benito et al., 2000), but all conclude that they must be considered as good quality plant growth substrates.

In a case study using manure compost, there were increased soil macro- and micro-nutrients for plant growth. From the plant elemental uptake, they found that manure compost application did not result in excessive uptake of Zn, Cu and Cd from manure compost for two types of crops.

The most important requirements of a good plant growing substrate is a high capacity for moisture retention, and drainage of excess water (i.e., to prevent waterlogging). Analytical testing and practical trials have, on several occasions, demonstrated the potential of composted materials from the standpoint of their physical and hydrological properties. In this regard, mixing finished compost with peat in a ratio of 40 to 70 percent (especially those composts with optimum hydrological properties) will yield excellent plant growth media (Bugbee, 1994; Y. et al., 1988).

The application of composted manure can result in increased soil concentrations of nutrients and organic matter (Eghball et al., 2002). The residual effects of increased nutrients and organic matter in soil following compost application on crop yield and soil properties can last for several years (Mugwira, 1979).

Organic farmers often use composts as soil amendments, particularly in intensive vegetable production systems to improve soil fertility and quality and sustain productivity. Composts improve the biological, chemical, and physical properties of amended soils and can provide effective biological control of diseases caused by plant pathogens.

CHAPTER 6 (Continues) (Relevant Laws&Legistations)

6.2 Compost quality: In this section "Status of National Compost Guidelines "of partner countries will be summarized. Compost standards will be compared, and suggested standards will be summarized.

6.2.1 Status of National Compost Guidelines in Spain

In the Royal decree 865/2010 (Real Decreto 865/2010), through the order PRA/1943 (Orden PRA/1943, 2016) products that can be marketed as growing substrates or as components thereof must belong to one of the groups included in Annex I of the mentioned order; in such a way that those products that are not integrated into one of the established groups cannot be put on the market. Compost is within Group I, defined as organic products such as growing substrates or components thereof. Annex I show the

Table 1313 with a classification of the organic products such as growing media or growing substrate components:

Table 13 Minimum specification of compost according to the legislation RD 865/2010

Description	Specifications	Mandatory disclosures	Optional Statements
Sanitized and stabilized product, obtained by aerobic biological decomposition (including thermophilic phase), of manure with or without addition of plant materials, under controlled conditions.	Organic matter on dry matter >20% (m/m).	▪ Main components (more than 10 % (v/v)) arranged in decreasing order of percentage. ▪ Organic matter over dry matter. ▪Electrical conductivity, EC. ▪ pH. ▪ Amount in volume.	▪ Dry bulk density. ▪ Volume of air. ▪ Volume of water at 1, 5 and 10 Kpa. ▪ Dry matter. ▪ Total pore space. ▪ Name of animal species(es). If from poultry indicate "poultry manure". ▪ Granulometry

Spanish legislation, through the Royal Decree 999/2017 (Real Decreto 999/2017) amending (Real Decreto 506/2013), of 28 June concerning to fertilizer products (see Annex I), regulates -for the different types of compost- certain quality requirements that are shown in

Table 13 . In this Royal Decree, a classification of fertilizer products" where compost[1] is included in Group 6: organic amendments[2], differentiating four types:

- Organic amendment Compost: compost obtained from biodegradable organic materials included in Annex I of the same (Real Decreto 999/2017) and which would include the compost of organic fraction collected separately and urban sewage from treatment plant. It also includes biostabilized materials[3] from Mixed Waste (Rest Fraction) that according to Ley 7/2022 on Waste cannot be considered compost.
- Organic Amendment Vegetable Compost: compost obtained exclusively from leaves, cut grass and vegetable, or pruning remains.
- Organic amendment Manure Compost: compost obtained exclusively from manure.
- Organic amendment Vermicompost: compost obtained from organic materials by digestion with worms.

For compliance with this Royal decree, a later order (Orden AAA/2564, 2015) published that it is necessary to control and comply with the following parameters of humidity, total organic matter content, C/N ratio, granulometry and impurities

Table 14. Compost requirements according to the legislation Orden AAA/2564/2015

Information on how to obtain and the essential essential components	**Minimum and maximum content (% by mass) Other requirements**	**Other information on the type designation or labeling**	**Nutrient content to be declared and guaranteed. Nutrient forms and solubility Other criteria**
• Organic amendment Compost Sanitized and stabilized product, obtained by biological decomposition decomposition (including thermophilic thermophilic phase), exclusively from manure, under controlled controlled conditions	- Total organic matter: 35%. - Maximum humidity: 40%. - C/N < 20. -May not contain impurities or inerts of any kind such as: stones, gravel, metals, glass or plastics. – 90% of the particles will pass through the 25 mm mesh.	- pH. - Electrical conductivity. - C/N ratio. - Minimum and maximum humidity. – Treatment or elaboration process, according to the description indicated in column 2	-Total organic matter. - Organic C. - Total N (if over 1%). - Organic N (if over 1%). - Ammoniacal N (if more than 1%). - Total P2O5 (if more than 1%). - Total K2O (if more than 1%). - Humic acids. - Granulometry.
• Organic Amendment Vegetable Compost Sanitized and stabilized product, obtained by aerobic biological decomposition (including thermophilic phase), exclusively from leaves, cut grass and plant or pruning remains, under controlled conditions	– Total organic matter: 40%. – Maximum humidity: 40%. – C/N < 15. – It may not contain impurities or inerts of any kind such as stones, gravel, metals, glass or plastics	– pH. – Electrical conductivity. – C/N ratio. – Minimum and maximum humidity. – Treatment or elaboration process, according to the description indicated in column 2	– Total organic matter. – Organic C. – Total N (if it exceeds 1%). – Organic N (if it exceeds 1%). – Ammoniacal N (if it exceeds 1%). – Total P2O5 (if it exceeds 1%). – Total K2O (if it exceeds 1%). – Humic acids. – Granulometry.
• Organic amendment Manure Compost Sanitized and stabilized product, obtained by aerobic biological decomposition (including hermophilic phase), exclusively of manure, under controlled conditions	– Total organic matter: 35%. – Maximum humidity: 40%. – C/N < 20. – It may not contain impurities or inerts of any kind such as stones, gravel, metals, glass or plastics.	– pH. – Electrical conductivity. – C/N ratio. –Minimum and maximum humidity. – Treatment or elaboration process, according to the description indicated in column 2	– Total organic matter. – Organic C. – Total N (if it exceeds 1%). – Organic N (if it exceeds 1%). – Ammoniacal N (if it exceeds 1%). – Total P2O5 (if it exceeds 1%). – Total K2O (if it exceeds 1%). – Humic acids. – Granulometry.
Organic amendment Vermicompost. Stabilized product obtained from organic materials, by digestion with earthworms, under controlled conditions	– Total organic matter: 30%. – Maximum humidity: 40%. – C/N < 20. – 90% of the particles will pass through the 25 mm mesh.	– pH. – Electrical conductivity. – C/N ratio. –Minimum and maximum humidity	-Total organic matter. - Organic C. - Total N (if over 1%). - Organic N (if over 1%). - Ammoniacal N (if more than 1%). - Total P2O5 (if more than 1%). - Total K2O (if more than 1%). - Humic acids. - Granulometry.

			– Type or types of manure used.

and metal content indicated in Table 8.

Table 14. Compost requirements according to the legislation Orden AAA/2564/2015

Information on how to obtain and the essential essential components	Minimum and maximum content (% by mass) Other requirements	Other information on the type designation or labeling	Nutrient content to be declared and guaranteed. Nutrient forms and solubility Other criteria
• Organic amendment Compost Sanitized and stabilized product, obtained by biological decomposition decomposition (including thermophilic thermophilic phase), exclusively from manure, under controlled controlled conditions	- Total organic matter: 35%. - Maximum humidity: 40%. - C/N < 20. -May not contain impurities or inerts of any kind such as: stones, gravel, metals, glass or plastics. – 90% of the particles will pass through the 25 mm mesh.	- pH. - Electrical conductivity. - C/N ratio. - Minimum and maximum humidity. – Treatment or elaboration process, according to the description indicated in column 2	-Total organic matter. - Organic C. - Total N (if over 1%). - Organic N (if over 1%). - Ammoniacal N (if more than 1%). - Total P2O5 (if more than 1%). - Total K2O (if more than 1%). - Humic acids. - Granulometry.
• Organic Amendment Vegetable Compost Sanitized and stabilized product, obtained by aerobic biological decomposition (including thermophilic phase), exclusively from leaves, cut grass and plant or pruning remains, under controlled conditions	– Total organic matter: 40%. – Maximum humidity: 40%. – C/N < 15. – It may not contain impurities or inerts of any kind such as stones, gravel, metals, glass or plastics	– pH. – Electrical conductivity. – C/N ratio. – Minimum and maximum humidity. – Treatment or elaboration process, according to the description indicated in column 2	– Total organic matter. – Organic C. – Total N (if it exceeds 1%). – Organic N (if it exceeds 1%). – Ammoniacal N (if it exceeds 1%). – Total P2O5 (if it exceeds 1%). – Total K2O (if it exceeds 1%). – Humic acids. – Granulometry.
• Organic amendment Manure Compost Sanitized	– Total organic matter: 35%.	– pH.	– Total organic matter. – Organic C.

and stabilized product, obtained by aerobic biological decomposition (including hermophilic phase), exclusively of manure, under controlled conditions	– Maximum humidity: 40%. – C/N < 20. – It may not contain impurities or inerts of any kind such as stones, gravel, metals, glass or plastics.	– Electrical conductivity. – C/N ratio. –Minimum and maximum humidity. – Treatment or elaboration process, according to the description indicated in column 2	– Total N (if it exceeds 1%). – Organic N (if it exceeds 1%). – Ammoniacal N (if it exceeds 1%). – Total P2O5 (if it exceeds 1%). – Total K2O (if it exceeds 1%). – Humic acids. – Granulometry.
Organic amendment Vermicompost. Stabilized product obtained from organic materials, by digestion with earthworms, under controlled conditions	– Total organic matter: 30%. – Maximum humidity: 40%. – C/N < 20. – 90% of the particles will pass through the 25 mm mesh.	– pH. – Electrical conductivity. – C/N ratio. –Minimum and maximum humidity	-Total organic matter. - Organic C. - Total N (if over 1%). - Organic N (if over 1%). - Ammoniacal N (if more than 1%). - Total P2O5 (if more than 1%). - Total K2O (if more than 1%). - Humic acids. - Granulometry. – Type or types of manure used.

