Post-harvest storage of ‘Paluma’ guavas produced by plants fertirrigated with nitrogen and biofertilizer

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Abstract

The association between mineral fertilizer and biofertilizers can contribute to guavas quality. An experiment was carried out in order to assess, over the days, ‘Paluma’ guavas physical-chemical quality in function of nitrogen fertilization and biofertilizer doses. It was adopted a randomized blocks with treatments distributed in a factorial 5 x 2 x 5 referring to evaluation days post-harvest (0, 3, 6, 9 and 12), nitrogen fertilization (50 and 100% culture recommendation) and application of bovine biofertilizer doses by fertigation (0.0, 2.5, 5.0, 7.5 and 10.0%). The physical-chemical quality of ‘Paluma’ guava fruit was influenced by the association between liquid bovine biofertilizer and nitrogen fertilization. This combination increased soluble solids, titratable acidity, ratio, vitamin C, pH, firmness and loss of fresh mass, but did not affect the pulp percentage. The bovine biofertilizer, together with mineral fertilization, is important to increase the post-harvest quality of ‘Paluma’ guava.

Keywords: irrigated fruticulture, organic fertilizers, Psidium guajava, physical and chemical properties, semiarid climate

Introduction

The irrigated poles in the Northeast of Brazil have water and edaphoclimatic conditions suitable for growing fruit trees, making this region one of the largest guava producers especially in the São Francisco Valley, which is responsible for almost 43% of the total Guava produced in Brazil (IBGE, 2017).

The productivity of high-quality fruits is a consequence of factors related to climatic conditions, soil, irrigation and nutritional balance (Santana et al., 2017). However, the nutritional affects not only the productivity, but also quality of the fruit in terms of size, weight and post-harvest conservation (D’Egidio et al., 2019).

To supply guava tree nutritional demand and reach high yields, high fertilizer applications are required (Natale, 2009). The combination between mineral and organic fertilizers can reduce production costs by as well as reducing environmental impacts by avoiding the phytotoxic effects of mineral fertilizers high doses that may unbalance the relationships between nutrients and salinize the soil (Sediyama et al., 2009). The biofertilizer can have an effect on vegetative and productive plants development, on the qualitative parameters of the production and still be able to reduce the depressive effects of the salinity of the soil or water (Dias et al., 2011).

Despite the promising results regarding biofertilizer use in agriculture (Dias et al., 2011; Santos et al., 2014; Nascimento et al., 2015; Santana et al., 2017), studies on the combination of nitrogen fertilizer and biofertilizer and the influence on the physical and chemical quality of guavas are still scarce in the literature, especially related to storage time. The aim of this work was to evaluate the quality of guava fruits produced as a function of nitrogen fertilization, biofertilizer fertirrigation and different storage days at room temperature.
Material and Methods

The study was carried out in April of 2016, on the experimental farm of Federal University of São Francisco Valley, Petrolina PE, Brazil. The climate of this region was classified as Bswh (Köeppen), which corresponds to a semi-arid region. In this study was used one-year-old guava (Psidium guajava) plants cv. Paluma with, spaced 4x4 meters, they were daily irrigated by micro-sprinkle and fertigated.

The biofertilizer consisted of water and fresh bovine manure under anaerobic fermentation, according to Santana et al. (2017) recommendations. It presented 0.72 g dm⁻³ of N, 0.04 g dm⁻³ of P, 0.50 g dm⁻³ of K, 0.20 g dm⁻³ of Ca, 0.12 g dm⁻³ of Mg and 0.39 g dm⁻³ of S in your composition. Biofertilizer was biweekly applied by fertirrigation water and ratio according to each treatment but firming the amount of 2.4 L m⁻² of plant canopy as proposed by Santana et al. (2017).

