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REVIEW

Review: Bokashi technology as a promising technology for crop production in Europe

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ABSTRACT

The main aim is to describe plant production systems and introduce bokashi technology for the advanced utilisation of food waste in Europe. The secondary objective is to demonstrate that the new Bokashi technology fertiliser products for field crops can improve soil fertility, plant health, yield and food quality in Europe. Bokashi technology is a straightforward yet innovative technology to recycle and valorise various kinds of biowaste into a nutrient-rich product that can be used as an organic fertiliser. Bokashi technology is a method for treating biowaste in general and food waste in specific, using controlled lactic acid fermentation (LAF) under anaerobic conditions. The term is based on a traditional Japanese method of the same name. The acidic and anaerobic environment quickly suppresses the viability of pathogens so even contaminated biowaste can be recycled. The Bokashi technology is almost absent in Europe at the moment. Conclusion: Bokashi technology – coming from Asia (Japan) – is an innovative technology to improve soil fertility, plant health, yield and food quality. This technology has a huge potential to be applied in Europe, but the right methodology should be developed based on the knowledge of temperature regimes for effective microorganisms that will influence the crop production.

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Bokashi technology; food quality; food waste; plant health; soil fertility; yield

Introduction

A major problem facing communities throughout Estonia and Europe is the treatment, disposal, and/or recycling of food wastes (FW, Figure 1). FW is becoming an increasingly important issue both on the local and global level. Different studies show that ca. One-third to half of the world food production is lost or wasted. FW was recently defined in the EU project FUSIONS as 'any food, and inedible parts of food, removed from (lost to or diverted from) the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea) (Östergren et al., 2014)'. Around 88 million Mg (metric tons) of food are wasted annually in the EU, with associated costs estimated at 143 billion € (Stenmarck et al., 2016) – 20% of the total food produced. This estimate is for 2012 and includes both edible food and inedible parts associated with the food supply chain (FSC) and equates to 173 kg of food waste per person.

Discharge of food material occurs along the entire FSC and it involves sectors involved in the production, distribution and consumption of food as well as all sectors of waste management. The sectors contributing to food waste the most are households and processing, altogether accounting for 72% of EU food waste. Of the remaining 28%, the biggest contributors are the food services, primary production, wholesale and retail (Stenmarck et al., 2016). A FSC starts with the production of food from the agricultural sector where both farming and husbandry produce waste or sub-products that may be either organic waste (e.g. manure), FW or food loss (i.e. low-quality fruit or vegetables, good products or by-products with a low or absent commercial value). The food industry produces FW throughout the entire production phase, e.g. damage during/non-appropriate transport or storage, losses during processing and inappropriate packaging.

The composition of food waste (FW) varies depending mainly on dietary/cultural habits and the economical level – as a consequence, the physio-chemical characteristics of FW differ widely. However, FW has general features such as a (i) relatively high solids contents (ca. 20%), (ii) high carbohydrate content, low in cellulose and lignin, and (iii) high protein (15–25%) and lipid (13–30%) contents. As a result, FW has a relatively low C:N ratio when compared to other organic substrates. Other important features of FW are the (iv) high concentrations of macroelements (e.g. P, K, Ca or Mg) and v) its relatively low content of trace elements (TE; e.g. Fe, Se, Ni or Mo). These characteristics make FW a suitable substrate for anaerobic processes, however,

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Figure 1. Bokashi in a container and grate in the bottom of the container.

issues like its low C:N ratio and its lack of TE have to be addressed (Capson-Tojo et al., 2016).

Food waste is directly linked with environmental (e.g. energy, climate change, water, depletion of resources, disruption of biogenic cycles due to intensive agricultural activities), *economic* (e.g. resource efficiency, price volatility, increasing costs, consumption, waste management, commodity markets) and *social* (e.g. health, equality) *impacts*. Greenhouse gas (GHG) emissions from food production and consumption as well as from its disposal, the depletion of natural resources and pollution are the most prominent environmental impacts associated with food waste. FW has economic implications for everyone within the FSC, from the farmer to the food producer and the consumer. These include food production and purchasing costs as well as costs associated with the final disposal. In the context of the fast-growing world population and diminishing natural resources, the disparity between food poverty and FW raises concerns over global food security and highlights the severe social and moral dimensions (Papargyropoulou, Lozano, Steinberger, Wright, & Bin Ujang, 2014).

