PEREIRA, G. L.; ARAÚJO, L. L.; WENNECK, G. S.; SAATH, R., GHUIDOTTI, G. C.; BERTOLO, R. P. Physicochemical characterization of fermented Bokashi compost produced on-farm in southern Brazil. **Revista de Agricultura Neotropical**, Cassilândia-MS, v. 9, n. 2, e6926, abr./jun. 2022. ISSN 2358-6303. DOI: https://doi.org/10.32404/rean.v9i2.6926.

Physicochemical characterization of fermented Bokashi compost produced on-farm in southern Brazil

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Received: 18/03/2022; Accepted: 10/06/2022.

ABSTRACT

Bokashi is fermented organic compost capable of improving the physical, chemical, and biological conditions of the soils. The compost action in the agricultural production system is influenced by its preparation, resulting in products with different physicochemical characteristics. The study aimed to characterize bokashi produced on-farm and compare it with commercial products. The produced composts in southern Brazil were obtained through efficient microorganisms (EM), collected in an area of permanent preservation, and kefir. Two commercial composts were used for comparison (Plantae FertTM and Bokashi Sementes BrasilTM). Physical characteristics related to apparent specific gravity, water content, and water retention capacity and chemical characteristics related to nutrient contents, pH, and electrical conductivity were analyzed. For the physical characteristics, the mean and standard deviation were determined. The data from chemical parameters were submitted to the analysis of variance, and the means were compared by the Tukey test with 5% significance. Bokashi produced on-farm and commercial Bokashi showed similar physical characteristics. Commercial bokashi composts showed higher contents of nutrients than the composts produced on-farm. The analyzed composts showed adequate physicochemical parameters, with no factors limiting their use in agriculture.

Keywords: Microorganisms, On-farm, Organic compost; Residues.

Caracterização físico-química do composto fermentado Bokashi produzido em propriedade rural no sul do Brasil

RESUMO

Bokashi é um composto orgânico fermentado capaz de melhorar as condições físicas, químicas e biológicas dos solos. A ação do composto no sistema de produção agrícola é influenciada pelo preparo, resultando em produtos com diferentes características físico-químicas. O objetivo do estudo foi caracterizar o Bokashi produzido em propriedade rural e comparar com produtos comerciais. Os compostos produzidos no sul do Brasil foram obtidos através de microrganismos eficientes (EM), coletados em área de preservação permanente, e kefir. Dois compostos comerciais foram utilizados para comparação (Plantae Fert® e Bokashi Sementes Brasil®). Foram analisadas características físicas relacionadas à massa específica aparente, teor de água e capacidade de retenção de água, características químicas relacionadas ao teor de nutrientes, pH e condutividade elétrica. Para as características físicas, foram determinados a média e o desvio padrão. Os parâmetros químicos foram submetidos à análise de variação e as médias comparadas pelo teste de Tukey com 5% de significância. O Bokashi produzido e comercial apresentaram características físicas semelhantes. Os compostos comerciais de Bokashi apresentaram características químicas superiores aos compostos produzidos na propriedade rural. Os compostos analisados apresentaram parâmetros físico-químicos adequados, não havendo fatores limitantes ao seu uso na agricultura.

Palavras-chave: Microrganismos, On-farm, Composto orgânico, Resíduos.

Under conditions of native forests, the high microorganism population in the soil provides nutrients to the plants through organic matter degradation, phosphate solubilization, and nitrogen fixation (Rondina et al., 2019). The increase in fertilizers prices stimulates the search for alternatives sources, which allow improvements in the chemistry, biology, and physics of the soil with the use of residues such as Bokashi compost (Viana et al., 2020), obtained from the action of microorganisms in the organic matter, simulating natural ecosystems (Lew et al., 2021).

The use of Bokashi promotes productive increment and causes benefits in the production system, increasing organic matter, fertility, and microorganisms (Khaeruni et al., 2020; Lasmini et al., 2018; Viana et al., 2020). Besides, many agriculture residues can be used as raw materials, which allows producers to produce from available materials (Abo-Sido et al., 2021).

