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Use of Two Types of Bokashi and their Effect on Tomato Fruit Quality Variables

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Abstract

Soil is the support and reservoir of nutrients. Excessive use of chemical fertilisers has led to its degradation, so modern agriculture has turned towards the incorporation of organic fertilisers. Organic fertiliser known as bokashi incorporates organic matter and nutrients into the soil. Hence, it has been reported that organic fertilisation effectively promotes plant growth and reproduction and can increase fruit quality. The aim of this study has been to apply two types of bokashi during tomato crop growth and to evaluate their effect on fruit quality variables. Initially, fertilisers were made and then applied to the soil. The applied treatments consisted of: T1: Bokashi added with bovine blood; T2: traditional Bokashi and T3: Control. Saladette tomato seedlings were transplanted, and thirty fruits were collected at random at harvest time; the following variables were measured: weight, polar diameter (PD), equatorial diameter (ED), percentage weight loss (%WL), °Brix, pH, titratable acidity, firmness and color. Results show better firmness and lower titratable acidity (TA) at T1; no significant differences were observed between treatments in the pH and °Brix variables; the highest color index (CI) was obtained with the T1 treatment, and no differences were observed in weight loss between treatments during the first five days of storage. Finally, it is concluded that the addition of bokashi promotes bigger fruits, does not influence the weight loss variable during the first five days of storage and does not negatively affect the quality of the fruit.

Keywords: °Brix, firmness, Organic fertilizar, Postharvest, Weight loss.

1. Introduction

Soil is made up of living organisms, organic matter, water, air and minerals. It is the support and reservoir of nutrients and water that sustain plants, making it indispensable for the maintenance of biodiversity worldwide (Montaño *et al.* 2018). Since the excessive use of chemical fertilisers has led to soil degradation, modern agriculture has incorporated the use of organic fertilisers to increase crop growth and yields, as well as crop quality (Luna *et al.* 2016). In particular, the bokashi, a fermented organic fertiliser that incorporates into the soil organic matter and essential nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese, zinc, copper and boron; all of which improve the physical and chemical conditions of the soil (Ramírez-Builes & Naidu, 2010) and have the function of stimulating microbial growth and plant nutrition (Cotrina-Cabello *et al.* 2020).

On the other hand, the tomato (*Solanum lycopersicum* L.) is the most consumed vegetable in the world, its demand is continuously increasing and with it also its cultivation, production and trade (Florido & Álvarez, 2015; Allende *et al.* 2017). In this sense, there are problems that can occur once the fruit has been harvested, such as loss of weight, decrease in quality due to mechanical damage and reduction of nutritional elements. Tomato losses could be as high as 50% from global production (Addo *et al.* 2015; Pila *et al.* 2010). Moreover, during ripening, color changes occur in the fruit that have been related to the production of lycopene, an antioxidant that together (Mortensen & Skibsted, 1997) with β - carotene contribute significantly to the pigmentation of tomato fruit, as they are responsible for the deep red and orange colors of the pericarp tissue, respectively (Tijsken & Evelo, 1994).

In addition, fertilisation has been shown to be an essential growth factor influencing tomato yield and fruit quality (Wang & Xing, 2017). In this sense, organic fertilisation effectively promotes plant growth and reproduction by improving their quality (Ye *et al.*, 2022), it can increase fruit quality (size, shape, color, brightness, firmness, freedom from defects and decay), fruit quality (pH, total soluble solids and acidity) and antioxidant capacity (Aguiñaga-Bravo *et al.* 2020; Ciro, 2005; Knee, 2008).

Therefore, the aim of this study was to apply two types of bokashi (traditional and bovine blood-added) during crop growth and to evaluate their effect on tomato fruit quality variables.

2. Methodology

2.1. Preparation of Traditional Bokashi and Bokashi Added with Bovine Blood

The following inputs were used to make traditional bokashi: 3 sacks of stubble, 1 sack of ash, manure, 1 sack of wheat bran, 2 kg of lime, 2 L of molasses and water. All the dry inputs were mixed, and molasses were dissolved in water and then added to the mixture until a moisture content of approximately 40-50% was obtained. The percentage of moisture was verified by performing the first test. Finally, bokashi was removed over a period of 15 days to control temperature and for the incorporation of oxygen. In the case of the bokashi added with bovine blood, the above-mentioned procedure was also followed, but bovine blood was added to the mixture. For the addition of blood, this was dissolved in water and then added after applying the molasses dissolved in water.

