Biological Waste Treatment

Unit 2

Input material for aerobic and anaerobic waste treatment

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2 Input material for aerobic and anaerobic waste treatment

The word **Compost** derives from the Latin word “Compostus” what means “composed”. On account of this the compost raw material, the input material for composting, is composed of many different materials. Nearly every material that can be decomposed by microorganisms is suitable for composting. On the other hand not all these materials are able to deliver a good final product (→ source material for composting)

In general the suitability of a substrate for composting depends on (compare Chapter 2.3 Physical and chemical material properties – qualification criteria for composting):

- content and ability for the degradation of an organic matter,
- its water content,
- its structure,
- the grain size,
- the oxygen demand,
- the density,
- the **nutrient content** and salt content,
- the pH value and
- the portion of harmful substances.

The properties of different organic original substrates are presented in Chapter 2.1 Organic natural material - components of the input material for aerobic waste treatment.

2.1 Organic natural material - components of the input material for aerobic waste treatment

For a better understanding of the **decomposition** processes before dealing with the different input material – i.e. the waste material that is meant for composting – the components of this material should be described as they have an essential influence on the **decomposition** process. The original material for the **biological waste treatment** consists of natural material and a more or less inorganic residue (compare *Chapter 1.5.4 Decomposition of natural substances*).

Main groups are divided in [3]:

- Carbohydrates (sugar, starch, lignin, hemicelluloses and celluloses),
- proteins,
- fats and waxes.

Sugar, starch, hemicelluloses and celluloses belong to the group of carbohydrates. These can be classified in

- monosaccharides (e.g. glucose),
- oligosaccharides (e.g. sugar) and
- polysaccharides (e.g. hemicelluloses and cellulose) [3].

Plants and plant parts, mostly the greatest part of the organic material to be composted, mainly consist of cellulose (from 40 - 70 %). Further important plant components are e.g. xylanes, galactanes, mannanes and pectines, which are summarised under the term hemicelluloses [15].

The lignins are added. They represent very complex chemical compounds of three-dimensionally interlaced ring compounds and, as a ligneous component, care for solidity in the plants.

The starch in the plants serves as storage substance, in addition to fats and oils. The protection of the plant parts above soil is often made from wax. Proteins contain organically bound nitrogen, carbon, hydrogen and oxygen as well as smaller amounts of sulphur and phosphorous.

All these materials have a more or less great **biological decomposition ability.** The graduation ranges from very easily biologically available up to a biological decomposition of several years. The range of decomposition is shown in the following *Table 2.1* (decreasing decomposition ability from top to bottom), compare *Chapter 1.1 Introduction*.

Thus the distribution and the individual contents of natural material in the organic waste material used for composting, influence also the biological decomposition in the composting process (compare *Chapter 1.5.4 Decomposition of natural substances*).

Tab. 2.1: Natural materials and their decomposition ability [30]

Natural material	Presence	Chemical structure	Decomposition1) and decomposing organisms
Starch	Prevailing storage substance in seeds, bulbs and roots	Poly-D-glucose chains, polymerisation degree very different	Very quickly
			Aerobe: fungi and bacteria
			Anaerobe: types of bacilli and clostridium
Pectins	Intermediate lamella between cell walls. In young plant tissue, especially rich in berries, stone fruit and pomaceous fruit	On the whole built from galacturonic acids, strongly thickened polysaccharide	Very quickly degradable by many fungi and bacteria (little actinomycetes), most active decomposing types: sporulates like bacillus macerans and bacillus polymyxa
Proteins	Component of the cell plasma	Macromolecules from amino acids	Easily degradable
			Numerous fungi and bacteria
			Aerobe: bacillus, pseudomonas, serratia, flavo bacterium spp.
			Anaerobe: clostridium spp.
Hemicelluloses	Skeleton substance of the cell wall (together with cellulose and lignin)	Polymerate from different hexoses, pentoses and uronic acids	Degradation from easy (arabane) to difficult (galactane), degradation by actinomycetes, bacteria and fungi