[1]*It should be recalled that* Ley 7/2022 *on Waste and Contaminated Soils only considers compost that organic amendment obtained from biodegradable waste collected separately and subjected to aerobic and thermophilic biological treatment.*

[2]*Definition of organic amendment in the* Real Decreto 506/2013*: amendment from carbonated materials of plant or animal origin, used mainly to maintain or increase the organic matter content of the soil, improve its physical properties and also improve its properties or chemical or biological activity, the types of which are included in group 6 of Annex I.*

[3]*It should be remembered that* Ley 7/2022 *on Waste and Contaminated Soils establishes that organic material obtained from mechanical biological treatment plants of mixed waste, which will be called bio-stabilized material, will not be considered compost.*

6.2.2 Status of National Compost Guidelines in TURKIYE

In March 2015, in an attempt to better the waste handling situation in Turkey and bring it uptopar with developed countries, Turkish Ministry of Environment released a regulation on collection and recycling (composting) of biowaste in Turkey Composting Communique (No 29286, 2015).

March.5.2015 (Thursday) **Official Gazete** Numberı : 29286

COMMUNIQUE

From the Ministry of Environment and Urbanization:

COMPOST COMMUNIQUE

CHAPTER 1

Purpose, Scope, Basis and Definitions

AIM

ARTICLE 1 – (1) The purpose of this Communiqué; biodegradable wastes resulting from an activity or arising from businesses;

a) To ensure its management by collecting it separately at the source without harming the environment and human health,

b) Reducing the amount to be disposed of in landfills by recycling,

c) Determining the technical criteria of compost facilities,

ç) Determining the quality criteria of the products obtained from the compost facilities,

determination of the relevant procedures and principles.

SCOPE

ARTICLE 2 – (1) This Communiqué covers the technical principles regarding the processing of the biodegradable wastes in the Annex-1 waste list of this Communiqué, arising from the activities and/or consumption of the enterprises, in the compost facilities, the properties and use of the resulting product.

(2) The provisions of this Communiqué,

a) Radioactive wastes,

b) Wastewaters,

c) Animal cadavers, animal excrement used for agricultural purposes,

ç) Except for animal wastes sent to incineration, incineration or sanitary storage facilities together with recovery facilities such as biogas or compost, provided that the provisions of the Regulation on Animal By-Products Not Used for Human Consumption published in the Official Gazette dated 24/12/2011 and numbered 28152 are reserved. Animal by-products not covered.

BASIS

ARTICLE 3 – (1) This Communiqué;

a) Articles 8, 11 and 12 of the Environmental Law No. 2872 dated 9/8/1983,

b) The Law on the Preparation and Implementation of the Technical Legislation Regarding the Products, dated 11/7/2001 and numbered 4703,

c) Article 9 of the Decree-Law on the Organization and Duties of the Ministry of Environment and Urbanization dated 29/6/2011 and numbered 644,

ç) Regulation on General Principles of Waste Management published in the Official Gazette dated 5/7/2008 and numbered 26927,

d) Regulation on Regular Storage of Wastes published in the Official Gazette dated 26/3/2010 and numbered 27533, prepared on the basis of its provisions.Tanımlar

ARTICLE 4 – (1) In this Communiqué;

a) Waste treatment: The recovery or disposal processes in Annex-2/A and Annex-2/B of the Regulation on General Principles of Waste Management,

b) Waste processing facility: The facility that recovers and/or disposes of wastes with the activities in Annex-2/A and Annex-2/B of the Regulation on General Principles of Waste Management,

c) Ministry: The Ministry of Environment and Urbanization,

ç) Residual waste: The wastes that cannot be processed from the wastes accepted to the waste processing facility for processing or that remain as a result of processing,

d) Biodegradable waste: The wastes included in Annex-1 of this Communiqué, among the wastes that can degrade in an oxygenated or oxygen-free environment originating from parks, gardens and houses, restaurants, sales points, food production and similar facilities,

e) Environmental license: The license issued within the scope of the Environmental Permit and License Regulation published in the Official Gazette dated 10/9/2014 and numbered 29115,

f) Recycling: Transactions listed in Annex-2/B of the Regulation on General Principles of Waste Management,

g) Provincial directorate: Provincial directorate of environment and urban planning,

ğ) Operator: The natural or legal person responsible for the operation of the facilities,

h) Compost: The product produced by the decomposition of organic-based wastes in an oxygenated or oxygen-free environment,

ı) Pre-treatment: One or more of the physical, thermal, chemical or biological processes applied to the waste in order to reduce the volume or hazardous properties of the waste, facilitate its management or increase its recovery, including the separation process,

i) Facility owner: The real or legal person who owns the facility, who can also be the operator of the facility,

j) Product: The substance obtained as a result of waste processing and meeting certain criteria in accordance with the purpose of use,

k) Product accumulation area: It refers to the place where the product is kept in the facility.

CHAPTER 2

General Principles, Duties, Powers and Obligations

General principles

ARTICLE 5 – (1) The general principles regarding the management of compost and compost facilities are as follows:

a) Within the scope of waste management plans, it is essential to classify and collect biodegradable wastes separately, without mixing them with other wastes at their source or where they are produced.

b) It is obligatory to transport the wastes in a closed manner in a way that does not pollute the environment in terms of appearance, odor, dust, leakage and similar factors.

c) Persons, institutions and organizations responsible for waste management are obliged to take measures to prevent harm to the environment and human health at every stage of waste management.

ç) Pre-treatment of biodegradable wastes is essential.

d) It is obligatory to prevent the negative effects that may arise from the pollution sources, which are caused by the operation and pose a direct risk to human health, by taking the necessary measures as of the acceptance of the waste.

e) It is essential to reduce the amount of biodegradable waste to be disposed of in landfills. The provisions of the Regulation on Landfilling of Wastes are applied for the disposal of wastes by landfill method and for the targets of the amount of biodegradable waste to be stored.

f) Provisions of the Communiqué on Waste Derived Fuel, Additional Fuel and Alternative Raw Material published in the Official Gazette dated 20/6/2014 and numbered 29036 shall apply to the use of biodegradable wastes, residual wastes and/or compost that cannot be utilized in the production of waste-derived fuel.

g) It is obligatory to obtain the approval of the Ministry for the preliminary feasibility report prepared in accordance with the format in Annex-4 of this Communiqué regarding the compost facilities planned to be established, and the application projects prepared in accordance with the format in Annex-5 of this Communiqué on the implementation of technology and projects.

ğ) Pre-feasibility report and implementation projects are prepared by institutions and organizations holding the environmental impact assessment qualification certificate or by environmental consultancy firms authorized by the Ministry.

h) Compost facilities must obtain an environmental license in accordance with the

Environmental Permit and License Regulation.

(2) It is essential that the products covered by this Communiqué are placed on the market in a way that does not harm the environment and human health.

(3) Responsible parties, in order to reduce the negative effects of products and wastes on the environment and to manage them safely, by training their relevant personnel, raising awareness in the public, making or contributing to social responsibility projects and environmental education projects, making spot broadcasts in the written and visual media. They are obliged to do or contribute to the studies carried out for this purpose.Bakanlığın görev ve yetkileri

ARTICLE 6 – (1) The Ministry;

a) To ensure cooperation and coordination for the implementation of this Communiqué and to take the necessary administrative measures,

b) Evaluating the preliminary feasibility report and application projects of the compost facilities planned to be established and giving appropriate opinion,

c) Issuing a facility approval letter stating that the construction of the facility, whose implementation project is approved by the Ministry, has been completed in accordance with the implementation project and technical specifications,

ç) It is responsible for issuing and inspecting environmental licenses for compost facilities in accordance with the Environmental Permit and License Regulation.

(2) The Ministry may transfer its powers specified in the first paragraph to the provincial directorates when it deems necessary.

