

Fermentation (Bokashi) versus Composting of Organic Waste Materials: Consequences for Nutrient Losses and CO₂-footprint

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Abstract— Composting of organic (waste) materials has already been applied for many years in the agro- and horticulture. During composting, the material is aerated by regularly turning the windrow with a grinder. This strongly stimulates the growth of microorganisms. These microorganisms use organic matter as their energy source. This will heat up the windrow and as a result a considerable part of the organic matter will be lost as heat and CO₂, which is emitted into the environment.

Another option is fermentation of the organic (waste) materials. This process takes place without aeration and without any extra processing. Following the Agriton method, Ostrea Seashell lime, Edasil Clay minerals and Microferm (Effective Microorganisms) are added to the windrow when the windrow is prepared for fermentation. After this the windrow will be closed by putting a plastic foil tightly stretched over the windrow. During a period of 6 to 8 weeks the windrow is fermented. The final product is called Bokashi; fermented organic matter.

The aim of this experiment was to compare this Bokashi process with the traditional way of composting. As expected, the anaerobic conversion (fermentation) of the organic material will result in considerably lower organic matter losses and an enormous reduction in CO₂ emission (lower CO₂-footprint) to the environment.

Index Terms—Organic Waste Materials, Bokashi, EM, Fermentation, Environment, Compost

I. INTRODUCTION

In the agro- and horticulture, enormous amounts of organic materials are being produced which are not appropriate for human or animal consumption and can be regarded as waste products. Traditionally, these materials were composted and the compost was used as fertilizers on the fields. During this traditional composting process, a large part of the organic material is lost as heat and CO₂. As a consequence, the carbon/nitrogen ratio (C/N) is reduced enormously compared to the original material. The C/N ratio of the compost is too low for optimal plant growth [1]. The energy level of the compost does not optimally support plant growth, and N-containing compounds will be used as energy source (providing carbon) by the soil life, resulting in a relative shortness of nitrogen. Besides, the enormous emissions of CO₂ are a high burden to the environment. With the world

population growing rapidly, we need all the organic matter to grow foods and feeds and we have to take care of our environment.

Instead of traditional composting, another method to treat these waste materials is available: Bokashi, which is the Japanese word for “good fermented organic matter”. Organic materials are stored airtight. During this process complex structures are broken down by the microorganisms. Due to a lack of oxygen, however, organic material is not completely broken down to CO₂, water and heat. Compared to traditional composting it should be possible to reduce energy losses and CO₂ emission considerably when making Bokashi instead of compost. Two experiments using roadside mowing material were conducted to compare nutrient losses between traditional composting and making Bokashi.

II. BOKASHI VERSUS TRADITIONAL COMPOST

A. Experimental setup

In 2013 and in 2015, roadside mowings were collected and split into two equal portions. In each year, one half was used to make traditional compost, the other half was used to make Bokashi according to the Agriton method [2]. In both years, for both production methods (Bokashi and Composting), approximately 13 MT starting material was used. For the traditional composting, this material was put on a windrow, approximately 3 m wide and 1.1 m height in the middle. This windrow was mixed with a tractor powered mixer four or five times a week during the 6 weeks (2013) or the 8 weeks (2015) of storage. For the Bokashi, the windrow had the same width and length. According to the Agriton method, to the Bokashi row 30 L Microferm, diluted in 300 L well water, 300 kg Edasil Clay minerals and 300 kg Ostrea Seashell lime were added. The Bokashi rows were built up in two stages. After the first layer 2/3 of the additions were added on top, the final 1/3 was added on top of the second layer. Then, the row was mixed using a tractor powered mixer. Finally the material was compressed with a tractor to press the air out of the material and the material

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was covered with plastic foil to keep it air-tight. Microferm, is a mixture of micro-organisms containing lactic acid microbes, yeasts, phototrophic microbes, actinomycetes and fungi and commercialised as Effective Microorganisms or EM. EM is an inoculant and has been developed by EMRO (Effective Microorganism Research Organisation) from Okinawa Japan. Compositions of the clay minerals and seashell lime are given in Table 1.

Table 1. Composition of the additives Edasil Clay minerals and the Ostrea Seashell lime.