2.2. Treatment Application

The soil was prepared where the treatments T1: Bokashi added with bovine blood; T2: Traditional Bokashi and T3: Control were applied. Bokashi was added to the soil at a rate of 3 kg/m^2. Once the soil was prepared, the transplanting of the tomato seedling variety saladette, Galilea genotype, was carried out.

2.3. Determination Of Fruit Quality Variables

Thirty healthy and disease-free fruits of uniform color were harvested for each of the treatments and the variables of weight, polar diameter (PD) and equatorial diameter (ED) were measured using a Rhino scale and a digital vernier. Subsequently, the fruits were taken to a laboratory and were hydro-cooled. Once the fruits were dried, the following variables were determined: brix degrees (by using a SPECTRONIC 334610 digital refractometer), pH (using a HANNA HI98127 potentiometer) and firmness (using a GY-1 fruit penetrometer). Titratable acidity was obtained according to AOAC (2000) procedure. Weight loss was evaluated for a period of seven days and in the following is presented as % weight loss. Fruit color was measured using a Minolta CR-400 colorimeter. Equation 1 was used to determine the color index in the fruit.

$$CI = \frac{2000a*}{B*\sqrt{(a*^2)+(b*^2)}} \quad (1)$$

where:
CI= Color index
*B** = Brightness
*a** = Red/green coordinate (+a indicates red, -a indicates green)
*b** = Yellow/blue coordinate (+b indicates yellow, -b indicates blue)

2.4. Data Analysis

For data analysis, a non-parametric Kruskal-Wallis test and a Dunn's test were performed using the GraphPad Prism version 7 software.

3. Results and Discussions

3.1. Size and Weight of Fruits

Table 1 shows the values obtained for the variables of fruit weight, equatorial diameter and polar diameter, where it can be observed that the fruits with the highest weight were recorded in T1, whereas the fruits of T3 showed the lowest value. On the other hand, the fruits with the highest polar diameter were found in T2 while the lowest value was obtained in the fruits of T3. In the same way, the highest value of the equatorial diameter variable was observed in the fruits of T2 and the lowest in T3.

Table 1. Weight, equatorial diameter and polar diameter of tomato fruit with treatments of T1: bokashi added with bovine blood; T2: traditional bokashi and T3: control plants.

Treatment	Weight (g)	PD (cm)	ED (cm)
T1	166.62 ± 57.03 ^{c}	6.46 ± 1.53 ^{ab}	6.92 ± 1.01 ^{ab}
T2	154.30 ± 57.70 ^{b}	6.72 ± 1.31 ^{b}	6.95 ± 1.31 ^{b}
T3	143.34 ± 58.76 ^{a}	6.09 ± 1.66 ^{a}	6.25 ± 0.98 ^{a}

Values correspond to the mean ± the standard deviation.
Values with the same letters within the same column are statistically equal.

Rodríguez-Esquivel (2020) found no significant statistical differences in the variables of fruit weight, polar diameter and equatorial diameter when applying three different organic treatments (Vermicompost Tea, Humic Acids and Vermicompost Leachate), a chemical treatment (18-18-18; N - P_2O_5 - K_2O) and the control treatment. On the other hand, Salas-Pérez *et al.* (2018) observed that the control treatment showed the highest values in weight, polar diameter and equatorial diameter variables (84 g, 64 mm and 49 mm, respectively) in tomato fruits compared to the values obtained from organic fertilisation (different concentrations of bovine compost and river sand). These results differ from the results found in the present research, since significant differences were found in these variables. The results obtained agree with those reported by Reyes-Pérez *et al.* (2020), where the authors mention that in the variables of weight, polar diameter and equatorial diameter of the fruit, the treatment using 300 mg L^{-1}

of chitosan applied foliarly to tomato plants was superior (with values of 188.48 g, 7.38 cm and 5.18 cm, respectively) to the rest of the doses used and to the control.

Table 2 shows the values corresponding to the variables titratable acidity (TA, expressed as percentage of citric acid), °Brix, pH and firmness in kg/cm², observed in tomato fruits obtained under the different treatments applied to the soil, where it can be observed that the lowest TA value was found in treatment T1 (0.256 ± 0.05) and that this value was statistically different with respect to T3 (0.384 ± 0.05) ($P>0.0001$).