Duties and powers of provincial directorates

ARTICLE 7 – (1) Provincial directorates;

a) To ensure cooperation and coordination for the implementation of this Communiqué and to carry out inspections,

b) It is obliged to notify the Ministry of information and documents regarding the biodegradable wastes collected within the scope of the waste management plan of the municipalities.Mahalli idarelerin, özel ve tüzel kişilerin görev ve yükümlülükleri

ARTICLE 8 – (1) Metropolitan municipalities, unions of local administrations, provincial and district municipalities, natural and legal persons;

a) To collect/have biodegradable waste collected separately at its source, within the scope of its responsibilities, within the scope of the waste management plan,

b) To submit the information and documents regarding the collected wastes to the provincial directorate until the end of March of the following year,

c) To take the necessary measures to prevent the collection, transportation and processing of biodegradable wastes covered by this Communiqué by unauthorized persons,

ç) To prepare a pre-feasibility report for the compost facility planned to be established in accordance with the format in Annex-4 of this Communiqué and to submit it to the Ministry and obtain appropriate opinion,

d) To prepare an application project in accordance with the format in Annex-5 of this Communiqué in accordance with the zoning plan of the compost facilities planned to be established, and to submit the project to the Ministry and obtain appropriate opinion,

e) At the end of the facility construction, submitting the operation plan prepared in accordance with the format in Annex 6 of this Communiqué to the Ministry and obtaining appropriate opinion,

f) Providing the necessary tools and equipment, providing the necessary tools and equipment, adapting health and safety measures to changing conditions, by providing periodic training of the personnel involved in biodegradable waste management, undergoing health checks, preventing occupational risks, taking and organizing all kinds of measures, including providing training and information. In addition, to work to improve the current situation and to take other protective and preventive measures.

(2) In addition to the provisions in the first paragraph of this article, local administrations are obliged to carry out or contribute to awareness and training activities, together with the party's assigned responsibility with this Communiqué, within the scope of the management of biodegradable wastes.

Obligations of the operator

ARTICLE 9 – (1) The operator;

a) To implement the operation plan related to the operation of the facility,

b) To ensure that the wastes and residual wastes generated as a result of the activities of the facility are managed in accordance with the provisions specified in the relevant legislation,

c) To carry out the collection, processing and use of the gases that may originate from the facility, including the greenhouse effect, in a way that does not harm the environment and human health,

ç) Not accepting wastes that are not suitable for processing in the facility,

d) Disposing of wastes coming to the facility that are not suitable for processing, and products that come out of the facility and are not suitable for use, in accordance with the relevant legislation,

e) To submit the information and documents regarding the wastes to the provincial directorate until the end of March of the following year,

f) To provide training of personnel regarding the measures to be taken in case of emergency, and to inform the Ministry in case of an emergency,

g) It is obliged to ensure all kinds of health and safety of the personnel working in the risky sections of the facility, and to prevent unauthorized and unauthorized access to these sections by the authorized persons.

(2) In case the owner and operator of the facility are different persons, necessary measures are taken by the facility owner in order to prevent possible environmental pollution after the facility has completed its service period in the areas where the facilities are located.

CHAPTER 3

Features of Compost Plants

General characteristics of compost plants

ARTICLE 10 – (1) Except for those established within the boundaries of the sanitary landfill facility, the location is selected so that the closest distance of the facility boundary to the settlement areas is 250 meters, taking into account the prevailing wind direction. The receiving environment is designed to prevent contamination of soil, surface waters and groundwater.

(2) All kinds of preventive measures are taken to minimize odor, dust, leachate, gas and similar negative effects that may arise from the facility.

(3) Wastes are accepted to the facility in a way that does not pose an environmental risk, and necessary control systems are established to monitor the processing of wastes.

(4) It is obligatory to have a car park, weighbridge, wheel washing unit and administrative building in the facility. If the facilities are integrated facilities, it is sufficient to have one of these units.

(5) Before production, a waste reception unit is built in such a size that the wastes can be accumulated for at least one day, where unloading and loading to the preconditioning line will be carried out.

(6) Waste reception units are built as covered against the effect of precipitation. The bottom of the waste reception unit is made of C30 concrete and non-combustible material with a thickness of at least 30 cm to ensure tightness. A separate collection mechanism is developed at the bottom to prevent the waste from coming into contact with sewage or surface water. In order to collect the leachate that will occur in the waste reception area, the ground is sloped appropriately.

(7) A closed product warehouse is established at the facility, where the product formed as a result of the processing of wastes will be stored in such a way that it will not be affected by precipitation.

(8) Suitable areas are created for the wastes coming to the facility and not suitable for processing, and the products and residual wastes that come out of the facility and are not suitable for use, and are disposed of in accordance with the relevant legislation.

(9) Rain water to be generated throughout the facility is collected separately from washing and similar waste water.

(10) A data recording system is established, which includes information such as the source, code, amount of waste accepted to the facility, and access to the facility.

(11) The provisions of the Regulation on the Control of Odor-Creating Emissions published in the Official Gazette dated 19/7/2013 and numbered 28712 shall be complied with for all emission sources that cause odor in the facilities.
(12) Leakage water, washing water and similar wastewaters generated during the operation of the facilities are treated in accordance with the Water Pollution Control Regulation published in the Official Gazette dated 31/12/2004 and numbered 25687, in order to bring them into compliance with the discharge standards.
(13) In facilities that do not have a leachate treatment plant, connection permission is obtained in accordance with the provisions of the Regulation on Water Pollution Control, provided that the connection principles to the sewerage system are complied with in places where there is a wastewater infrastructure facility.

Technical characteristics of compost plants

ARTICLE 11 – (1) Compost facilities are obliged to comply with the provisions specified in Article 10 of this Communiqué. In addition to these provisions;

a) The preconditioning unit where the separation process, size reduction or crushing and screening processes are carried out in order to facilitate the degradation process carried out by microorganisms,

b) Composting unit,

c) Final conditioning unit,

ç) Final elimination unit,

d) Product accumulation area,

is found.

(2) In order to control the composting process, the heap temperature is monitored daily and the moisture content is monitored weekly, and a recording system is established.
(3) In closed or bulk compost facilities; It is obligatory to install and operate the ventilation system in a way that will ensure the cleaning of volatile compounds, pollutants that may arise as a result of decay, microorganisms and allergens, emissions to the environment and odor.
(4) The provisions of this Communiqué do not apply to garden type compost systems and worm type compost systems where wastes are processed at the source. However, leachate control system is installed in worm type compost systems.

(5) In case of using animal waste, 70 ºC temperature in the composting unit must be maintained uninterruptedly for at least 1 hour and it must be documented or a hygiene unit where 70 ºC temperature will be applied for 1 hour in the facility is required.

CHAPTER 4

Products and Residual Wastes

Using compost

ARTICLE 12 – (1) In determining the product properties obtained by processing biodegradable wastes;

a) Feed raw material characteristics,

b) Compliance with the process conditions of the compost facility is mandatory.

(2) In order for the product obtained as a result of the processes carried out in the compost facility to be used as a soil improver, it is obligatory to meet the compost criteria in Annex-2 and Annex-3 of this Communiqué.

(3) In determining the compost quality; pH, hygiene, trace element, moisture content, C/N ratio, organic matter, salt, non-biodegradable foreign matter, weed and stability parameters are taken into account.

(4) Production, Import, Export of Organic, Organomineral Fertilizers and Soil Conditioners Used in Agriculture, and Other Microbial, Enzyme Containing and Organic Origin Products, published in the Official Gazette dated 29/3/2014 and numbered 28956, in determining whether the compost is used in agriculture and the compost is produced appropriately. And the provisions of the Regulation on Placing on the Market shall apply.

(5) The sampling of the samples representing the product is done in quarterly periods, with four samples per year, based on the sampling methods specified within the framework of the Regulation on the Market Surveillance and Inspection of Fertilizers published in the Official Gazette dated 29/3/2014 and numbered 28956.

Putting the product on the market

ARTICLE 13 – (1) The compost covered by this Communiqué is placed on the market in packaged form. Packaging should be suitable for recycling. The provisions of the Regulation on the Production, Import, Export and Market Placement of Organic, Organomineral Fertilizers and Soil Conditioners Used in Agriculture, and Other Products with Microbial, Enzyme Content and Organic Origin are applied in placing the compost on the market.

(2) On the label of the product package placed on the market;

a) pH,

b) Total organic matter,

c) Maximum humidity value,

ç) Total nitrogen value (if it exceeds 1%),

d) Total phosphorus pentoxide (P2O5) value (if it exceeds 1%),

e) Water-soluble potassium oxide (K2O) value (if it exceeds 1%),

f) C/N ratio,

g) Compost stability information,

ğ) The source of raw materials used in compost production,

h) Water-soluble chloride (Cl-)

Information must be included.

CHAPTER 5

Miscellaneous and Final Provisions

Administrative sanction

ARTICLE 14 – (1) Sanctions stipulated in Articles 12 and 20 of Law No. 2872 and related articles of Law No. 4703 are applied to those who violate the provisions of this Communiqué.

regulatory authority

ARTICLE 15 – (1) The Ministry is authorized to make all kinds of arrangements regarding the management of wastes and products within the scope of this Communiqué.