Considering the varied combinations of microorganisms and the used raw materials, the standardization and quantification of Bokashi composts are complex. Different raw materials and preparation times originate products with different characteristics (Quiroz and Céspedes, 2019), being necessary studies about these combinations. The study aimed to characterize Bokashi produced on-farm and compare it with commercial products, considering physical and chemical parameters.

The study was developed using two fermented Bokashi compost produced on-farm and compared to two commercial products. For the fermentative process of the composts, the used microbial inoculants were kefir and efficient microorganisms (EM). The EM were collected within a permanent preservation area (PPA) on-farm in the city of Ubiratã (24°32’10" S, 52°58’50" W, and 550 m of altitude), in southern Brazil. The EM and kefir underwent an activation process before utilizing them as inoculates of Bokashi. The preparation procedures were conducted as described by Siqueira and Siqueria (2013).

Organic brown sugar in the concentration of 10% (m/v) in mineral water was used for the kefir grains multiplications. For each 350 mL of culture medium, 35 g of kefir grains were transferred. The culture mediums were kept in a transparent glass bottle at an ambient temperature. The fermented supernatant was collected every three days, and the kefir grains were reinoculated in new bottles containing the same culture medium. When kefir grains reached a total of 10 g, it was placed in a corked bottle for seven days to occur its activation and fermentation for posterior inoculation. In this context, after seven days of activation, the following proportion was used: 100 kg of produced Bokashi and 2 L of filtrated Bokashi solution (without the grains).

For the collection of EM, a moist place on-farm was chosen. Posteriorly, 150 g of rice were cooked and placed in a bamboo stem segment buried in the selected place. The rice served as a substrate for local EM to colonize and multiply. After 10 days, the bamboo stem segment was removed, and the beneficial microorganisms were selected (EM), discarding the gray and dark-colored microorganisms.

As in the kefir grains, activation was also conducted in the EM by dissolving the previously separated concentrated EM in water and brown sugar, using 80% mineral water, 10% inoculum, and 10% brown sugar. Then, these suspensions were kept in corked plastic bottles (polyethylene terephthalate) for seven days for activation and until their use in inoculation in organic composts. From the acquisition of agro-industrial residues, the manufacture of fermented organic composts (Bokashi) on-farm was performed. The proportions of 55% wheat bran, 40% soybean meal, 3% bone meal, and 2% dolomitic limestone were used. The pairs of organic residues, dried and ground, were mixed proportionately. Then, the composts were inoculated with one of the activated suspensions (EM or *kefir*).

For both treatments, 300 mL of solution were added for each 10 kg of compost. After homogenization, the mixed product was heaped and revolved every two days to ferment. This fermentation process lasted for 10 days. Posteriorly, the organic compost was spread out and dried under ambient temperature for four days. According to package information, the commercial product Plantae Fert^{TM} comprises fish meal, rice and wheat bran, molasses, bone meal, neem pie, coal dust, and marine seaweeds.

The commercial product Bokashi Sementes Brasil^{TM} has in its composition meat and blood meal, wheat bran, bone meal, fish meal, soybean meal, rice bran, borax, castor bean, brown sugar, and *Rhizobium japonicum*, according to the manufacturer. The different products were characterized by analyzing the apparent specific gravity, water content, and water retention capacity. The apparent specific gravity was measured using a cylinder with a 1 dm^{-3}. The cylinder was inserted carefully into the composts to not compacted the material. The cylinder was removed, and the excess mass discarded. The mass of the cylinder content was determined in analytical balance (±0,001g), and the result was expressed in kg m^{-3}.