- Man- nanes	Cell substance in different lower plants, in some coniferous woods up to 11 %	Dissolving polysaccha- rides from mannoses	Easily degradable by numerous microorganisms
- Xylanes	Spare or supporting substance, straw and bast: 15-20 %, foliage wood: 20-25 %, coniferous wood: 7-12 %	Polysaccharides from 1,4-glycosidic b-D-xylose with medium polymerisation degree	Easily degradable by numerous microorganisms
- Fruc- tanes	In some plant families stored in- stead of or along with starch, in pasture grass 12-15 % DM, root chicory 11-15 %	Polysaccharide from b- 2,1- or b-2,6-glycosidic D- fructose units	Easily degradable by numerous microorganisms
Fats and resins	Plant and animal residues	Fats: glycerine ester of higher fatty acids	Efficient degradable
		Resins: fatty acids estered with primary univalent al coholics	Fats: Many bacteria and actinomyc etic waxes preferred by bacteria, e.g. mycobacterium phlei, mycobacte rium lacticola
Chitin	Skeleton substance in the animal regnum as well as in the vegetable regnum, forms the exoskeleton of many invertebrate animals, main component of many fungi	Extreme stability on ac- count of the N-bridge linkages coming from the N-acetyl sidegroups (cross linkages)	Easily degradable by many bacteria and fungi
Cellulose	Most important polysaccharide, cell wall substance from superior	Chains of b-1,4-D-glucose with a high degree of po-	Hard to attack, as being not soluble

	plants	lymerisation	
	Hay approx. 28 %, straw 32-36 %, cotton and flax approx. 100 %, wood approx. 50 %	High mechanical solidity, soluble in water	Aerobe: fungi (especially when pH low and when incrusted with lignin), actinomycetes (micromonospora), myxobacteria
			Anaerobe: clostridium and other bac teria (e.g. cellulomonas)
Lignin	Following cellulose and along with hemicellulose quantitatively most important plant component, wood 18-30 %	Phenylpropane units with different three-dimen- sional linkages (=incrusta tion)	Very resistant and only slowly degra dable, higher fungi (basidiomycetes) in addition to actinomycetes, strepto mycetes spp. and other bacteria

[1] The degradability decreases from top to bottom

2.2 Waste types for composting

2.2.1 Mixed waste

Unsorted mixed waste was decomposed without problems in pre-industrial times. Impurities like plastics were not known and glass, as a precious object, was rather reused than put into the household waste. Heavy metal loads and problems with dioxin did not exist or were not known, respectively.

The composting of refuse is nowadays combined with an essentially higher technical expenditure in order to produce a visually and chemically acceptable compost. However, even with the help of advanced techniques of separation it is not possible to produce the same quality as from material collected separately at the source (e.g. from biowaste or green waste, compare *Chapter 2.2.2 Biowaste* and *Chapter 2.2.3 Green waste*).

Most composts from mixed waste are not suitable for food production on account of their relatively high contamination. However, nowadays considerably improvements can be stated. Yet these types of composts are more suitable for a use in **landscaping** or for restoration purposes.

Table 2.2 shows the different loads of heavy metals of composts made from mixed waste and of those based on separate collection (**biowaste composts**).

Tab. 2.2: Heavy metal contents from mixed waste composts and biowaste composts from separate collection (mean contents in Germany in [mg/kg DM])

	Mixed waste compost1)	After separate collection2)
Zinc	1570	222
Lead	513	68
Cadmium	5.5	0.7
Chromium	71	34
Copper	274	50
Nickel	45	21
Mercury	2.4	0.2

1) according to [6]; 2) according to [1]

2.2.2 Biowaste

Biowaste is the usual term for separately collected organic waste material from households. This is how the term is used in the following. The German Biowaste Ordinance (BioAbfV) broadens the term essentially and defines the biowaste as biologically usable waste material.

Since the mid-eighties an approximately area-wide collection system has been established in Germany, the “green bin” or “brown bin”. In these bins that part of the waste stream is collected which can be composted.

The source material of compost that is collected herewith consists of the following macroscopically identifiable components:

- Food residues, overaged or spoiled food, fruit residues, seeds, scales, vegetable residues, egg scales, used coffee powder, tea leaves,
- potting plants, used potting soil,
- material < 25 mm like nut scales,
- paper handkerchiefs, uncoloured newspaper, coffee filter, tea bags.

Garden waste (or green waste) represents material that arises at maintenance work in gardens, like:

- Cuttings from lawns, bushes and trees,
- weeds, withered plants,
- harvest residues.

The compounds of biowaste depend very strongly on:

- The type of the area, i.e. rural or urban,
- the lifestyle and consumer practice of the inhabitants,
- the type of collection and
- the information and public relation work of the individual municipality.