Existing compost facilities

PROVISIONAL ARTICLE 1 – (1) Existing facilities operated before the date of entry into force of this Communiqué are obliged to comply with this Communiqué with physical conditions within one year and other provisions on the date of publication of this Communiqué.

Force

ARTICLE 16 – (1) This Communiqué enters into force on the date of its publication.

Executive

ARTICLE 17 – (1) The provisions of this Communiqué are executed by the Minister of Environment and Urbanization.

Annex -1

WASTE LISTS

WASTE GROUPS	
Vegetable Containing wastes and forestry wastes	
02 01 03	Plant tissue waste
02 01 07	Forestry waste
Animal-Containing Wastes	
02 01	Wastes from Agriculture, Horticulture, Aquaculture, Forestry, Hunting and Fishing
02 01 02	Animal tissue waste
02 01 06	Animal excrement, urine and manure (including straw that has come into contact with them), runoff liquids collected separately and to be handled off-site
02 02	Wastes from the preparation and processing of meat, fish and other foodstuffs of animal origin
02 02 02	Animal tissue waste
Food Production Wastes	
02 02	Wastes from the preparation and processing of meat, fish and other foodstuffs of animal origin
02 02 03	Substances unsuitable for consumption or processing
02 03	Preparation and processing of fruit, vegetables, grains, edible oils, cocoa, coffee, tea and tobacco; Wastes from canning production, yeast and yeast extract production, molasses preparation and
02 03 04	Substances unsuitable for consumption or processing
02 05	Wastes from the dairy industry
02 05 01	Substances unsuitable for consumption or processing
02 06	Wastes from the bakery and confectionery industry
02 06 01	Substances unsuitable for consumption and processing
02 07	Wastes from the production of alcoholic and non-alcoholic beverages (excluding coffee, tea and cocoa)
02 07 01	Wastes from washing, cleaning and mechanical squeezing of raw materials
02 07 02	Wastes from alcohol distillation
02 07 04	Substances unsuitable for consumption or processing
Woodworking, Paper and Paper Production Wastes	
03 01 01	Bark and cork waste
03 03	Wastes from pulp, paper and paperboard production and processing
03 03 01	bark and wood waste
03 03 07	Mechanically separated rejects during pulping of waste paper and cardboard
03 03 08	Waste from paper and cardboard classified for recycling
20 01 01	Paper and cardboard
Textile Industry Wastes	
04 02 10	Organic substances from natural products (eg oil, wax)
Anaerobic Treatment Wastes	
19 06 04	Pulp from anaerobic treatment of municipal waste
19 06 06	Residues from anaerobic treatment of animal and vegetable wastes
Kitchen Waste	
20 01 08	Biodegradable kitchen and canteen waste
20 01 25	Edible oils and fats
Park, Garden and Other Green Waste	
20 02 01	Biodegradable waste
20 03 02	Waste from markets

Annex-2

Compost Quality Parameters

<table>
<tr><th>Parametre</th><th colspan="2">Value</th></tr>
<tr><td>PH</td><td colspan="2">5.5-8.5</td></tr>
<tr><td rowspan="16">Hygiene Value</td><td colspan="2">It will be treated uninterruptedly at 55 °C for 2 weeks, at 60 °C for 1 week, at 65 °C for 5 days, at 70 °C for 1 hour.</td></tr>
<tr><td colspan="2">Pathogens</td></tr>
<tr><td>Total Bacteria</td><td>1 x 10^{J} kob/g or kob/ml</td></tr>
<tr><td>Enterobacterice a group bacteria</td><td>< 3cfu/ml</td></tr>
<tr><td>Mycobacterium</td><td>None (25 g or ml)</td></tr>
<tr><td>Total yeast and</td><td>l<10 kob/gr-ml</td></tr>
<tr><td>Salmonella spp</td><td>None (25 g or ml)</td></tr>
<tr><td>Staphylococcus</td><td>None (25 g or ml)</td></tr>
<tr><td>Bacillus cereus</td><td>None (25 g or ml)</td></tr>
<tr><td>Bacillus</td><td>None (25 g or ml)</td></tr>
<tr><td>Clostridium spp</td><td><2 kob/g or kob/ml</td></tr>
<tr><td>Clostridium</td><td>None</td></tr>
<tr><td>Listeria spp</td><td>None</td></tr>
<tr><td>Staphylococcal</td><td>None</td></tr>
<tr><td>E.coli</td><td>None</td></tr>
<tr><td>E.coli</td><td>0157 None</td></tr>
<tr><td rowspan="10">Trace elements</td><td>Parame</td><td>ppm in compost (mg/kg dry matter)</td></tr>
<tr><td>Arsenic</td><td>20</td></tr>
<tr><td>Cadmiu</td><td>3</td></tr>
<tr><td>Chromi</td><td>350</td></tr>
<tr><td>Copper</td><td>450</td></tr>
<tr><td>Mercury</td><td>5</td></tr>
<tr><td>Nickel</td><td>120</td></tr>
<tr><td>Lead</td><td>150</td></tr>
<tr><td>Zinc</td><td>1100</td></tr>
<tr><td>Tin (Sn)</td><td>10</td></tr>
<tr><td>Moisture Content of Compost</td><td colspan="2">< % 30</td></tr>
<tr><td>Carbon/Nitrogen Ratio (C/N)</td><td colspan="2">10-30</td></tr>
<tr><td>Organic Matter (in dry matter)</td><td colspan="2">> %35</td></tr>
<tr><td>Salts as mineral ions</td><td colspan="2">< lOdS/cm</td></tr>
<tr><td>Non-Biodegradable Foreign Matter Content (by Dry Weight)</td><td colspan="2"><%2</td></tr>
<tr><td>Weed value in compost</td><td colspan="2">< 5 adet/lt</td></tr>
<tr><td colspan="3">90% of the product will pass through the 10 mm sieve.</td></tr>
<tr><td colspan="3">The size of particles of plastic or other possibly non-recyclable material shall not exceed 10 mm.</td></tr>
</table>

Annex -3

STABILITY PARAMETERS

Group (A) Tests: CO2 Formation and Respiration, O? The need includes Dewar Tests. It is mandatory for the products to meet the stability characteristics for placing on the market.

<table>
<tr><td></td><td colspan="3">Unit</td><td>Stability</td></tr>
<tr><td>OUR Test</td><td colspan="3">mg O_2 / gr OM /h</td><td><0,4</td></tr>
<tr><td>CO_2 Formation</td><td colspan="3">mg CO_2-C / gr OM /day</td><td><2</td></tr>
<tr><td rowspan="4">Dewar Test</td><td colspan="3">Temperature Class</td><td>V</td></tr>
<tr><td colspan="3">Dewar İndex:</td><td rowspan="3"></td></tr>
<tr><td>Temperature Rise</td><td>Class</td><td>Stability Identification</td></tr>
<tr><td>0-10 °C</td><td>V</td><td>Completely stable compost, storable</td></tr>
<tr><td>Solvita Test</td><td colspan="3">İndex Value</td><td>7-8</td></tr>
</table>

*OM: Organic Matter

Annex-4

PRELIMINARY FEASIBILITY REPORT FORMAT

1. General information about the facility location

a. Distances to the nearest settlement

b. Field capacity, size

to. Ownership status

D. Plant life

2. Types and codes of waste to be accepted

3. Current population and population projection

4. Waste amount and projection

5. The compost facility to be built

6. Units to be located in the facility and information about these units (weighbridge, wheel washing, administrative building, transformer, generator, etc.)

a. Information on other units, if any

7. Gas and leachate management

8. Surface water and wastewater management

9. Cost analysis

Annex -5

APPLICATION PROJECT FORMAT

Ran	Layout Name	Description
1	General Layout Plan	It should show the general layout of the facility and the country coordinates should be applied. The existing road, puddles, structures, electricity, water and natural gas lines
2	Layout Plan of the Pre-preparation Unit	It should show the layout plans of the equipment used in the pre-preparation unit.
3	Sectional Plans of the Pre-preparation Unit	It should contain the cross-sectional plans of the equipment in the pre-preparation unit.
4	Composting Unit Plan and cross sections	It should include the composting unit plan and the cross and longitudinal section plans.
5	Conveyor Bridge Layout	If the conveyor bridge is used, the plans must be given.
6	Compost Transfer Machine Layout and Section	Plans and sections showing the location of the compost transfer machine in the field should be given.
7	Ventilation System Plans	It should include the ventilation system location, plan and
8	Process Flow Chart	It should show the flow of processes in the whole system
9	Wastewater P&I Diagram	These are the diagrams showing the collection and
10	Exhaust Air P&I Diagram	These are the diagrams showing the collection and flow of
11	Plant Equipment List	Lists showing the function, location and specific
12	Final Conditioning Unit	
13	Final Screening Unit Plans	
14	Product Warehouse Plans	
15. Other Layouts		

Facility Building Project	Facility Building Electrical Project	Facility Building Installation Projects
Administrative Building Project	Security Building Electrical Project	Administrative Building Plumbing Project Project
Security Building	Admin.Building Electrical Project	Admin.Building Heating Installation Project
Water tank	Environmental Lighting Project	Workshop Building Plumbing Project
Workshop Building	Medium and Low Voltage Dist. Project.	Wastewater Sewer Line Plan
Weighbridge	Workshop Building Electrical Project	Fire and Service Water Plan
Wire Fence Detail	Transformer	Water tank
Weighb. Electricity project	Lightning rod	

Annex -6

BUSINESS PLAN FORMAT

1. FACILITY GENERAL LAYOUT PLAN

a. Field infrastructure

b. General site plan (1/5000)

2. FACILITY OPERATION PRINCIPLES

a. flow chart

b. Waste acceptance and registration

to. Operating conditions (unit capacity, area, equipment used, temperature, pH, C/N ratio, holding time, hygiene, moisture content, organic matter content, sieve dimensions, mixer features, ventilation system, gas management, etc.) should be listed in order according to the activities performed.)