Thus, there is a pressing need to prevent and reduce food waste to make a transition towards a resource-efficient Europe (Stenmarck et al., 2016). However, in addition, food waste upcycling/conversion to bioproducts gathers increasing attention with systems being developed to produce a wide range of value-added products such as biofuels and materials (Girotto, Alibardi, & Cossu, 2015; Nielsen, Rahman, Rehman, Walsh, & Miller, 2017). The major aim of the review article is to describe novel methodologies for Europe, based on fermentation, and allowing for most complete conversion of food waste into innovative fertiliser products.

Several options are currently available or explored for an industrial-scale use of FW beside composting, ranging from the use for energy production by means of anaerobic digestion (e.g. bio-methane productions) to the production of specific chemical compounds (Girotto et al., 2015). Hot composting, both on FW or residues from industrial processes (e.g. digestate from methane production), is applied to recover some nutrients or as a carbon sequestration process (by formation of humic substances) and for sanitising purposes, but is generally generating low-value-added products. Aerobic composting and anaerobic digestion represent the vast majority of the processes currently used. However, of origin, large proportions of food waste are edible and of high nutritional value.

Assuming collection routines maintain nutritional quality, Bokashi fermentation of food waste with effective microorganisms (EM) is a form of biological treatment that stabilises the bio-waste and provides a nutrient-rich growth-promoting fertiliser for field- and greenhouse-based food production systems. Thus, in the sense of circular economy and zero-waste, a more complete utilisation of food waste will be achieved. To promote the industry-scale use of this innovative technology in Europe, the end products of EM Bokashi treatment have to be effective, safe for the environment and human health, and economical. EM Bokashi fermentation is proposed to upcycle food waste to (partially) replace traditional composting of food waste (and secondary residues from industrial processes) to facilitate both plant production and soil quality as well as to reduce greenhouse gas emissions.

The main aim of the review article is to describe plant production systems and introduce bokashi technology for the advanced utilisation of food waste in Europe. The secondary objective of the review article is to demonstrate that the new Bokashi technology fertiliser products for field crops can improve soil fertility, plant health, yield and food quality in Europe.

Fundamentals of EM Bokashi fermentation

Anaerobic fermentation in general can accommodate a great variety of substrates and is thus predestined for FW treatment. In a nutshell, the Bokashi substrate (i.e. almost any biogenous material, shredded; Figure 2) is inoculated with a mixture of beneficial microbes (EM) that flourish in anaerobic, acidic environments. In contrast to anaerobic fermentation

Figure 2. The food waste in container and the tap (on the container) to collect bokashi tea (liquid fertilizer).

for hydrogen production, no costly buffer for pH stabilisation needs to be added. To prepare the inoculant, a carbohydrate-rich brew is prepared, the host material is immersed, and the microbes are allowed to ferment the biogenous material in closed bioreactors (usually large barrels with plug valve). A carrier substrate (i.e. molasses) provides an initial energy source for the microbes. Once the fermentation stage is over, after as little as 10 to 20 days, the inoculated host can be packaged and stored for long periods as a Bokashi starter. Two fractions, a solid one and a liquid one ('Bokashi tea'), can be retained separately from the bioreactor or are used in combination as a semi-liquid fertiliser. Moisture regulation is necessary for optimal fermentation as well as temperatures >18–20°C. To standardise industrial fertiliser products, substrate mixing for adjusting the C:N ratio, balancing macronutrient and by supplying trace elements can be implemented. The products can be stored for several months in dark, airtight conditions and lower temperatures without changing its properties.

Effective microorganisms

Effective microorganisms consist of a mixed culture of beneficial ('effective'), naturally occurring microorganisms such as purple non-Sulphur bacteria (PNSB), lactobacilli (LAB), yeasts, and Actinomycetes (Olle, 2015, 2016a, 2016b, 2019). All microbes in EM are derived from nature (Footer, 2013). The concept of EM is based on the inoculation of substrates with the intention of shifting the microbial equilibrium and thus creating an improved microbiome that favours improved productivity. In addition, secondary metabolites produced by the modified microbiome are a relevant mode of action (Boechat, Santos, & Accioly, 2013).