Table 2. Physicochemical characteristics of tomato fruits produced under treatments T1: bokashi added with bovine blood; T2: traditional bokashi and T3: control plants.

Treatment	TA (% citric acid)	° Brix	pH	Firmness (Kg/cm²)
T1	0.256 ± 0.05^{a}	3.79 ± 0.56^{a}	4.8 ± 0.11^{a}	2.30 ± 0.17^{a}
T2	0.328 ± 0.03^{ab}	3.70 ± 0.28^{a}	4.8 ± 0.09^{a}	1.63 ± 0.52^{ab}
T3	0.384 ± 0.05^{b}	3.73 ± 0.46^{a}	4.8 ± 0.08^{a}	1.37 ± 0.18^{b}

Values correspond to the mean ± the standard deviation.
Values with the same letters within the same column are statistically equal.

In this regard, Dinu et al. (2023) report titratable acidity values at harvest of 0.69 and 0.74 in Tiger F_1 and Sacher F_1 tomatoes, respectively, when applying organic fertilisation with grape pomace. The authors comment that this value decreases during the ripening process. The values obtained in the present study are below those reported by the authors, suggesting that the nature of organic fertilisation could influence the titratable acidity of the fruit. On the other hand, Romdhane *et al.* (2023) found no significant statistical differences in the variable titratable acidity in tomato fruit between manure fertilisation and the control when evaluating two varieties (OSTGL and Rio Grande). Although Bilalis *et al.* (2018) reported significant statistical differences between chemical fertilisation and organic fertilisation (seaweed compost) in 2016. The authors reported values of 0.33 ± 0.03 in the case of organic fertilisation and 0.27 ± 0.02 for inorganic fertilisation, these values being like those found in the present research. The authors mention that organic acids generally decrease during ripening because they are used as a substrate during fruit breathing (Aoun *et al.* 2013, Beckles, 2012 and Tigist *et al.* 2011). In this sense, it could be observed that in the present investigation a lower value was obtained with respect to that reported by the authors who used organic fertilisation, in such a way that it is reaffirmed that the type of organic fertiliser used influences the titratable acidity of the tomato fruit.

For the °Brix variable, no significant statistical differences were found between treatments ($P<0.0001$) suggesting that the addition of bovine blood to the bokashi does not influence this variable.

°Brix is a taste indicator because reducing sugars (glucose and fructose) are soluble in the main components of tomatoes. Fruits with a high °Brix concentration have a better taste, a higher processing yield and a better transportability and keeping quality during storage (Dinu *et al*, 2023). Moreover, Ilić *et al.* (2014) also mention that acidity tends to decrease with fruit ripeness meanwhile the °Brix increases.

Bilalis *et al.* (2018) found °Brix values for tomatoes grown with compost of 4.34± 00 and 4.43±0.05 in 2016, these values were higher than those obtained with inorganic fertilisation (4.22±0.03 and 4.27±0.02). Furthermore, Kai *et al.* (2020) report that in organic fertilisers such as commercial cow manure compost, the °Brix value was of 8.18 and of 7.69 when inorganic fertilisers were applied, being approximately 0.6% higher with organic fertilisers than with chemical fertilisers, but no significant difference was found. Gao *et al.* (2023) report that the °Brix content of tomatoes grown organically in greenhouses was higher (16.81%) than those grown in the field with alkaline soil (4.98%). In the present research, °Brix values of 3.79 ± 0.56 and 3.69 ± 0.28 were obtained when applying bokashi added with bovine blood and traditional bokashi, respectively. These values are lower than those reported in the previously mentioned papers. It is worth stating that the tomatoes were harvested at a light red stage of ripeness, suggesting that the type of fertiliser and the stage of ripeness at harvest are factors that influence the amount of °Brix present in the fruit.

For the pH variable, it can be observed that all treatments are statistically equal ($P< 0.0001$). In the three treatments, a pH of 4.8 was registered. The results obtained are in corcodance with those reported by Romdhane *et al.* (2023) since these authors found no significant statistical differences in the pH variable between the fertilisation with cattle manure and the control, showing an average value of 4.4. Murariu *et al.* (2021) mention that the average pH value of tomatoes using organic fertilisers is 4.41. In addition, Pradhan & Mupparapu (2022) found higher pH values (pH=4.78) in conventionally produced tomatoes than in organically produced tomatoes (pH=4.44). In the present research, higher values were obtained than those reported in the investigations, since an average value of pH=4.8 was obtained in all the treatments applied. Dinu *et al.* (2023) mentioned that the pH value is related to the concentration of organic acids in the fruit such as citric and malic acid. Tigist *et al.* (2013) comment that this value increases during the ripening of the fruit. In addition, this value depends on factors such as the cultivation method, the place where the crop is grown, the season of the year and the ripening stage (Akbudak, 2010).