3. Storage and management of the product

4. FACILITY CONTROL AND MONITORING

a. Waste Amount, Weighing and Analysis

b. Containment Channel and Surface Water

c. Leachate Water

D. Ground-water

to. Gas Management

5. CLOSING AT THE END OF OPERATION

a. Post Operation Control and Monitoring

6. EQUIPMENT-STAFF

a. Construction Machinery

b. Personnel (job descriptions and competency criteria of facility personnel should be documented.)

7. WORKER HEALTH AND OCCUPATIONAL SAFETY

(There should be gradual trainings to be received by all personnel who will work at the facility, personal protective equipment to be used and principles to be followed in use, fire protection and response, emergency action plan, facility security measures, etc.)

ATTACHMENTS

Annex-1 Waste Acceptance and Registration Form

Annex-2 Plant Leachate Monitoring Form

Annex-3 Business Organization Chart

Annex-4 Mass-Equilibrium Records

Annex-5 Weighbridge Tonnage Information Form

Annex-6 Gas Measurement Reports

6.2.3 Lithuanian compost regulation

ENVIRONMENTAL REQUIREMENTS FOR COMPOSTING AND ANAEROBIC TREATMENT OF BIODEGRADABLE WASTE

CHAPTER I
GENERAL PROVISIONS

1. Environmental Requirements for Composting and Anaerobic Treatment of Biodegradable Waste (hereinafter, the Requirements) determine the conditions for composting and anaerobic treatment of biodegradable waste, types of compostable, anaerobically treated waste, requirements for the quality, contamination and use of compost and anaerobic digestate, as well as criteria for classifying compost and anaerobic digestate as fertilising products.

2. In accordance with the Law on Waste Management of the Republic of Lithuania, Waste Management Rules approved by Order No 217 of the Minister for the Environment of the Republic of Lithuania of 14 July 1999 'On the Approval of the Waste Management Rules', Rules on the Issue, Amendment and Withdrawal of Pollution Permits approved by Order No D1-259 of the Minister for the Environment of the Republic of Lithuania of 6 March 2014 'On Approval of the Rules on the Issue, Amendment and Withdrawal of Pollution Permits', Requirements for the Quality and Use of Technical Compost, Technical Digestate and Stabilate, approved by Order No D1-778 of the Minister for the Environment of the Republic of Lithuania of 26 September 2012 'On the Approval of the Requirements for the Quality and Use of Technical Compost, Technical Digestate and Stabilate', persons composting biodegradable waste (except for persons performing household composting and using the produced compost for their own needs) are classified as waste managers and must comply with the requirements set out therein.

3. The requirements apply to persons producing and/or using compost, anaerobic digestate, including domestic composting. It is recommended to apply the requirements to persons who use straw and other natural non-hazardous agricultural or forestry material in farming, when the forestry processes or methods used do not harm the environment nor endanger human health. The parameters related to temperature and to storage time, as specified in the requirements, do not apply when composting or anaerobic treatment methods are used for initial treatment of biodegradable waste, and when the resulting compost and anaerobic digestate are not intended for improvement of soil or for the preparation of a growing medium.

4. The requirements do not apply to sewage sludge (nor to composting with other biodegradable waste); the latter must be treated and used for fertilisation and rehabilitation in

accordance with the Requirements for the Use of Sewage Sludge for Fertilisation and Rehabilitation approved by Order No 349 of the Minister for the Environment of the Republic of Lithuania of 29 June 2001 approving the normative document LAND 20-2005 'Requirements for the Use of Sewage Sludge for Fertilisation and Rehabilitation', for technical compost and technical digestate that are used in accordance with the Requirements for the Quality and Use of Technical Compost, Technical Digestate and Stabilate, approved by Order No D1-778 of the Minister for the Environment of the Republic of Lithuania of 26 September 2012 'On the Approval of the Requirements for the Quality and Use of Technical Compost, Technical Digestate and Stabilate'.

5. The terms used in the requirements correspond to the ones used in the Law on Waste Management of the Republic of Lithuania, the Waste Management Rules approved by Order No 217 of the Minister for the Environment of the Republic of Lithuania of 14 July 1999 'On the Approval of the Waste Management Rules', Requirements for the Quality and Use of Technical Compost, Technical Digestate and Stabilate, approved by Order No D1-778 of the Minister for the Environment of the Republic of Lithuania of 26 September 2012 'On the Approval of the Requirements for the Quality and Use of Technical Compost, Technical Digestate and Stabilate', the Law of the Republic of Lithuania on Fertilising Products (hereinafter, the Law), Commission Regulation (EU) No 142/2011 of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive, as last amended by Commission Regulation (EU) 2017/1262 of 12 July 2017 (hereinafter, Commission Regulation (EU) No 142/2011), Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation), as last amended by Regulation (EU) No 2019/1009 of the European Parliament and of the Council of 5 June 2019 (hereinafter, Commission Regulation (EU) No 1069/2009).

CHAPTER II
REQUIREMENTS FOR THE INSTALLATION OF BIODEGRADABLE WASTE TREATMENT PLANTS

6. A composting site intended for composting of biodegradable waste (receiving, storing, composting and storing compost resulted from treatment) shall be installed in such a way that storm water and other surface waters (during floods) cannot flow into it from the surrounding areas, and storm water and other liquids generated at the site may enter the environment only through an appropriate wastewater management system that complies with the requirements specified in the legal acts regulating wastewater management, and no groundwater (underground water) should flow from the environment into the site and back to the environment. A waterproofing layer must be installed over the entire composting site area (superstructure) to ensure its tightness throughout the life span of the site.

7. When installing biodegradable waste treatment plants, the prevailing wind direction in the area must be taken into account; the facilities must be placed in such a way as to protect them from the prevailing winds and the activity must be carried out within the noise limit values stipulated in the Lithuanian Hygiene Norms HN 33:2011 'Noise Limit Values in Residential and Public Buildings and Their Surroundings', approved by Order No V-604 of the Minister for Health of the Republic of Lithuania of 13 June 2011 'On the Approval of the Lithuanian Hygiene Norm HN 33:2011 'Noise Limit Values in Residential and Public Buildings and Their Surroundings', and odour limit values stipulated in the Lithuanian Hygiene Norm HN 121:2010 'Odour Concentration Limit Value in the Ambient Air of a Residential Environment', approved by Order No V-885 of the Minister for Health of the Republic of Lithuania of 4 October 2010 'On the Approval of the Lithuanian Hygiene Norm HN 121:2010 'Odour Concentration Limit Value in the Ambient Air of the Residential Environment' and the Rules on Odour Control in the Ambient Air of the Residential Environment'.

8. Newly installed composting and anaerobic treatment plants must ensure that treated waste is received, stored and composted (compost is turned over), anaerobically treated indoors, ensuring prevention of the spread of odours, gas cleaning before discharge into the environment, except for sites where green waste only is composted. Sites where only green waste will be composted must be equipped with measures to prevent dust generation during shredding of green waste.

9. In all composting and anaerobic treatment plants, waste is received, stored, composted and anaerobically treated indoors, ensuring prevention of the spread of odours, gas cleaning

before discharge into the environment, except for sites where green waste only is composted. Sites where only green waste is composted must be equipped with measures to prevent dust generation during shredding of green waste.

10. Wastewater generated at composting sites must be collected and used for irrigation of compost or treated in accordance with the Wastewater Management Regulation approved by the Order No D1-236 of the Minister for the Environment of the Republic of Lithuania of 17 May 2006 ‘On the Approval of the Wastewater Management Regulation’.

11. The surfaces of the areas for the receiving, preparing for composting, composting, maturation and compost storage of biodegradable waste must be impermeable, clearly separated and schematically indicated and marked in the Technical Regulation on the Use or Disposal of Waste, in the form provided for in Annex 3 to the Waste Management Rules approved by Order No 217 of the Minister for the Environment of the Republic of Lithuania of 14 July 1999 ‘On the Approval of Waste Management Rules’ (hereinafter, the Regulation on Waste Recovery or Disposal).

12. When planning the installation or reconstruction of composting sites or anaerobic treatment plants, after assessing the planned capacity of the plants, environmental impact assessment procedures must be carried out in accordance with the Law on Environmental Impact Assessment of the Proposed Economic Activity of the Republic of Lithuania.

13. Installation of biodegradable waste treatment plants is prohibited:

13.1. If such activity in a particular location is not possible due to improper land use or special land use conditions;

13.2. In floodplains (below the highest flood altitude level (1% probability).

14. The distance between composting sites and water extraction facilities (mine wells and boreholes, etc.) for which no protection zones are established must be at least 50 m downstream of the groundwater flow and 25 m upstream thereof.