In addition to using EM Bokashi to increase food production, the EM microbes in the Bokashi starter, especially LAB, PNSB and yeast, have the ability to perform a variety of beneficial environmental functions, including breaking down harmful chemicals and immobilising heavy metals.

The scientific value of the Bokashi technology

Bokashi technology is a straightforward yet innovative technology to recycle and valorise various kinds of biowaste into a nutrient-rich product that can be used as an organic fertiliser. Bokashi technology is a method for treating biowaste in general and food waste in specific, using controlled lactic acid fermentation (LAF) under anaerobic conditions (Boechat et al., 2013). The term is based on a traditional Japanese method of the same name.

Research has shown that EM must be applied along with organic matter. They can be applied as a liquid or mixed with nutrient-rich organic matter as a fermented compost ('Bokashi' in Japanese). The benefits of applying EM plus organic matter lie in the ability of the EM to ferment organic matter, thereby releasing nutrients and nutrient-rich organic acids which can be utilised by plants. Derivatives of EM in which leaf material, especially leaves from spice or medicinal plants, are fermented with the microbial solution offer prophylactic benefits to plants (Higa, 2012). EM can also be applied to crop plants, and research has shown that this can enhance physiological parameters, such as photosynthesis, which results in higher crop yields, a key factor in organic farming (Higa, 2012).

The original use of EM was in agriculture (Sangakkara, 2012). EM were first applied to enhance the productivity of organic or natural farming systems. EM were applied directly onto the organic matter being added to cropping fields, or to composts, which reduced the time required for the preparation of this bio-fertiliser. EM were also added in the form of 'Bokashi' (compost) made with waste material such as rice husks and sawdust as a carrier, mixed with nitrogen-rich materials such as rice, corn, wheat bran, fish meal, or oil cakes. The benefits of EM have been attributed to many factors. These include a greater release of nutrients from organic matter when composted with EM, and/or enhanced photosynthesis and protein synthetic activity. Studies have also identified greater resistance to water stress, higher rates of mineralisation of carbon, improved soil properties, and better penetration of plants roots following the use of EM (Sangakkara, 2012).

Unlike standard aerobic composting, Bokashi waste treatment is performed in closed bioreactors or unaerated piles in order to create anoxic conditions. To control the breakdown of organic matter under lactic acid fermentation (LAF) conditions, a mixture of biowaste is inoculated with a defined mixture of (facultative) anaerobic microorganisms (EM). The acidic and anaerobic environment quickly suppresses the viability of pathogens so even contaminated biowaste can be recycled.

Lactic acid bacteria perform an vital role in the preservation and production of wholesome foods. The lactic acid fermentations are generally inexpensive, and often little or no heat is required in their preparation (Steinkraus, 1992).

The Bokashi technology is almost absent in Europe at the moment. The great potential of the technology is demonstrated by its extensive and successful use in the Asia/Oceania region. The main ambition is to introduce the technology in Europe as the initial technology was developed for tropical climates and soil conditions. The organic matter decomposes best at the temperature +27° C, and the EM working regime is above + 6° C, and most appropriate between temperatures +20° C … +30° C. The EM bokashi technology is not yet ready for usage in European countries and needs further a major attention to start the experimental investigation on that direction.

EM Bokashi fermentation (Footer, 2013), and its 'sub-sections' fermentation (Hitman, Bos, Bosch, & Kolk, 2013) and EM (Olle & Williams, 2013) benefits are as follows (in brackets the name of technology):

- A most wide variety of biowaste fractions, including organic household waste, animal by-products, contaminated waste and other types such as biowaste of bakeries and beer breweries can be used (fermentation);
- The chemical composition of biowaste is not as crucial as for traditional compost (fermentation);
- No mechanical mixing of the waste (as for composting) is needed during the process (fermentation);
- Faster than traditional composting, can be used on any scale and at ambient temperatures (fermentation);
- No insect or rodent issues as for composting (fermentation);
- No putrid odours as for composting plants (fermentation, EM);
- Minimal greenhouse gas emission compared to composting (fermentation);
- No loss of nutrients and carbon to the ground or the atmosphere during FW processing resulting in higher nutritional values of products (fermentation);
- The finished fertiliser products are rich in beneficial microorganisms (EM);
- Low pH and antimicrobial compounds ensure the inactivation of pathogens (EM, fermentation);
- Improving soil health and structure incl. enhanced C sequestration (EM);
- Enhancing both quality of fertiliser and fertiliser uptake (fermentation, EM);
- Improving the stabilisation of heavy metals and the decomposition of pesticide residues in soils (EM);
- Improving plant and animal health and food product quality (EM);
- Improving crop yield and meat production (EM, fermentation).