Biowastes from the collection in rural areas are similar to wastes from green cuttings (compare *Chapter 2.2.3 Green waste*)

Biowastes from urban areas have usually a higher amount of impurities, a higher water content, a higher salt content and a higher bulk density. *Table 2.3* shows an example from Hamburg [4].

Tab. 2.3: Impurities in the biowaste (city of Hamburg) [4]

Settlement structure	Impurities in biowaste (% by weight)
Villa	0.6
Terraced houses	0.4
Multistorey constructions	3.6
Tower block dwellings	7.2

Table 2.4 shows the high portion of organic and thus compostable components in wastes from some selected countries:

A rule of thumb number for the arising of these wastes is approx. 100 kg per inhabitant and year. The basis of this calculation is the waste quantity of 331 kg which is produced annually in Germany per inhabitant. With an organic portion of 29.9 % it corresponds to a potential of compostable mass of 99 kg per inhabitant and year.

Tab. 2.4: Representative waste composition in selected countries, in percentage to total weight[12]

Country	Organics [Total %]	Paper/ cardboard [Total %]	Plastics [Total %]	Glass [Total %]	Metal [Total %]	Residues [Total %]
USA1)	21	39	9	6	8	16
Japan1)	32	38	11	7	6	6
Belgium1)	37	16	7	7	4	29
France1)	29	25	11	13	4	18
Greece1)	49	20	9	5	5	13
Spain1)	44	21	11	7	4	13
Czech Republic1)	18	8	4	4	2	64
Hungary1)	33	18	6	5	4	34
Poland1)	38	10	10	12	8	22
Switzerland1)	38	29	15	3	3	12
Lithuania2)	36	38	6	6	3	11
Brasov (Romania)3)	41-59	10-14	5-6	7-10	4-5	13-19
Turkistan4)	60	7	3	4	3	23
Kyrgyzstan4)	44	25	2	3	3	23

1) Data for 1995. Source: Environmental data compendium 1997

2) Data for 1990 [27]

3) Data for 1994 [28]

4) Data for 1996-1997 [29]

2.2.3 Green waste

Green wastes usually delivered by hobby gardeners, private or public landscaping and horticulture enterprises to the compost plant or the collection points.

These green wastes are coming from:

- Parks,
- private gardens,
- landscaping and
- private or public green areas.

They mainly consist of:

- Grass cuttings or cuttings from bushes, trees and shrubs,
- flowers, potting plants, cones, leaves, weeds and
- harvest residues etc.

Green wastes are usually characterised by:

- A lower impurity content,
- a wide C/N ratio (except grass cuttings),
- but often show a low water content.

Further characteristics are the seasonal variations of the delivered quantity and a lower potential **degradation degree** along with a surplus of wooden components.

2.2.4 Sewage sludge and other materials

Approximately 230 million Mg of sewage sludge is generated annually in the area of the EU. Composts cannot be produced from all of this sludge material, because it complies only partly with the severe quality requirements for agriculture, horticulture and fruit culture (compare *Chapter 7 Comparison of decomposition and digestion processes*)

Sludge with a low content of harmful matter can be found in areas with little industrialisation. It can be mixed with structure building material (see *Chapter 2.3.3 Pore volume/bulk density*) like green waste, wood chips, bark, paper, cardboard etc., thus resulting in an acceptable source material for composting.

Besides the named materials, a great number of different organic materials which can be composted are available. These are for example:

- Organic **industrial wastes** from the food industry or restaurants,
- residues from agriculture and forestry,
- **biologically degradable material** and
- others.

2.3 Physical and chemical material properties – qualification criteria for composting

Before composting is considered to become a method for the disposal, tests are recommended regarding

- degradability,
- harmful matter load and
- quality of the final product.

Even separately collected biowastes are not at all of a uniform but of a very heterogeneous composition. Besides the already described organic matter, **inert** material and water, they contain impurities from misplaced material in different concentrations.

Depending on the collection region and season, considerable deviations may arise in the composition of the compost raw material and thus in material properties.

2.3.1 Water content

Sufficient water content must be available for the growth of microorganisms as the necessary nutrients can only be taken up from a watery solution (compare *Chapter*

1.1 Introduction). It depends on the individual microorganisms, which water contents are necessary in fact.

The maximum water content, at which an aerobic conversion of the biowaste is stillpossible, is determined by the physical “rivalry” of water and air in the pores of the compost raw material.