To determine the water retention capacity, 500 g of dried compost was used. The compost was submerged in water for 24 hours, removed, and kept under ambient conditions for excess water drainage. After 24 hours of drainage, the wet mass of the product was determined. The water retention capacity determination was performed considering the amount of water removed in the wet mass concerning the dry mass of the compost (g of water kg^{-1} Bokashi). To determine the water content, samples of fresh material were previously weighed and dried in a forced-air circulation oven at 105 °C for 24 hours. After, the dry mass of the product was determined, and the water content was calculated. The pH and electrical conductivity were evaluated using 5 g of compost, diluted in 50 mL of deionized water. The solution was shaken on an agitation plate (model TE-1400) for 30 minutes with 1-hour rest, repeated for five cycles. After the shake, the reading was performed with a pH meter (model PA 200) and benchtop conductivity meter (LUCADEMA, model LUCA-150).

The nitrogen (N) content was determined by the Kjeldahl method. Phosphorus (P) and sulfur (S) content were determined by UV-Vis spectrophotometry in a sample digested by nitro-perchloric solution. The calcium (Ca), potassium (K), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) were determined by atomic absorption spectrometry in a sample digested by nitro-perchloride solution, and the boron content (B) by UV-Vis spectrophotometry in an incinerated sample with extraction using hydrochloric acid (Silva, 2009).

The mean and standard deviation of the data from the physical characterization of the composts (apparent specific gravity, water content, and water retention capacity) were estimated. The data from the chemical characterization were submitted to the analysis of variance, and the means were compared by the Tukey test with $p<0.05$ of significance. For data analysis, Microsoft Excell® and SISVAR software were used (Ferreira, 2019). For the physical parameters analyzed (Table 1), the values obtained in the Bokashi composts were similar and close. Due to the physical characteristics, the utilization of composts can promote improved soil structure and increased water retention capacity and infiltration (Lasmini et al., 2018).

EM Bokashi presented the lower apparent specific gravity, indicating greater total porosity than other types of Bokashi. Although this condition may favor the presence of macropores in the soil, according to Šrank and Šimanský (2020), significant changes in soil physical properties by applying organic compounds and substrates occurred due to the interaction such as soil characteristics and product quality.

Although the particle size and the proportion of macro and micropores was not analyzed in the study, characteristics related to product size directly impact water retention and infiltration capacity (Werdin et al., 2021). Therefore, it is believed that on-farm Bokashi production (EM and kefir) results in a large amount of micropores that justify the highest water retention capacity (Table 1). The water content of the product is related to the form and interaction with the storage environment.

According to Quiroz and Céspedes (2019), the characteristics of Bokashi compost are related to the raw materials used in the preparation, with direct reflection mainly on the availability of nutrients. Thus, variations were expected mainly between the production of Bokashi on-farm and commercial composts. However, variations between the Bokashi composts produced on-farm were also obtained (Table 2). Since Bokashi composts of EM and kefir present similar raw materials for preparation, the chemical changes are directly related to microorganisms and the fermentation process.

Comparing the products produced on-farm, EM Bokashi compost had superior levels of P, S, Mn, and Zn; kefir Bokashi compost presented a higher content of Ca. There was no difference in the other variables (Table 2). It is worth noting that the P content in Bokashi produced with EM was approximately eleven times higher than that of kefir. This result differs from Trindade et (2020), which, producing Bokashi with the same raw materials, obtained higher P contents of Bokashi produced with Kefir than with EM. However, Abo-Sido et al. (2021), when they produced Bokashi, in different periods and with different microorganisms, from the same ingredients, obtained similar levels of PO_4^{3}.

Table 1. Characterization of fermented Bokashi composts based on apparent specific gravity, water content, and water retention capacity.

Bokashi	Apparent specific gravity (kg m^{-3})	Water content (%)	Water retention capacity (g g^{-}
EM	346.01±12.1	10.19±0.03	2.18±0.08
Kefir	408.54±7.3	9.69±0.02	2.06±0.05
Plantae Fert™	417.58±11.7	11.33±0.03	1.94±0.03
Sementes Brasil™	419.54±5.6	16.23±0.03	2.02±0.03