The influence of bokashi technology on the crop yield and yield quality

Overall, EM inoculation increases crop yield and growth (Figure 3) as evidenced by a recent meta-analysis of Megali, Schlau, and Rasmann (2015). Most likely, a substantial reason for these yield increases is improved plant nutrition. The combined application of organic material plus EM, or as combined in EM Bokashi fermentate, is most advantageous to improve crop yield. Evidence exist that EM Bokashi inoculation/fertilisation leads to significantly greater yield increases than other growth promotors (Mohan, 2008). The fact that not all species respond positively to EM application (see, e.g. the (partially) negative effect of EM inoculation on lettuce, watermelon, pea, *Trifolium* and cabbage; (see e.g. Escano, 1996; Megali et al., 2015) suggests that either (i) not all plant species are responsive to EM effects on the soil/root microbiome (Hayat, Ali, Amara, Khalid, & Ahmed, 2010) or (ii) soil amendment might

Figure 3. The container colser provides anaerobic environment and powerful healthy plants growing on the compost containing bokashi fermented product.

not have resulted in the (sufficient) establishment of EM's constitutive microbial species into the local soil microbiome (Mayer, Scheid, Widmer, Fließbach, & Oberholzer, 2010). The first possibility underlines the need for EM Bokashi fertiliser producers and farmers alike to evidence and quantity the growth and yield promoting effects for European cropping systems. However, in support of the second possibility is the fact that abiotic and biotic factors have been previously shown to strongly influence the soil microbiome (Lentendu et al., 2014) and may thus affect EM's ability to establish or sufficiently improve inoculated soils.

Potential mechanisms underlying increased crop yield and yield quality as mediated by EM Bokashi are diverse and not elucidated in full detail yet. While the EM microbiome is composed of a large consortium of microorganisms, LAB generally become the most active and dominant group in mature ferments with EM microbiome (Kyan et al., 1999) and constitutes major parts of commercial EM products (Ahn, Lee, Kim, & Koo, 2014). Overall plant stimulation is likely based on three main effects of the EM microbiome: (i) biofertilization, (ii) biocontrol, and (iii) biostimulation. As organic fertilisers, increased productivity in crops treated with EM-inoculated organic matter vs. Composts is likely due to the hastened decomposition of organic compounds into plant available nutrients.

Plant responses to traditional composting and to the Bokashi technology are summarised in the Table 1.

The influence of bokashi technology on the soil suppressiveness and plant protection

Recent studies shows that beneficial microbial soil communities play a decisive role in resistance to pathogens (van de Voorde, van der Putten, & Bezemer, 2012; Weller, Raaijmakers, Gardener, & Thomashow, 2002) – a phenomenon known as 'soil suppressiveness'. Pineda, Zheng, Van Loon, Pieterse, and Dicke (2010) have highlighted the importance of microbiome-mediated positive effects on the induction of both direct and indirect plant defences, acting as biological control agents (BCA). There are three known mechanisms by which e.g. LAB act as a BCA: (i) through the production of antimicrobial compounds and reactive oxygen species (ROS; Trias, Bañeras, Montesinos, & Badosa, 2008) and bacteriocins (Perez, Zendo, & Sonomoto, 2014), (ii) by excluding pathogens by pre-emptively colonising plant tissues, and (iii) by altering the plant immune response (Konappa et al., 2016).

It was noted by Escano (1996) that Bokashi alone or in combination with EM reduced the incidence of the soft rot disease in lettuce and cabbage, and Ndona, Friedel, Spornberger, Rinnofner, and Jezik (2011) concluded that the number of tomato fruits damaged by blossom-end rot was reduced in EM-treated plants. Good results of Xu, Wang, Mridha, and Umemura (2012) and Fontenelle et al. (2015) suggest that Bokashi amendments helped to decrease disease

Table 1. Plant responses to the Bokashi technology.