15. Green waste composting sites installed near cemeteries shall comply with the requirements set out in this Chapter. Procedures for the operation and maintenance of such sites are determined by municipalities, taking into account, for example, aspects of cemetery development and/or territorial planning.

16. Where biodegradable waste is composted or anaerobically treated with animal by-products, it must be treated in a plant, which complies with the installation requirements laid down in this Chapter and which:

16.1. is approved in accordance with Article 24 of the Commission Regulation (EU) No 1069/2009;

16.2. is in accordance with the requirements of Regulation (EU) No 142/2011.

CHAPTER III
REQUIREMENTS FOR COMPOSTING AND/OR ANAEROBIC TREATMENT OF BIODEGRADABLE WASTE

17. The following non-hazardous biodegradable waste may be composted/anaerobically treated:

17.1. catering waste and foodstuffs unfit for consumption that became waste generated from catering establishments and kitchens, including public and domestic kitchens, food production and sale establishments;

17.2. separately collected bio-waste generated in households or from other sources, when its composition is identical to the household-generated bio-waste, or separated (sorted) biodegradable waste from mixed municipal waste flow;

17.3. green waste (such as branches, grass, leaves of trees, shrubs, flowers);

17.4. natural non-hazardous agricultural and horticultural waste and residues (for example, straw, haulms, sugar beet leaves);

17.5. non-hazardous wood processing waste;

17.6. non-hazardous biodegradable waste from production and other economic activities;

17.7. non-recyclable paper and paperboard waste (excluding paper and paperboard waste coated with a non-biodegradable coating).

18. It is prohibited to compost hazardous, infected and other medical waste (for example, in veterinary hospitals, hospitals), dead animals, faeces.

19. Wood fuel ash that complies with the Rules for the Handling and Use of Wood Fuel Ash approved by Order No D1-14 of the Minister for the Environment of the Republic of Lithuania of 5 January 2011 approving the Rules for the Handling and Use of Wood Fuel Ash, in terms of the established maximum chemical concentrations in ashes used in agriculture, may make up no more than 20% of treated biodegradable waste.

20. Persons treating non-hazardous biodegradable waste referred to in paragraph 17 of the Requirements, which are not classified as animal by-products, or persons treating food waste generated from catering establishments and kitchens, including public and domestic kitchens, food production and sale establishments, shall comply with the following requirements:

20.1. when composting biodegradable waste, at least one of the following temperature regimes must be ensured:

20.1.1. maintain a temperature of at least 65°C for at least 5 days;

20.1.2. maintain a temperature of at least 60°C for at least 7 days;

20.1.3. maintain a temperature of at least 55°C for at least 14 days;

20.2. when anaerobically treating biodegradable waste, at least one of the following temperature regimes must be ensured:

20.2.1. maintain a temperature of at least 55°C for at least 24 hours, ensuring that the treated waste is stored in the plant for at least 20 days;

20.2.2. after treatment of biodegradable waste at a temperature of at least 55°C, it must be pasteurised at a temperature of at least 70°C for at least one hour;

20.2.3. after treatment of the biodegradable waste at a temperature of at least 55°C, it must be composted ensuring at least one of the temperature regimes specified in points 20.1.1–20.1.3 of the Requirements;

20.2.4. after treatment of biodegradable waste at a temperature of at 37–40°C, it must be pasteurised at a temperature of at least 70°C for at least one hour;

20.2.5. after treatment of the biodegradable waste at a temperature of 37–40°C, it must be subsequently composted ensuring at least one of the temperature regimes specified in points 20.1.1–20.1.3 of the Requirements.

21. Waste categorised as animal by-products (with the exception of food waste referred to in point 20 that is generated in catering establishments and kitchens, including public and domestic kitchens, food production and sales establishments) must be treated in accordance with Commission Regulations (EU) No 1069/2009 and (EU) No 142/2011.

22. When composting green waste in piles, the composted material must be regularly mechanically turned over or reloaded to ensure that all material is composted.

23. Persons treating biodegradable waste, with the exception of persons treating only green waste, must ensure that the temperature parameters and the required oxygen content specified in this chapter are maintained throughout the composted waste pile, and that they are continuously measured, monitored and recorded throughout active composting. Persons

treating only green waste must ensure that the temperature parameters and the required oxygen content specified in this chapter are maintained and that the temperature measured during the composting process using measuring instruments is recorded in a logbook. The proportions of waste being composted, measuring points, measuring devices, measurement frequency and other technical parameters shall be described in the Technical Regulation on the Recovery or Disposal of Waste, which is an annex to the Integrated Pollution Prevention and Control and/or Pollution Permit.

24. When the compost is turned over, sieved and in other cases where there is a high probability of odours spreading into the environment, odour reduction measures must be used.

25. Persons composting biodegradable waste must record the following data in the logbook for each compost pile formed:

25.1. the amount (in tonnes) of biodegradable waste used for composting, indicating the waste code and name;

25.2. The start and end of composting;

25.3. The results of oxygen and temperature monitoring;

25.4. The dates of turning the piles over;

25.5. Disturbances in the composting process;

25.6. The start and end of compost maturation;

25.7. The dates of sifting of compost.

26. Maturation is a mandatory step in the composting process, when the compost cools down to 40–50°C. At this stage, the following should be avoided:

26.1. Formation of anaerobic conditions due to excessive moisture, compacted material structure or excessive dykes;

26.2. Excessive drying of the material;

26.3. Dust handling of maturing compost;

26.4. Mixing and contamination of maturing compost with other wastes or materials, including pathogens;

26.5. Seed spread in compost (vegetation must be prevented from growing on maturing compost piles).

27. The compost must be sieved, separating out non-composted parts of biodegradable waste and impurities. All impurities that are sieved out and suitable for composting are returned for composting.

CHAPTER IV
ANALYSING COMPOST AND ANAEROBIC DIGESTATE

28. Compost and anaerobic digestate shall be analysed after the composting or anaerobic treatment process has been completed.

29. The frequency of analyses of the quality and contamination parameters for compost and anaerobic digestate is given in Annex 1.

30. Analyses of treated compost and anaerobic digestate should be performed in laboratories that are accredited under LST EN ISO/IEC 17025 to perform specific measurements and/or analyses and to take samples for laboratory tests and/or measurements, or authorised to carry out measurements and analyses of pollutants emitted into the environment by source of contamination and emissions in environmental elements in accordance with the Description of the Procedure for Issuance of Permits to Carry Out Measurements and Analyses of Pollutants Emitted into the Environment by Source of Contamination and Emissions in Environmental Elements, approved by Order No D1-711 of the Minister for the Environment of the Republic of Lithuania of 30 December 2004 approving the Description of the Procedure for Issuance of Permits to Carry Out Measurements and Analyses of Pollutants Emitted into the Environment by Source of Contamination and Emissions in Environmental Elements.

31. Compost and anaerobic digestate are analysed using standardised methods of analysis. Only after the compost and anaerobic digestate are analysed, they:

31.1. May be assigned as fertilising products in accordance with the criteria of Chapter VII of the Requirements;

31.2. Might not to be assigned to fertilising products in accordance with the quality indicators of Chapter VIII of the Requirements;

31.3. Deemed as waste in accordance with the requirements of Chapter X of the Requirements.

CHAPTER V
REQUIREMENTS FOR STORAGE OF COMPOST IN THE PLANT

32. Compost produced in accordance with the provisions of these Requirements shall be stored in the area belonging to the biodegradable waste treatment plant and in a dedicated

storage area or another area that meets the requirements set forth in Chapter II of the Requirements, where the compost is allowed to be kept. To prevent contamination, one batch of compost shall not be mixed with another batch of compost, other waste or materials. Specific requirements for the storage (including the maximum amount of compost produced allowed to be stored at a time) and use must be laid down in the Technical Regulation on the Recovery or Disposal of Waste.

33. The following data must be recorded in the logbook when compost is transferred to a storage area:

33.1. A schematic indication of the specific compost storage location in the biodegradable waste treatment plant;

33.2. The date of compost production and types of biodegradable waste used for composting;

33.3. The date of transfer of compost to the storage area;

33.4. The amount of compost;

33.5. The serial number of compost.

34. An air-proof mark must be placed on the stored compost, allowing information on the date of compost piling and the serial number of the compost to be found in the logbook.