Table 2. Chemical characterization of Bokashi composts

Parameter	Unity	Kefir	EM	Plantae Fert™	Sementes	CV (%)
N	kg t^{-1}	41.53 c	46.37 bc	69.87 a	49.79 b	5.60
P	kg t^{-1}	1.39 d	16.08 b	9.13 c	25.14 a	10.92
K	kg t^{-1}	21.52 a	19.75 ab	17.37 b	12.12 c	8.42
Ca	kg t^{-1}	25.67 b	18.20 c	21.47 bc	36.35 a	10.11
Mg	kg t^{-1}	10.79 a	10.24 a	9.12 ab	7.73 b	7.09
S	kg t^{-1}	1.82 c	2.32 b	1.73 c	5.10 a	9.88
Fe	g t^{-1}	435.90 c	516.15 c	619.20 a	584.85 b	11.37
Cu	g t^{-1}	21.75 a	20.39 a	7.00 c	14.05 b	23.18
Mn	g t^{-1}	177.91 c	209.53 b	416.07 a	284.74 b	13.89
Zn	g t^{-1}	48.01 b	62.57 a	39.21 c	60.58 a	9.88
B	g t^{-1}	17.51 c	20.07 c	32.56 b	160.77 a	34.68
pH	-	5.73 b	5.78 b	6.96 a	7.06 a	4.87
EC	µS mL^{-1}	123.94 a	123.82 a	61.05 b	54.64 b	20.36

* Different letters in the column indicate significant difference by the Tukey test ($p<0.05$).

In the present study, the differences in P contents, also obtained for other nutrients, may be associated with the capacity of nutrient solubilization by microorganisms present in the permanent preservation area. Paiter et al. (2019) describe that different microorganisms collected in the western region of Paraná presented differences in the efficiency of phosphate solubilization. This fact may evidence that the microbiological constitution between EM and Kefir would explain the difference in nutrient content. When comparing the Bokashi composts manufactured on-farm to the commercial products, there is superiority in the supply of nutrients from commercial products, being only the Cu the exception (Table 2).

Under natural conditions, the activity of microorganisms contributes to the biomass decomposition, nutrients cycling, respiration, and soil structuring, sustaining the ecosystem (Rondina et al., 2019; Lew et al., 2021), so the utilization of fermented composts may act as a source of microorganisms benefiting the production of the agricultural system. According to Bononi et al. (2020), the utilization of microorganisms allows an increment of up 41% in the growth rate and 141% in the efficiency of phosphorus absorption by soybean. Considering the diversity of the microorganisms that the compost may contain, its use in agricultural management in tropical and subtropical regions can improve biological aspects of soil because, in agricultural succession systems, microbial biomass indexes are reduced, which compromises system sustainability (Santos et al., 2018).

In the manufacture of fermented organic composts, evaluating parameters like pH and electric conductivity (EC) is essential since they present the potential to cause phytotoxicity (Siles-Castellano et al., 2020). In this study, the manufactured composts showed lower pH and higher electric conductivity concerning commercial products; however, the values obtained are lower than the limits established for organic composts (Jain et al., 2019). The presence of phytotoxicity is related to the raw material used and the fermentation process of the product, where the final product may present chemical immaturity and fault of biological stability (Quiroz and Flores, 2019), requiring technical criteria for production and utilization.

In the present study, the commercial composts of Bokashi showed similarities in the physical characteristics and advantages in chemical characteristics concerning the composts produced on-farm. However, the production context must also be observed, in which using existent residues on the farm can increase production efficiency and reduce costs. Commercial Bokashi and Bokashi produced on-farm showed similar physical characteristics. Commercial Bokashi composts showed higher contents of nutrients than Bokashi composts produced on-farm. The analyzed composts showed adequate physiochemical parameters, existing no factors that limit their use in agriculture

Authors' Contribution

Gustavo Lopes Pereira contributed to the data collection, writing, and revision. Larissa Leite de Araujo contributed to the data collection and writing. Gustavo Soares Wenneck contributed to the experiment setup, statistical analysis, and revision. Reni Saath contributed to the experiment setup and technical supervision. Gabriela Cristina Ghuidotti contributed to the data collection and revision. Raissa Presotto Bertolo contributed to revision.

Acknowledgments

To the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

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