The problem	Limitations with traditional composting	Progress with the Bokashi method
Susceptibility of plants to unfavourable conditions at the stage of germination	In some cases poor germination	Improved germination
Limited growth without extra nutrition	Growth is improved slightly depending on composition (e.g. elongation)	Improved growth due to rich composition, including bio-active compounds.
Often delaying plant ripening	Prolonged ripening time due to vigour vegetative growth	Fastens ripening
Few methods for increasing photosynthetic capacity	Low influence on photosynthetic capacity	Increased photosynthetic capacity
Challenges in biofortification of vegetable crops	Slightly changed nutrient content	Increased nutrient content

incidence on tomato. Aljarah (2016) rates the EM Bokashi technology as promising for managing seed rot and seeding damping-off caused by *P. aphanidermatum* and *R. solani* in cucumber. Soil application of EM contributed to inhibiting fungal pathogen infestation on pea plants (Okorski, Olszewski, Pszczółkowska, & Kulik, 2008).

The influence of bokashi technology on the soil quality

With respect to the addition of organic matter, Bokashi is advantageous over compost since most of the organic carbon is retained (and not lost as CO_2) and can be sequestered in the soil. Compared to compost (of the same material), Bokashi fermentate retains a much higher C:N ratio which stimulates microbial activity; the mineralisation rate of Bokashi, as for compost, depends on the C:N ratio (Boechat et al., 2013). Thus, Bokashi can stimulate microbial, meso- and macro-fauna activity, thereby increasing soil aggregate abundance and stability (Amezketa, 1999). An increased aggregate abundance and stability will improve soil drainage and aeration especially in heavy soils; in more coarse soils, the organic matter instead increases the water holding capacity of the soil. In accordance Ginting (2019) shows that Bokashi applications are improving soil fertility.

The EM in Bokashi have been shown to increase soil organic matter (SOM) stabilisation (Colec et al., 2007; Dębska, Długosz, Piotrowska-Długosz, & Banach-Szott, 2016; Valarini, Alvarez, Gasco, Guerrero, & Tokeshi, 2003).

As an organic fertiliser, increased productivity in crops treated with Bokashi and other EM-inoculated organic matter vs. compost is attributed to the rapid decomposition of organic compounds into plant available nutrients.

With respect to heavy metals, Nielsen (2010) and Yakovleva, Klyvenok, and Vovk (2012) reported that EM-treated organic matter (sludge) contained significant smaller amounts of heavy metal ions than standard compost made from the same material; immobile complexes of heavy metals are not harmful for plants or the environment.

Soil responses to traditional composting and to the Bokashi technology are summarised in the Table 2.

Conclusion

Bokashi technology is a straightforward yet innovative technology to recycle and valorise various kinds of biowaste into a nutrient-rich product that can be used as an organic fertiliser. Bokashi technology is a method for treating biowaste in general and food waste in specific, using controlled lactic acid

Table 2. Soil responses to the Bokashi technology.

The problem	Limitations with traditional composting	Progress with the Bokashi method
Limited fixation of atmospheric nitrogen	Fixation of atmospheric nitrogen is low	Fixation of atmospheric nitrogen is improved
Challenges with the decomposition of organic wastes and residues	The decomposition of organic wastes and residues is depending from soil biological activity	The decomposition of organic wastes and residues is increased due to presence of EM
Suppressing soil-borne pathogens are spreading more intensively with changing climate	Suppresses soil-borne pathogens poorly	Suppresses soil-borne pathogens better
Challenges with recycling and increasing the availability of plant nutrients	Recycles and increases the availability of plant nutrients in moderate level	Recycles and increases the availability of plant nutrients more efficiently
The concentration of toxins, including pesticides and their breakdown products in the conventional cropping systems is increasing	Low ability to reduce the concentration of toxins, including pesticides	Reduces the concentration of toxins, including pesticides better
The production of antibiotics and other bioactive compounds in conventionally used soils usually is negligible depending on soil biological activity	The production of antibiotics and other bioactive components is low	Good production of antibiotics and other bioactive compounds
The complexation of heavy metals to limit plant uptake in conventionally used soils usually is low	There is low influence on the complexation of heavy metals to limit plant uptake	Complexation of heavy metals to limit plant uptake is more efficient
The solubilisation of insoluble nutrient sources takes place slowly depending on soil characteristics	There is neutral influence on solubilisation of insoluble nutrient sources	The solubilisation of insoluble nutrient sources is increased
The production of polysaccharides to improve soil aggregation usually is very low	There is negligible influence on production of polysaccharides to improve soil aggregation	The production of polysaccharides to improve soil aggregation is better
Challenges to enhance the photosynthetic capacity of crops	Enhances the photosynthetic capacity of crops poorly	Enhances the photosynthetic capacity of crops better
Challenges with promoting germination, flowering and fruiting	Promotes germination, flowering and fruiting poorly	Promotes germination, flowering and fruiting better
Challenges to increase the effectiveness of fertilisers	Increases the effectiveness of fertilisers poorly	Increases the effectiveness of fertilisers better
Root system architecture (RSA) and development has received increased attention due to advances in phenotyping	Low focus on the underground characteristics of plants	A better understanding of root traits in currently available technologies and their adaptive plasticity under environmental constraints