CHAPTER VI
RECOMMENDATIONS FOR COMPOSTING IN HOUSEHOLDS AND CATERING ESTABLISHMENTS

35. It is recommended that persons composting biodegradable household waste in composting containers (boxes) or composters that are equipped accordingly:

35.1. The composting site is selected at a preferably remote location of the plot of land (a distance of at least 2 meters from the boundary of adjacent plots is recommended, taking into account the prevailing wind direction);

35.2. Waste suitable for household composting, such as fruit, vegetables, eggshells, tea bags, coffee and tea grounds, wood fuel ash, charcoal, paperboard, other paper products (excluding paper products coated with a non-biodegradable coating), egg trays from paper and paperboard, natural litter for domestic rodents (hamsters, guinea pigs), plant leaves, cut grass, young weeds (without mature seeds), old pot soil, manure from farm animals (e.g. chickens, rabbits, cows, horses), small branches, old straw, hay, turf;

35.3. Do not use unsuitable waste for household composting, e.g. meat, fish, fat, bones, dairy products, plastic, synthetic waste, plants infected with plant diseases, dog and cat excrements, weeds with mature seeds, carcass waste, diapers, newspapers, magazines dead animals, faeces or sewage sludge;

35.4. Composted waste must be free of hazardous and contaminated substances (for example, radioactive, toxic substances, resins, lubricants, etc.), glass and plastic impurities;

35.5. Prior to composting the branches, it is recommended to chop or shred them;

35.6. It is recommended to sieve the compost through a sparse mesh (size of the openings from 1 to 2.5 cm) before using it, in order to separate branch residues and other impurities. All sieved compostable impurities may be used in the preparation of another compost;

35.7. Suitable compost should be homogeneous, dark and smell of soil.

36. Specific requirements and/or recommendations for the installation of household composting sites may be stipulated by municipalities.

37. Persons who treat food waste generated from public and household kitchens, and food waste generated from public catering establishments, using special plants adapted for indoor use, are recommended to comply with the requirements specified in point 20 of the Requirements.

38. Persons treating green waste generated during their activities are recommended to comply with the requirements set out in points 20.1 and 20.2 of the Requirements.

39. The compost produced in households, public catering establishments and household kitchens, and food waste generated from catering establishments may be used in special plants adapted for indoor use and only for own purposes, such as amateur horticulture, floriculture and growing house-plants.

CHAPTER VII
CRITERIA FOR CLASSIFYING COMPOST AND ANAEROBIC DIGESTATE AS FERTILISING PRODUCTS

40. Compost and anaerobic digestate are classified as fertilising products, if they comply with the requirements established by the Law and are included in the identification list of

fertilising products placed on the market and supplied to the market of the Republic of Lithuania, pursuant to Order No 3D-292 of the Minister for Agriculture of the Republic of Lithuania of 10 May 2019 adopting the Description of the procedure for the inclusion in the identification list and the exclusion of fertilising products placed on the market and supplied to the market of the Republic of Lithuania and adopting the identification list of fertilising products placed on the market and supplied to the market of the Republic of Lithuania (hereinafter, Identification List of Fertilising Products). Compost and anaerobic digestate that meet the requirements established by the Law shall be used in accordance with the procedure established by the Law.

CHAPTER VIII
QUALITY INDICATORS OF COMPOST AND ANAEROBIC DIGESTATE NOT CLASSIFIED AS FERTILISING PRODUCTS

41. Compost and anaerobic digestate are considered to be ready and suitable for use for improvement of soil properties or preparation of a growing medium, when:

41.1. It does not comply with the requirements established by the Law and the Identification List of Fertilising Products;

41.2. The oxygen uptake rate (stability) of the compost is no more than 15 mmol O_2/kg organic matter per h;

41.3. The oxygen uptake rate (stability) of the anaerobic digestate is no more than 50 mmol O_2/kg organic matter per h;

41.4. Concentrations of heavy metals do not exceed the permissible limits specified in Table 1 of Annex 2 to the Requirements;

41.5. Microbiological-parasitological indicators do not exceed the permissible limits specified in Table 2 of Annex 2 to the Requirements;

41.6. Undesirable impurities comply with the permissible limits specified in Table 3 of Annex 2 to the Requirements.

42. Producers of compost and anaerobic digestate are responsible for ensuring that the following plant pathogens are not spread with the compost and anaerobic digestate: parasitic

fungi, bacteria, viruses, insects, viroids, nematodes and weed seeds, and do not cause harm to consumers of compost and anaerobic digestate.

CHAPTER IX
REQUIREMENTS FOR THE USE OF COMPOST AND ANAEROBIC DIGESTATE

43. Compost and anaerobic digestate that do not comply with the requirements provided in the Law and in the Identification List of Fertilising Products must be used for improvement of soil properties or preparation of a growing medium, such that:

43.1. The maximum rate of compost and anaerobic digestate shall be no more than 170 kg/ha of nitrogen per year, 40 kg/ha of phosphorus or 90 kg/ha of phosphorus (V) oxide (P_2O_5) per year are released into the soil;

43.2 The amount of the compost and anaerobic digestate is calculated on the basis of the nitrogen and phosphorus content in it, and is in accordance with the maximum rates of incorporation of these in the soil specified in point 43.1 of the Requirements.

44. Compost and anaerobic digestate that do not comply with the requirements provided in the Law and in the Identification List of Fertilising Products must be used for improvement of soil properties or for the preparation of a growing medium as follows:

44.1. Persons producing compost and anaerobic digestate, in accordance with the provisions of the Requirements, by transferring compost and anaerobic digestate from biodegradable waste to the user, must issue a certificate stating:

44.1.1. The dry matter content;

44.1.2. The organic matter content;

44.1.3. pH;

44.1.4. Total nitrogen and phosphorus content;

44.1.5. Heavy metal concentrations;

44.1.6. Amount of compost and anaerobic digestate transferred;

44.1.7. Recommendations for use and usage rates calculated in accordance with the qualitative parameters of compost and anaerobic digestate specified in points 44.1.1 to 44.1.5 of the Requirements;

44.2. Persons who, in accordance with the provisions of these Requirements, produce compost and anaerobic digestate from biodegradable waste, must record and store data on the quality and use of the compost and anaerobic digestate delivered. The form for the summary of the data on the quality and use of compost and anaerobic digestate (hereinafter, the Summary) is given in Annex 3 to the Requirements. Explanatory notes on the completion of the Summary are given in Annex 4 to the Requirements. If the information specified in the Summary changes, the Summary must be revised. Data on the quality and use of compost and anaerobic digestate shall be stored for at least five years from the date of completion/revision of the summary, and then destroyed in accordance with the procedure established by the Law. Personal data are collected for control purposes and processed in accordance with the Law on Legal Protection of Personal Data of the Republic of Lithuania and Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC.

44.3. The maximum amount of nitrogen (N), phosphorus (P) or phosphorus (V) oxide (P_2O_5) entering the soil per year with compost and anaerobic digestate (with other fertilisers), shall not exceed the amount specified in point 43.1 of the Requirements;

44.4 The amount of compost and anaerobic digestate must be calculated on the basis of the nitrogen and phosphorus content in it, in accordance with the maximum rates of incorporation of these in the soil specified in point 43.1 of the Requirements;

44.5. The rate of compost used for the rehabilitation of damaged areas must be provided for in state management plans for damaged lands, plans for the use of subsoil or projects for the use of mineral resources.

CHAPTER X
COMPOST AND ANAEROBIC DIGESTATE TRANSFORMATION INTO WASTE

45. Compost and anaerobic digestate that does not meet the requirements set out in the Law and the Identification List of Fertilising Products becomes waste when compost and anaerobic digestate do not meet the requirements of Chapter VII of the Requirements, quality indicators of Chapter VIII, requirements on use of Chapter IX, and cannot be recycled.

46. Compost and anaerobic digestate that correspond to the cases provided for in this Chapter shall be subject to the requirements set out in waste management legislation.

CHAPTER XI
FINAL PROVISIONS

47. Entities that violate the requirements are liable in accordance with the procedure established by legal acts of the Republic of Lithuania.

Annex 1 to the
Environmental Requirements
for Composting and
Anaerobic Treatment of
Biodegradable Waste

FREQUENCY OF TESTING OF COMPOST AND ANAEROBIC DIGESTATE QUALITY AND CONTAMINATION PARAMETERS

<table>
<tr><th>Criteria</th><th>Annual raw material input for processing</th><th>Frequency of testing</th></tr>
<tr><td rowspan="2">1.1. Limit values for heavy metals;
1.2. Microbiological contamination;
1.3. Physical contaminants (glass, metals, plastics, stones);
1.4. Organic matter and dry matter;
1.5. Fine seeds of plants;
1.6. Quality indicators.</td><td>Content of raw materials processed (t) ≤ 4 000.</td><td>1 for each 1 000 tonnes of raw material, rounded to the next integer.</td></tr>
<tr><td>Content (t) > 4 000 of raw materials processed.</td><td>At least 4 (one sample per season) in the first year. The number of tests in the following years shall be calculated as the number of tests per year = the annual raw material content (tonnes)/10 000 tonnes + 1(rounded to the next integer). Not less than 4 and no more than 12.</td></tr>
</table>

Annex 2 to the
Environmental Requirements
for Composting and
Anaerobic Treatment of
Biodegradable Waste

QUALITATIVE REQUIREMENTS FOR COMPOST AND ANAEROBIC DIGESTATE

Maximum concentration levels for heavy metals (mg/kg SM) in compost and anaerobic digestate

Table 1

Heavy metals	**Maximum concentration level, mg/kg SM**
Cadmium (Cd)	≤ 2
Lead (Pb)	≤ 120
Mercury (Hg)	≤ 1
Chrome (Cr)	≤ 70
Zinc (Zn)	≤ 800
Copper (Cu)	≤ 300
Nickel (Ni)	≤ 50
Arsenic (As)	≤ 40

Permissible limits for microbiological-parasitological contamination (mg/kg SM) in composts and anaerobic digestates

