Fermentation (Bokashi) versus Composting of Organic Waste Materials: Consequences for Nutrient Losses and CO_2-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 CO_2, 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 (a microbial inoculant containing Effective Microorganisms) are added to the windrow when the windrow is prepared for fermentation. After this the windrow is closed by putting a plastic foil tightly stretched over the windrow. During a period of 6 to 8 weeks the windrow is fermented. This is called Bokashi; fermented organic matter.

The goal of this experiment was to compare this Bokashi process with the traditional way of composting. As expected, this anaerobic conversion (fermentation) of the organic material resulted in considerably lower organic matter losses and an enormous reduction in CO_2 emission (lower CO_2-footprint) to the environment.

***Keywords*—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 consumed 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 CO_2. As a consequence, the carbon/nitrogen ratio (C/N) is enormously reduced compared to the original material. The C/N ratio of the compost is too low for optimal plant growth. The energy level of the compost does not optimally support plant growth, and N-containing compounds will be used as energy source by the soil life, resulting in a relative shortage of nitrogen. Besides, the enormous emissions of CO_2 are 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 CO_2, water and heat. Compared to traditional composting it should be possible to considerably reduce energy losses and CO_2 emission c 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. Materials and Methods

In 2013 and in 2015, roadside mowing’s 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 [1]. 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 with a mixer four or five times a week during 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 layers. After the first layer 2/3 of the additions were added on top, the remaining 1/3 was placed on top of the second layer. Then the row was mixed using a tractor with a mixer. At last the material was compressed with a tractor to press the air out of the material and was covered with plastic foil to keep it air-tight. Microferm, also called Effective Microorganisms or EM, is an inoculant which contains beneficial microorganisms such as lactic acid bacteria, photosynthetic bacteria and yeast [2]. Composition of the Edasil Clay minerals and the Ostrea Seashell lime are given in Table 1.

Edasil Clay minerals		*Ostrea Seashell lime*	
Montmorillonite level (%)	70-80	Dry matter (%)	99.5
Specific surface (m2/g)	600-800	Ash (%)	97.5
Ion exchange capacity (mvol/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/cm3)	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

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

At the start of the experiments, and weekly thereafter, temperatures in the windrows were measured at three places. Holes in the plastic foil covering the Bokashi rows were repaired immediately to minimize oxygen contamination. From the starting material, as well as from the material at the end of the trial (6 or 8 weeks, respectively), per windrow 3 samples were taken, which were pooled per windrow for chemical analysis. These data were used to calculate organic matter (OM) losses, carbon and nitrogen losses.

Figure 1 shows a picture of the Bokashi windrow at the start of the experiment. The windrow with Traditional Compost 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 surplus moist with soluble components was possible for both windrows.

Figure 1: Bokashi at the start.

Figure 2: Traditional Compost at the start.

III. Results and Discussion

The temperature of the material showed remarkable differences between the traditional Compost rows and the Bokashi rows (Figure 3). Aerobic degradation of the organic matter in the Compost rows led to CO_2 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). In the Bokashi rows however temperature declined rapidly to values close to the environmental temperature. No high amounts of heat loss indicated that the material was not completely fermented to CO_2, H_2O and heat. This was confirmed by weighing and analysing the material after 6 (2013) or 8 (2015) weeks (Table 2). The total amount of material only slightly declined when transforming it into Bokashi, whereas a tremendous amount of material was lost in the traditional composting process.

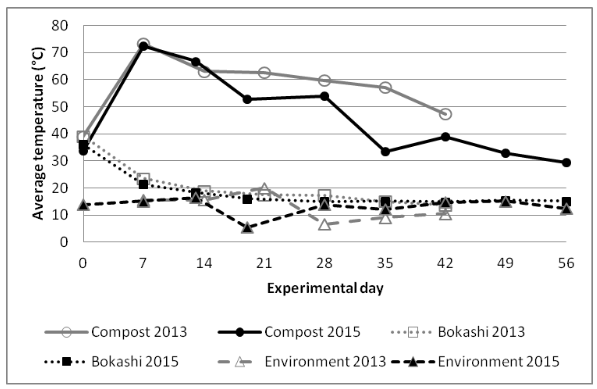

Figure 3: Temperature changes in time in the windrows.

In Table 2, the losses of organic matter, carbon and nitrogen, in both systems are shown. The Bokashi rows started with a higher amount of material due to the additional materials to optimise the fermentation process. Microbes and minerals were added to optimise the anaerobic fermentation process. These microbes convert material to structures more easily available for soil life and plant roots without "burning" a considerable amount to CO_2, water and heat.

	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

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

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

The end-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 around 20 is optimal for plant growth. 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. 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, CO_2, methane (CH_4) and NO_2, favour 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.

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 experience was that there were no seeds surviving the process, despite the low temperature. It was expected that seeds might germinate, but then didn't survive due to a lack of light. This is, however, an issue that also needs to be further investigated.

The effects on soil fertility and crop growth of applying Bokashi is probably determined by the organic fraction of the end-material, a direct effect of the introduced microorganisms (Microferm, EM) and the levels of microbially-synthesized metabolites (e.g., phytohormones and growth regulators) [2].

CO_2-footprint calculation

The CO_2-footprint declares how many CO_2-equivalents per kg end-material are released. Diesel was used for the transport of the roadside mowing's to the Composting company. Also the additions for Bokashi need to be transported to the composting company. Diesel was also used for mixing the materials. Besides the influence of the use of diesel on the CO_2-equivalents, the emission during the composting process contributes to the CO_2-footprint. One MJ of used diesel equals 0.074 kg of CO_2 equivalents. It was assumed that 2.4% of the converted carbon is converted into methane (CH_4), and 97.6% is converted into CO_2 [3]. Another assumption is that 1.15% of the available nitrogen in the starting material is converted into NO_2, the only reaction product of the converted nitrogen [3]. The calculated carbon footprint for the windrows in the 2013 experiment is shown in table 3.

	Bokashi	Traditional Compost
Losses from the windrow (CO_2, CH_4, NO_2)	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

Table 3. Calculated CO_2-footprint for the Bokashi and the Traditional Compost process (in kg CO_2-equivalents).

The kg CO_2-equivalents for diesel are lower 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 CO_2-equivalents per ton starting material were for Bokashi almost 10 times lower than for traditional Compost, and per megaton (MT) end-product it was almost 27 times lower than the Traditional Compost.

IV. CONCLUSIONS

Making Bokashi compared with traditional Composting, results in:

- Lower nutrient losses
- Considerable lower emissions of greenhouse gasses (CO_2, CH_4, NO_2)
- 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 the first result is promising, availability of the nutrients from the Bokashi product for plant growth after applying on the field needs further research.

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