fermentation (LAF) under anaerobic conditions. The term is based on a traditional Japanese method of the same name. The acidic and anaerobic environment quickly suppresses the viability of pathogens so even contaminated biowaste can be recycled. The Bokashi technology is almost absent in Europe at the moment.

Bokashi technology is low cost, energy and nutrient saving, greehouse gases decreasing environmentally safe technology to produce from food waste organic fertilisers needed in agriculture, i.e. supporting circular economy.

Bokashi technology is an innovative technology to improve soil fertility, plant health, yield and food quality. This technology has a huge potential to be applied in Europe, but the right methodology should be developed based on the knowledge of temperature regimes for EM that will influence crop production.

Disclosure statement

No potential conflict of interest was reported by the author.

References

Ahn, K., Lee, K.B., Kim, Y.J., & Koo, Y.M. (2014). Quantitative analysis of the three main genera in effective microorganisms using qPCR. *Korean Journal of Chemical Engineering*, *31*, 849–854. doi:10.1007/s11814-013-0274-6

Aljarah, N. (2016). Somebiochemical indicators of induced systemic resistance in cucumber seedling against damping off pathogens by local bokashi and fermented plant extracts (FPE). *Journal of University of Duhok. (Agri.and Vet.Sciences)*, *19*, 593–600.

Amezketa, E. (1999). Soil aggregate stability: A review. *Journal of Sustainable Agriculture*, *14*, 83–151. doi:10.1300/J064v14n02_08

Boechat, C.L., Santos, J.A.G., & Accioly, A.M.D.A. (2013). Net mineralization nitrogen and soil chemical changes with application of organic wastes with'Fermented Bokashi Compost'. Acta Scientiarum. *Agronomy*, *35*, 257–264.

Capson-Tojo, G., Rouez, M., Crest, M., Steyer, J.P., Delgenès, J.P., & Escudié, R. (2016). Food waste valorization via anaerobic processes: A review. *Reviews in Environmental Science and Bio/ Technology*, *15*, 499–547. doi:10.1007/s11157-016-9405-y

Golec, A.F.C., Pérez, P.G., & Lokare, C. (2007). Effective microorganisms: Myth or reality? *Revista Peruana de Biología*, *14*(2), 315–319.

Dębska, B., Długosz, J., Piotrowska-Długosz, A., & Banach-Szott, M. (2016). The impact of a bio-fertilizer on the soil organic matter status and carbon sequestration—results from a field-scale study. *Journal of Soils and Sediments*, *16*, 2335–2343. doi:10.1007/s11368-016-1430-5

Escano, C.R. (1996). *Experiences on EM technology in the Philippines*. Retrieved from http://www.futuretechtoday.net/em/index2.htm

Fontenelle, M.R., Lopes, C.A., Lima, C.E., Soares, D.C., Silva, L.R., Zandonadi, D.B., … Moita, A.W. (2015). Microbial attributes of infested soil suppressive to bacterial wilt by Bokashi Amendments. *Agricultural Sciences*, *6*, 1239–1247. doi:10.4236/as.2015.610119

Footer, A. (2013). *Bokashi composting: Scraps to soil in weeks* (pp. 1–176). Gabriola Island, BC, Canada: New Society Publishers.