Table 2

Name	**Allowed limit**
Faecal coliforms (*E. coli*)	≤ 1 000 CFU/g
Anaerobic clostridia (*Clostridium perfringens*)	≤ 100 000 CFU/g
Helminths eggs and larvae	0 pcs/kg
Salmonella spp. bacteria	0 pcs/kg

Permissible limits for undesirable impurities in compost and anaerobic digestate

Table 3

Name	**Allowed limit**
Glass, metals, plastics, with a particle size greater than 2 mm	≤ 0.5%
Viable plant seeds, including viable weeds, rhizomes	≤ 2 pcs/kg
Rocks larger than 10 mm in dry weight	≤ 5%

Annex 3 to the
Environmental Requirements
for Composting and
Anaerobic Treatment of
Biodegradable Waste

(_____ Form for the summary of the data on the quality and use of compost and anaerobic digestate)

Started to be filled in: _____________

I. The data of a legal entity submitting the Summary of the data on the quality and use of compost and anaerobic digestate

1. Identification of the legal entity

Legal entity number	Legal entity name

2. Domicile of the legal entity

Name of the location (city, town, small town, village)	Street address	House No

3. Contact details of the legal entity

Given name and surname of a contact person	Telephone	Email

II. Data on the quality and use of compost and anaerobic digestate

4. Identification of the recipient of the compost and anaerobic digestate

Batch ID of the compost and anaerobic digestate	Serial number of compost	Legal entity number	Name of legal person or given name(s) and surname(s) of natural person
4.1	4.2	4.3	4.4

5. Description of the site where the compost and anaerobic digestate is used

Batch ID of the compost and anaerobic digestate	Name of the location (city, town, small town, village)	Area in ha	Intended use of the compost and anaerobic digestate
5.1	5.2	5.3	5.4

6. Concentration of heavy metals in compost and anaerobic digestate (Batch ID of the compost and anaerobic digestate ________).

Batch ID of the compost and anaerobic digestate	Concentration of heavy metals, mg/kg of dry matter						
	Pb	Cd	Cr	Cu	Ni	Zn	Hg
6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8

7. Quality parameters of compost and anaerobic digestate (Batch ID of the compost and anaerobic digestate ________).

Batch ID of the compost and anaerobic digestate	Amount of compost and anaerobic digestate	Dry matter content, %	Organic matter content, %	pH	Total nitrogen (N), mg/kg of dry matter	Total phosphorus (P), mg/kg of dry matter	Estimated usage rates
7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8

Annex 4 to the
Environmental Requirements
for Composting and
Anaerobic Treatment of
Biodegradable Waste

PROCEDURE FOR COMPLETING THE SUMMARY OF THE DATA ON THE QUALITY AND USE OF COMPOST AND ANAEROBIC DIGESTATE

Sections	**Name**	**Explanation**
4.1 5.1 6.1 7.1	Batch ID of the compost and anaerobic digestate	Unique 10-digit batch identification code (ID) of the compost and anaerobic digestate delivered to the user is as follows: the first eight digits indicate the date of delivery (YYYY.mm.dd), the last two indicate the number of batches of compost or anaerobic digestate issued on the same day for different users of compost or anaerobic digestate; the date and the number of batches of compost or anaerobic digestate are separated by a dash. For example, 20181116_03 identifies 16 November 2018 as the date of issue of the third batch of compost or anaerobic digestate, i.e. two more batches were issued on this day.
4.2	Serial number of compost	To be completed if compost is delivered to the recipient.
4.3	Legal entity number	If the user of the compost or anaerobic digestate is a legal entity, indicate its code from the Register of Legal Entities.
4.4	Name of legal person or given name(s) and surname(s) of natural person	The name shall be entered if the recipient of the compost and anaerobic digestate is a legal person; The given name(s) and surname are inserted if the recipient of the compost and anaerobic digestate is a natural person.
5.2	Name of the location (city, town, small town, village)	Indicate the name of the city, town, small town or village, where the compost or anaerobic digestate will be used.

Sections	Name	Explanation
5.3	Area in ha	Indicate the area where compost and anaerobic digestate have been used.
5.4	Intended use of the compost and anaerobic digestate	Intended use of the compost and anaerobic digestate, for example, in agriculture, for rehabilitation of damaged areas, for the preparation of an energy crop growing medium, etc.
6	Concentration of heavy metals in compost and anaerobic digestate	The concentration of heavy metals in mg/kg dry matter are inserted in Sections 6.2–6.8.
7.3	Dry matter content, % (average)	Dry matter content in compost or anaerobic digestate, %.
7.4	Organic matter content, %	Organic matter content in compost or anaerobic digestate, %.
7.5	pH	The pH value of compost and anaerobic digestate is indicated.
7.6	Total nitrogen (N), mg/kg dry matter	Nitrogen (N) content in compost and anaerobic digestate, mg/kg dry matter.
7.7	Total phosphorus (P), mg/kg dry matter	Phosphorus (N) content in compost and anaerobic digestate, mg/kg dry matter.
7.8	Estimated usage rates	The amount of compost and anaerobic digestate must be calculated on the basis of the nitrogen and phosphorus content in it, in accordance with the maximum rates of incorporation of these in the soil specified in point 43.1 of the Requirements.

6.2.4 European Union compost regulation

REGULATION (EU) 2019/1009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32019R1009&from=EN

CMC 3: COMPOST

:An EU fertilising product may contain compost obtained through aerobic composting of
.exclusively one or more of the following input materials:

(a)bio-waste within the meaning of Directive 2008/98/EC resulting from separate bio-waste collection at source;

(b)derived products referred to in Article 32 of Regulation (EC) No 1069/2009 for which the end point in the manufacturing chain has been determined in accordance with the third subparagraph of Article 5(2) of that Regulation;

(living or dead organisms or parts thereof, which are unprocessed or processed only by manual,
cmechanical or gravitational means, by dissolution in water, by flotation, by extraction with
)water, by steam distillation or by heating solely to remove water, or which are extracted from
air by any means, except:

—the organic fraction of mixed municipal household waste separated through mechanical, physicochemical, biological and/or manual treatment,

— sewage sludge, industrial sludge or dredging sludge, and

—animal by-products or derived products falling within the scope of Regulation (EC) No 1069/2009 for which no end point in the manufacturing chain has been determined in accordance with the third subparagraph of Article 5(2) of that Regulation;

(composting additives which are necessary to improve the process performance or the
cenvironmental performance of the composting process provided that:

)(the additive is registered pursuant to Regulation (EC) No 1907/2006 [3], with a dossier
icontaining:

)—the information provided for by Annexes VI, VII and VIII to Regulation (EC) No 1907/2006, and

—a chemical safety report pursuant to Article 14 of Regulation (EC) No 1907/2006 covering the use as a fertilising product, unless explicitly covered by one of the registration obligation exemptions provided for by Annex IV to Regulation (EC) No 1907/2006 or by point 6, 7, 8 or 9 of Annex V to that Regulation, and

(ii)the total concentration of all additives does not exceed 5 % of the total input material weight; or

(any material listed in points (a), (b) or (c) which:

є(i) has previously been composted or digested, and

)(ii) contains no more than 6 mg/kg dry matter of PAH_{16} ([4]).

:The composting shall take place in a plant:

.(a)in which production lines for the processing of input materials referred to in point 1 are clearly separated from production lines for the processing of input materials other than those referred to in point 1, and

(b)where physical contacts between input and output materials are avoided, including during storage.

:The aerobic composting shall consist of controlled decomposition of biodegradable materials, .which is predominantly aerobic and which allows the development of temperatures suitable for thermophilic bacteria as a result of biologically produced heat. All parts of each batch shall be either regularly and thoroughly moved and turned or subject to forced ventilation in order to ensure the correct sanitation and homogeneity of the material. During the composting process, all parts of each batch shall have one of the following temperature-time profiles:

— 70 °C or more for at least 3 days,

— 65 °C or more for at least 5 days,

— 60 °C or more for at least 7 days, or

— 55 °C or more for at least 14 days.

‹The compost shall contain:

.(a) no more than 6 mg/kg dry matter of PAH_{16} ([5]);

(b)no more than 3 g/kg dry matter of macroscopic impurities above 2 mm in any of the following forms: glass, metal or plastics; and

(c)no more than 5 g/kg dry matter of the sum of the macroscopic impurities referred to in point (b).

From 16 July 2026, the presence of plastics above 2 mm within the maximum limit value referred to in point (b) shall be no more than 2,5 g/kg dry matter. By 16 July 2029 the limit-value of 2,5 g/kg dry matter for plastics above 2 mm shall be re-assessed in order to take into account the progress made with regards to separate collection of bio-waste.

5. The compost shall meet at least one of the following stability criteria:

(a) Oxygen uptake rate:

— Definition: an indicator of the extent to which biodegradable organic matter is being broken down within a specified time period. The method is not suitable for material with a content of particle sizes > 10 mm that exceeds 20 %,

— Criterion: maximum 25 mmol O_2/kg organic matter/h; or

(b) Self heating factor:

— Definition: the maximum temperature reached by a compost in standardised conditions as an indicator of the state of its aerobic biological activity,

— Criterion: minimum Rottegrad III.

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