Decisive for a sufficient water supply is not only the percentage of water in the original material, but also the so-called water activity (a_w). It is defined as the vapour pressure of water divided by that of pure water at the same temperature. Therefore, pure distilled water has a water activity of exactly one. In the first instance bacteria are sensitive against a decrease of the a_w-value. Yeast and mould fungi are more tolerant against smaller water contents [2].

Bidlingmaier [2] quotes an optimal water content in the decomposition material of 40 - 60 %. However, tolerable water contents for composting processes range from 25 % to 70 %.

According to Ottow and Bidlingmaier [2], a similar percentage of water content can lead to

- a lack of water in a favourable distribution of materials with a strong sorption property and a high pore volume, and to
- leachate in materials weak in structure and poor in pores.

Also a high water content and thus a not sufficient air content in the pores lead to the formation of anaerobic zones with a corresponding release of odour.

2.3.2 pH value

The **pH** value is an important selection factor for microbial biocoenosis. Along with an optimum of temperature (compare *Chapter 4.1.3.3 Anaerobic processes - classification according to process temperature*) there is also a pH optimum for microorganisms. Fungi are more capable to grow under acid conditions than bacteria, e.g. it is optimal at pH values around 5 [2].

The development of the pH value during decomposition follows certain rules:

1 The pH value of the source material at the beginning of composting usually lies in the acid range, often between 4.5 and 5.

2 Organic acids are built by anaerobic processes during the collection of household waste, as e.g. by materials with a high amount of water in unaerated collection bins.

3 Those lower free carbon acids, which arise at a great extent from higher fatty acids, are very quickly degraded during composting or are volatilised. [17].

4 The release of bases like ammonium, pyrazine and pyridine during the degradation process increases the pH value until 8 to 8.5 in the course of decomposition.

5 The re-decreasing of the pH value during the maturity phase down to 7 to 7.5 happens on account of the uptake of ammonium by the microorganisms and the nitrification processes.

2.3.3 Pore volume/bulk density

The **pore volume** plays a decisive role regarding the aeration properties of the material. Great demands must be made on the optimal distribution of the compost matrix in gas, water and solid material:

- On the one hand the necessary water supply must be provided for the microorganisms.
- On the other hand anaerobic processes during decomposition must be avoided.

The pore volume must be kept even at unfavourable preconditions (water content, load). This requires a high structure stability. In no case an inferior structure should occur due to subsidence on account of degradation.

Here arises a conflict situation between grain size and the required stability.

- The smaller the aggregates, the greater is the attacking area for the decomposing microorganisms.
- However, in cases where the aggregates are too small, this will deteriorate the structure stability and the pore volume.

Structure material must be added in an amount that a matrix can be built up within the compost heap which supports itself.

The **structure material** to be chosen (usually bark, wood chippings, green cuttings etc.) should be very dry in order to absorb surplus water. Bulk densities of more than

0.7 Mg/m^3 are leading to problems in most of the aerobic processes.

Ottow und Bidlingmaier [30] give a summary of the usual bulk densities in organic waste material:

Tab. 2.5: Bulk densities of some organic waste materials [30]

Waste type	Group	Bulk density in [Mg/m^3]
Biowaste	Separately collected kitchen and garden wastes	0.4-0.7
Green waste	Not comminuted cuttings from trees and shrubs	0.1-0.2
	Grass	0.4
	Leaves	0.2
Household waste	Collected as unsorted	0.1-0.3

2.4 Physical and chemical material properties – qualification criteria for anaerobic digestion

Many organic wastes are basically suitable for the **anaerobic treatment,** that otherwise can be composted only with great efforts. Here wastes with an inferior content of solid and structure materials can be named.

As the composting process needs a waste mix with a specific porosity in order to guarantee a sufficient aeration, structureless wet material must be mixed with green cuttings or other structure building materials for an optimal composting. The 2-step **digestion** system makes this structure unnecessary, as here no gas exchange is necessary.

Wastes which in the first instance are meant for a digestion plant are:

- Food residues,
- grease separator contents,
- wet biowastes from municipal collection,
- slaughter house wastes,
- wastes from agricultural industry and food production, from agriculture (liquid manure, solid manure, plant residues) and
- wastes from markets (fruits, vegetables, etc.).

2.5 Literature

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