Ginting, S. (2019). Promoting Bokashi as an organic fertilizer in Indonesia: A mini review. *International Journal of Environmental Science and Natural Resources*, *21*, 556070. doi:10.19080/IJESNR.2019.21.556070

Girotto, F., Alibardi, L., & Cossu, R. (2015). Food waste generation and industrial uses: A review. *Waste Management*, *45*, 32–41. doi:10.1016/j.wasman.2015.06.008

Hayat, R., Ali, S., Amara, U., Khalid, R., & Ahmed, I. (2010). Soil beneficial bacteria and their role in plant growth promotion: A review. *Annals of Microbiology*, *60*, 579–598. doi:10.1007/s13213-010-0117-1

Higa, T. (2012). *Kyusei nature farming and environmental management through effective microorganisms - The past, present and future*. http://www.infrc.or.jp/english/KNF_Data_Base_Web/7th_Conf_KP_2.html

Hitman, A., Bos, K., Bosch, M., & Kolk, A. (2013). *Fermentation versus composting* (pp. 25). Wageningen, Netherlands: Feed Innovation servises BV. Retrieved from http://www.infrc.or.jp/english/KNF_Data_Base_Web/7th_Conf_KP_2.html

Konappa, N.M., Maria, M., Uzma, F., Krishnamurthy, S., Nayaka, S.C., Niranjana, S.R., & Chowdappa, S. (2016). Lactic acid bacteria mediated induction of defense enzymes to enhance the resistance in tomato against Ralstonia solanacearum causing bacterial wilt. *Scientia Horticulturae*, *207*, 183–192. doi:10.1016/j.scienta.2016.05.029

Kyan, T., Shintani, M., Kanda, S., Sakurai, M., Ohashi, H., Fujisawa, A., & Pongdit, S. (1999). *Kyusei nature farming and the technology of effective microorganisms* (pp. 44). Bankok, TH: Interncional Nature Farming Research Center, Atami, Japan and Asia Pacific Natural Agriculture Network.

Lentendu, G., Wubet, T., Chatzinotas, A., Wilhelm, C., Buscot, F., & Schlegel, M. (2014). Effects of long-term differential fertilization on eukaryotic microbial communities in an arable soil: A multiple barcoding approach. *Molecular Ecology*, *23*, 3341–3355. doi:10.1111/mec.12819

Mayer, J., Scheid, S., Widmer, F., Fließbach, A., & Oberholzer, H.R. (2010). How effective are 'Effective microorganisms®(EM)'? Results from a field study in temperate climate. *Applied Soil Ecology*, *46*, 230–239. doi:10.1016/j.apsoil.2010.08.007

Megali, L., Schlau, B., & Rasmann, S. (2015). Soil microbial inoculation increases corn yield and insect attack. *Agronomy for Sustainable Development*, *35*, 1511–1519. doi:10.1007/s13593-015-0323-0

Mohan, B. (2008). Evaluation of organic growth promoters on yield of dryland vegetable crops in India. *Journal of Organic Systems*, *3*, 23–36.

Ndona, R.K., Friedel, J.K., Spornberger, A., Rinnofner, T., & Jezik, K. (2011). 'Effective Micro-organisms'(EM): An effective plant strengthening agent for tomatoes in protected cultivation. *Biological Agriculture & Horticulture*, *27*, 189–203. doi:10.1080/01448765.2011.9756647

Nielsen, C., Rahman, A., Rehman, A.U., Walsh, M.K., & Miller, C.D. (2017). Food waste conversion to microbial polyhydroxyalkanoates. *Microbial Biotechnology*, *10*, 1338–1352. doi:10.1111/1751-7915.12776

Nielsen, E. (2010). Reduction of heavy metals in sludge by EM treatment. *Journal of EM Research Organization Denmark*, 78–79. http://www.infrc.or.jp/knf/PDF%20KNF%20Conf%20Data/C6-7-245.pdf

Okorski, A., Olszewski, J., Pszczółkowska, A., & Kulik, T. (2008). Effect of fungal infection and the application of the biological agent EM 1TM on the rate of photosynthesis and transpiration in pea (Pisum sativum L.) leaves. *Polish Journal of Natural Sciences*, *23*, 35–47. doi:10.2478/v10020-008-0003-5

Olle, M. (2015). *Effective microorganisms influences vegetables and soybeans production* (pp. 117). Germany: LAP LAMBERT Academic Publishing.

Olle, M. (2016a). *Köögivilja istikute kasv paraneb kasutades efektiivseid mikroorganisme. Marko Kass (Toim.). Konverentsi "Terve loom ja tervislik toit 2016" artiklite kogumik* (pp. 107–112). Tartu, Estonia: Ecoprint.