Finally, for the firmness variable, it can be observed that the highest firmness value was obtained in those fruits that received the T1 treatment (2.30 ± 1.17 kg/cm²) meanwhile the lowest value was registered for T3 (1.37 ± 0.18 kg/cm²), being these values statistically different from each other ($P > 0.0001$).

Firmness is one of the most important quality attributes of tomato fruits for fresh consumption as well as for industrial cultivation, being related to post-harvest preservation. Romdhane *et al.* (2023) observed no statistically significant differences in the firmness variable when applying manure fertilisation to control fruit when evaluating two tomato varieties (OSTGL and Rio Grande). Alternatively, Bilalis *et al.* (2018) have reported higher tomato fruit firmness when applying inorganic fertilisers (4.58 and 4.63) with respect to organic fertilisation (4.30 and 4.48). Pradhan and Mupparapu (2022) have reported that using organic inputs yields firmer fruits in comparison to conventionally produced tomatoes. It is therefore suggested that the application of organic fertilisers contributes to a better fruit firmness.

3.2. Color in Tomato Fruits

The CIE L* a* b* color system represents the quantitative color relationship on three axes: the L* value indicates perceptual lightness and a* and b* are chromaticity coordinates. In the color space diagram, L* is represented on a vertical axis with values from 0 (black) to 100 (white). The a* value indicates the red-green component of a color, where positive and negative values indicate red and green values, respectively. Similarly, the yellow and blue components are represented on the b* axis as positive and negative values, as well (Bao *et al.* 2020).

Table 3 shows that the reddest fruits were obtained with T3, which obtained the highest values in the a* coordinate (26.15 ± 1.71) and in the CI variable (35.10 ± 2.60). On the other hand, the fruits with the lowest CI value are those of treatment T1 (32.99 ± 3.20) being this treatment statistically different in comparison with T3 (P >0.0001).

Table 3. CIE-L*a*b* color space of tomato fruit with treatments of T1: bokashi added with bovine blood; T2: traditional bokashi and T3: control plants.

Treatment	L*	a*	b*	IC
T1	40.00 ± 1.95 [a]	24.15 ± 2.28 [a]	27.55 ± 1.70 [a]	32.99 ± 3.20 [a]
T2	39.73 ± 2.66 [a]	24.59 ± 2.40 [a]	27.81 ± 1.72 [a]	33.48 ± 3.99 [ab]
T3	39.24 ± 1.65 [a]	26.15± 1.71 [b]	27.64 ± 2.07 [a]	35.10 ± 2.60 [b]

Values correspond to the mean ± the standard deviation.
Values with the same letters within the same column are statistically equal.

Bilalis *et al.* (2018) reported a value of 43.4 in the L* coordinate when applying seaweed compost, meanwhile the lowest value was recorded in the control treatment (L*= 42.2). The highest value obtained for the a* coordinate was 34.7 and was found in the seaweed compost organic treatment, so that the L* and a* values, comment the authors, were influenced by the application of fertilisers. These results differ from those found in the present study, where the opposite effect has been observed, since the highest value in the a* coordinate was obtained in the control, and no statistical differences were found in the L* values between treatments. Moreover, Carricondo-Martínez *et al.* (2022) have found a value of 26.93 for the CI in inorganic treatments and a value of 17.26 in vermicompost treatments. During the ripening of the fruit, the a* coordinate has initially shown negative values (green color), which progressively become positive (red color). The authors note that during tomato ripening, phytoene (colorless) is initially synthesized, followed by ζ-carotene (pale yellow), lycopene (red), β-carotene (orange) and xanthophylls and hydroxylated carotenoids (yellow); the synthesis of yellowish pigments precedes that of reddish pigments, but the massive accumulation of the latter masks the first ones. When the red pigments start to be synthesised, there is a decrease in the L* coordinate values indicating a darkening or decrease in brightness. Relationships a*/b* with negative values indicate the presence of green color (a* coordinate) whereas a tendency towards positive values implies a decrease of green color and an increase of yellow (b* coordinate) and red (a* coordinate) colors, which are characteristic of the progressive ripening of the fruits (Padrón *et al.* 2012; Shewfelt *et al.* 1988). According to the results, it can be suggested that the ripest fruits are those from treatment T3.