Edasil Clay minerals		Ostrea Seashell lime	
Montmorillonite level (%)	70-80	Dry matter (%)	99.5
Specific surface (m ² /g)	600-800	Ash (%)	97.5
Ion exchange capacity (mval/100g)	70-85	Phosphorous (%)	0.05
Water uptake capacity (%)	135	Calcium (%)	37.7
Water level (%)	6-8	Carbonate (%)	96.1
pH value	7-8	Sodium (%)	0.4
Alkaline function (%)	4	Potassium (%)	<0.01
Density (g/cm ³)	2.6	Magnesium (%)	0.02
Silicon oxide (%)	56	Copper (mg/kg)	1
Iron oxide (%)	0.4	Iron (mg/kg)	5,266
Aluminium oxide (%)	16.0	Manganese (mg/kg)	63
Calcium oxide (%)	4.0	Zinc (mg/kg)	5
Magnesium oxide (%)	4.0	Cobalt (mg/kg)	<0.5
Potassium oxide (%)	2.0	Arsenic (mg/kg)	15.9
Sodium oxide (%)	0.4	Selenium (mg/kg)	0.03
Boron (ppm)	1,000	Cadmium (mg/kg)	<0.2
Cobalt (ppm)	35	Lead (mg/kg)	<0.2
Copper (ppm)	20	Mercury (mg/kg)	0.03
Manganese (ppm)	300	Sulfate (mg/kg)	454
Molybdenum (ppm)	20	Chloride (mg/kg)	870
Nickel (ppm)	50	Iodide (mg/kg)	<15
Zinc (ppm)	90	Fluor (mg/kg)	160

Figure 1 shows a picture of the Bokashi windrow (2013) at the start of the experiment. The windrow with Traditional Compost (2013) at the start of the experiment is shown in figure 2. The rows were located inside, so rain could not dilute the compost windrow. Leakage of water with soluble components was however possible for both windrows.

Figure 1: Bokashi at the start.



Figure 2: Traditional Compost at the start.



B. Results and discussion

The temperature of the material, which was measured in both windrows at the start of the experiments and weekly thereafter, shows remarkable differences between the Traditional Compost rows and the Bokashi rows (Figure 3). Aerobic degradation of the organic matter in the Compost rows leads to CO₂ production and heat losses, the latter explaining the high temperatures of these rows. The material comes in after mowing with a temperature higher than environmental temperature (39 °C), but in the Bokashi rows temperature declines rapidly to values close

to the environmental temperature. No high amounts of heat loss indicate that the material has not been oxidised to CO₂, H₂O and heat. This is confirmed by weighing and analysing the material after 6 (2013) or 8 (2015) weeks (Table 2). The total amount of material only slightly declines when transforming it into Bokashi, whereas a tremendous amount of material is lost in the traditional composting process.

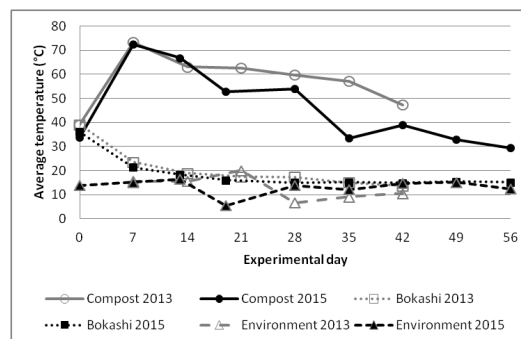


Figure 3: Temperature changes in time in the windrows.

In Table 2, also the losses of organic matter, carbon and nitrogen in both systems is shown. The Bokashi rows start with a higher amount of material due to the additional materials to optimise the fermentation process. Microbes and minerals are added to optimise the anaerobic fermentation process. These microbes convert material to structures more easily available for soil life and plant roots without “burning/oxidising” a considerable amount to CO₂, water and heat.

Table 2. Losses of material from the Bokashi windrows and the Traditional Compost windrows.