Olle, M. (2016b). *Organic cultivation of vegetables and potatoes* (pp. 132). USA: CreateSpace Independent Publishing Platform.

Olle, M. (2019). *Advances in tomato cultivation* (pp. 103). USA: Amazon Media EU S.à r.l.

Olle, M., & Williams, I.H. (2013). Effective microorganisms and their influence on vegetable production – A review. *Journal of Horticultural Science & Biotechnology*, *88*, 380–386. doi:10.1080/14620316.2013.11512979

Östergren, K., Gustavsson, J., Bos-Brouwers, H., Timmermans, T., Hansen, O.J., Møller, H., … Easteal, S. (2014). *FUSIONS definitional framework for food waste (full report)*. Sweden: The Swedish Institute for Food and Biotechnology.

Papargyropoulou, E., Lozano, R., Steinberger, J.K., Wright, N., & Bin Ujang, Z. (2014). The food waste hierarchy as a framework for the management of food surplus and food waste. *Journal of Cleaner Production*, *76*, 106–115. doi:10.1016/j.jclepro.2014.04.020

Perez, R.H., Zendo, T., & Sonomoto, K. (2014). Novel bacteriocins from lactic acid bacteria (LAB): Various structures and applications. *Microbial Cell Factories*, *13*, S3–S3.15. doi:10.1186/1475-2859-13-S1-S3

Pineda, A., Zheng, S.J., Van Loon, J.J., Pieterse, C.M., & Dicke, M. (2010). Helping plants to deal with insects: The role of beneficial soil-borne microbes. *Trends in Plant Science*, *15*, 507–514. doi:10.1016/j.tplants.2010.05.007

Sangakkara, U.R. (2012). *Effect of EM on nitrogen and potassium levels in the rhizosphere of bush bean*. Retrieved from http://www.infrc.or.jp/english/KNF_Data_Base_Web/3rd_Conf_S_6_7.html

Steinkraus, K.H. (1992). Lactic acid fermentations. In: N.R.C.U. P.O.T.A.O.B.T.T.F. Foods (Ed.), *Applications of biotechnology to fermented foods: report of an Ad Hoc panel of the board on science and technology for international development* (pp. 5). Washington, DC: National Academies Press.

Stenmarck, A., Jensen, C., Quested, T., Moates, G., Buksti, M., Cseh, B., Juul, S., Parry, A., Politano, A., Redlingshofer, B. & Scherhaufer, S. (2016). *Estimates of European food waste levels* (pp. 80). IVL Swedish Environmental Research Institute. http://eu-fusions.org/phocadownload/Publications/Estimates%20of%20European%20food%20waste%20levels.pdf

Trias, R., Bañeras, L., Montesinos, E., & Badosa, E. (2008). Lactic acid bacteria from fresh fruit and vegetables as biocontrol agents of phytopathogenic bacteria and fungi. *International Microbiology*, *11*, 231.

Valarini, P.J., Alvarez, D., Gasco, J.M., Guerrero, F., & Tokeshi, H. (2003). Assessment of soil properties by organic matter and EM-microorganism incorporation. *Revista Brasileira de Ciência do Solo*, *27*, 519–525. doi:10.1590/S0100-06832003000300013

van de Voorde, T.F., van der Putten, W.H., & Bezemer, T.M. (2012). Soil inoculation method determines the strength of plant–soil interactions. *Soil Biology & Biochemistry*, *55*, 1–6. doi:10.1016/j.soilbio.2012.05.020

Weller, D.M., Raaijmakers, J.M., Gardener, B.B.M., & Thomashow, L.S. (2002). Microbial populations responsible for specific soil suppressiveness to plant pathogens. *Ann Rev Phytopahol*, *40*, 309–348. doi:10.1146/annurev.phyto.40.030402.110010

Xu, H.L., Wang, R., Mridha, M.A.U., & Umemura, U. (2012). *Phytophthora resistance of tomato plants grown with EM Bokashi*. Retrieved from http://www.futuretechtoday.net/em/index2.htm

Yakovleva, A., Klyvenok, M., & Vovk, O. (2012). Reduction of heavy metals content in wastewaters during treatment process. *Proceedings of the National Aviation University*, *2*, 104–106.