3.3. Weight Loss in Fruit

Figure 1 shows the values obtained for the weight loss variable in tomato fruit over seven days using different treatments applied to the soil, where it can be seen that in the first five days there are no significant statistical differences between the fruit of the different treatments, although on days six and seven there were significant statistical differences, resulting in T2 being the one with the greatest weight loss.

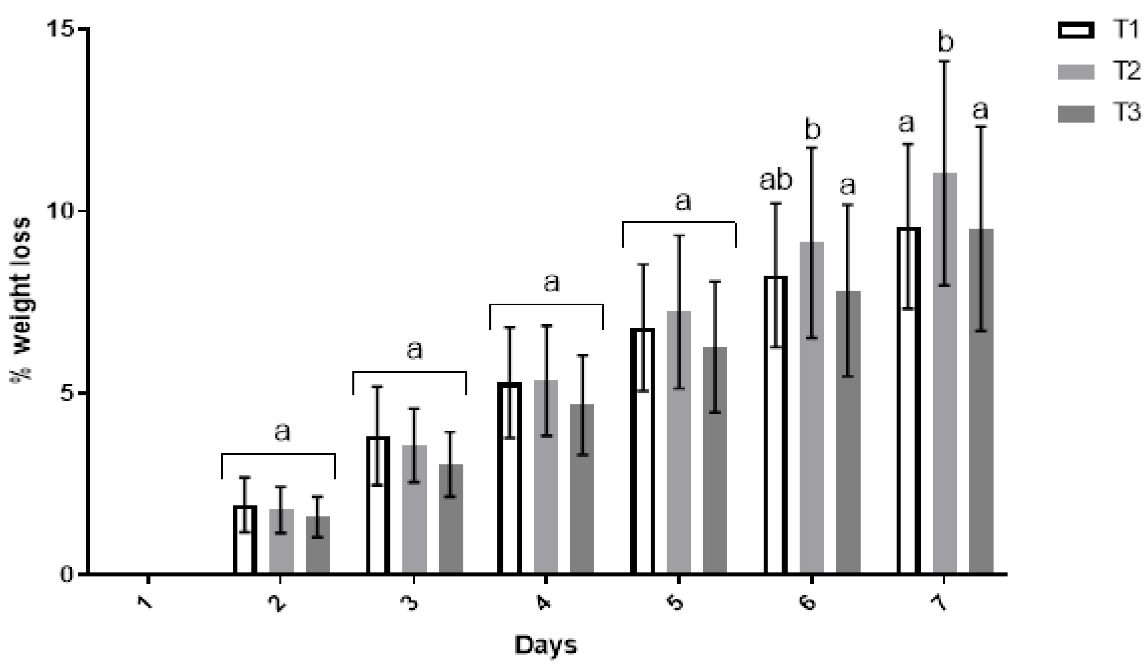

Figure 1. Tomato fruit weight loss with treatments T1: bokashi added with bovine blood; T2: traditional bokashi and T3: control plants.

Pradhan & Mupparapu (2022) found a greater weight loss in the first seven days in organically grown tomato fruit in comparison to conventionally raised fruit. On the other hand, Memon *et al.* (2020) mention that weight loss affects the quality of fruits and vegetables, which is mainly due to excessive moisture loss through metabolic activity such as breathing and transpiration processes. Wachiraya *et al.* (2006); Anchana *et al.* (2023), report additional causes such as vapour pressure deficit between their surface and the atmosphere in which the fruits are located, ethylene production, spoilage by micro-organisms, temperature, relative humidity, atmospheric air composition, storage time and light.

4. Conclusion

The addition of bokashi, either traditional or mixed with bovine blood, favours a bigger polar and equatorial diameter as well as a higher fruit weight, and its application in the crops does not influence on the weight loss variable during the first five days of storage at room temperature. It does not negatively affect the quality of the fruit and for bocashi added with bovine blood, it favours a better firmness of the fruit. Therefore, the addition of bokashi is an alternative to reduce the use of chemical fertilisers during production.

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