	Bokashi*		Traditional Compost	
	2013	2015	2013	2015
Total amount at start (kg)	14,330	13,750	13,400	12,820
Kg after 6 (2013) or 8 (2015) weeks	13,870	12,850	5,070	5,070
OM loss (%)	2.2	4.8	49	48
Carbon loss (%)	2.9	5.6	59	69
Nitrogen loss (%)	0.0	1.7	9.6	16.0

*For the Bokashi, the starting material is including the 930 kg additions of Microferm, Edasil Clay minerals and Ostrea Seashell lime

The final-material of the Bokashi process is chemically not very different from the starting material. A carbon/nitrogen ratio (C/N) of organic material in the soil of above 20 is needed for optimal for plant growth [1]. In the Bokashi material the C/N ratio was 19.5 in 2013 and 22.3 in the 2015 material. For the traditional compost this ratio was 10.1 (2013) and 11.4 (2015), which is too low for optimal activity of soil life without unnecessary nitrogen losses. The Bokashi material is much closer to the original material, chemically as well as when looking at the structure (figures 4 and 5). Energy losses from the product as well as an enormous reduction in the production of the greenhouse gasses CO₂, methane (CH₄) and N₂O, favor the production of Bokashi instead of Traditional Compost. There is, however, more research needed to gather information on the availability of the nutrients for the soil life and the plants after application on crop fields.

III. CONCLUSIONS

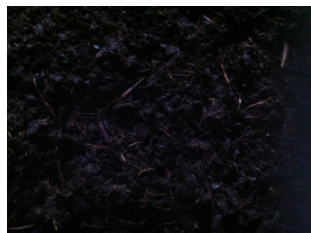
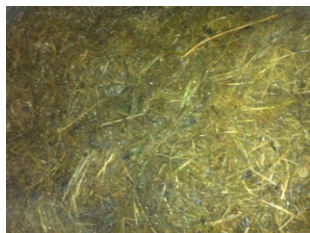


Figure 4: Bokashi after 6 weeks of fermentation

Figure 5: Compost after 6 weeks of composting

Besides, in Traditional Compost, seeds are eliminated due to the high temperatures. With the Bokashi material, first experiences are that there are no seeds surviving the process, despite the low temperature. It is expected that seeds might germinate, but then don't survive due to a lack of light. This is, however, an issue that also needs to be further investigated.

The positive effects on soil fertility and crop growth of applying Bokashi are probably related to the organic fraction of the final-material, a direct effect of the introduced microorganisms (Microferm, EM) and the levels of microbially-synthesized metabolites (e.g., phytohormones and growth regulators) [3].

CO₂-footprint calculation

The CO₂-foot print declares how many CO₂-equivalents per kg end-product are released during the whole process. Diesel is used for the transport of the roadside mowings to the Composting company. Also the additions for Bokashi need to be transported to the Composting company. Diesel is also used for mixing the materials. Besides the influence of the use of diesel on the CO₂-equivalents, the emission during the composting process contributes to the CO₂-footprint. One MJ of used diesel equals 0.074 kg of CO₂ equivalents. Assumed is that 2.4% of the converted carbon is converted into methane (CH₄), and 97.6% is converted into CO₂ [4]. Another assumption is that 1.15% of the available nitrogen in the starting material is converted into N₂O, which is assumed to be the only reaction product of the converted nitrogen [4]. The calculated carbon footprint for the windrows in the 2013 experiment are shown in table 3.

Table 3. Calculated CO₂-footprint for the Bokashi and the Traditional Compost process (in kg CO₂-equivalents).

	Bokashi	Traditional Compost
Losses from the windrow (CO ₂ , CH ₄ , N ₂ O)	166	3,305
Diesel for transport and mixing	184	87
Total per windrow	350	3,391
Per MT starting material	26	253
Per MT end-product	25	669

The kg CO₂-equivalents for diesel are less for Traditional Compost than for Bokashi, due to the transportation of the Bokashi additions to the composting company. Bokashi, on the other hand, only needs to be mixed once (at the start), while the traditional composting process requires almost daily mixing. The kg CO₂-equivalents per ton starting material were for Bokashi almost 10 times lower than for Traditional Compost, and per megaton end-product it was almost 27 times lower than for Traditional Compost.

Making Bokashi compared to Traditional Composting, results in:

- Lower nutrient losses
- Considerable lower emissions of greenhouse gasses (CO₂, CH₄, N₂O)
- Per unit of end-product, a 27 times lower carbon footprint
- Less labour required because it does not need to be mixed regularly

However, although first results are promising, availability of the nutrients from the Bokashi product for plant growth after applying on the field, needs further research.

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