The experimental design was randomized blocks with treatments distributed in a factorial arrangement (5 x 2 x 5) referring to biofertilizer concentrations (0, 2.5, 5.0, 7.5 and 10% of the fertirrigated volume). The mineral fertilizing with N (fertilization with 50% and 100% of N recommended by Natale (2009)), was applied using as source a formulated fertilizer composed of 12% N, 5% P, 11% K, 13.1% Ca and 0.2% B, and evaluation times after harvest (0, 3, 6, 9 and 12 days after harvest at room temperature) with four replications of eight plants each. Guavas were harvested at stage 1 of maturation (Cavalini et al., 2015) and fifteen fruits was selected for each treatment. Storage ambient temperature was set in (24±1°C) and relative humidity around (70±5%), until reaching the end of the commercialization period, that according to Cavalini et al. (2015) is defined by completely yellow color of the bark, firmness of pulp less than 15 N and presence of rot in 15% of the fruit.

The fruit analyses followed the Instituto Adolfo Lutz (2008) instructions and included the parameters: i) weight loss, measured using a brand balance and expressed in g; and the fruits were weighed at 0, 3, 6, 9 and 12 days after harvest ii) fruit firmness (N), measured using a fruit hardness tester; iii) percentage of pulp with seed; iv) titratable acidity (TA) expressed in g of acid citric 100 g of pulp⁻¹, 5.0 ml of guava pulp was weighed and then diluted into distilled water to give a final volume of 50 ml. In this solution was added 2 drops of the phenolphthalein indicator and titrated with 0.1 N sodium hydroxide (NaOH); v) soluble solids (SS), expressed as °Brix; were measured using an Abbe® refractometer; vi) vitamin C followed iodimetric method and expressed in mg 100 g of fresh fruit⁻¹, which 5g of fruit pulp was taken from guava and brought to a final volume of 100 mL by adding distilled water plus 1mL of 1% amid solution. A 20 mL sample was taken from the mixture and titrated with 1N iodine; vii) pulp pH, measured using a Marconi® pH meter; viii) relation between the soluble solids and the titratable acidity (SS/TA ratio) was calculated. Results was submitted to variance analysis to evaluate the significant effect between days, nitrogen fertilization and biofertilizer doses by F test in the statistical program ASSISTAT 7.7 Beta. For quantitative treatments a multiple regression analysis was applied.

Results and Discussion

Soluble solids

Although interaction among treatments, only the double interaction has adjustment to regression models. The fruits produced without biofertilizer, under 100% N fertilization showed higher or the highest SS compared to 50% N fertilization (Table 1).

During post-harvest or along the post-harvest, the SS increased from 9.8 to 10.5 ° Brix (100% N) and 7.7 from 9.15 °Brix (50% N) (Figure 1). In this work, the values are higher than those reported by Alencar et al. (2016), who found values were 7.95 and 9.26 ° Brix, working at different times and doses of potassium, and close those found by Brackmann et al. (2012) with values ranging from 7.26 to 8.12 ° Brix, evaluating controlled atmosphere for guava storage, both working with ‘Paluma’ guavas. According to Santos et al. (2014), organic fertilization promotes higher levels of soluble solids, which have occurred in the present work. Furthermore, probably the 100% N dose presented higher values for the N effects in the leaves sugar biosynthesis, so that concentration of soluble solids may increase due to translocation of the sugar from leaves to the fruit (Ramos et al., 2010). Andy possibly, the increase in the absorption of N provided a rise in the absorption of K, since the most common interaction of N occurs with K, in which the increment of one favors the accumulation of the other (Foloni et al., 2013). This increase in the concentration of sugars in the fruit may have been due to the role that K plays in the apoplastic co-transport during the sucrose charge from the mesophile to the phloem, mediate by ATPase enzymes. The highest level of SS usually obtained in fruits
with the highest concentrations of K (Bouzo et al., 2018).

The nitrogen fertilization associated to biofertilizer doses produced, initially, fruits with lower SS. This may have occurred because the fruits were harvested at stage 1 of maturation, based on the dark green color of the peel, according to a scale proposed by Cavalini et al. (2015). According to the same author, ‘Paluma’ guava fruits tend to be more acid when harvested in the early stages of ripening. This resulted in a decrease in the SS in the initial fruits, and with the advance of the maturation process, the SS can be increased (Figure 1A and B). However, during the guavas storage there was °Brix increase, reaching close to and even higher values than those obtained without biofertilizer on 12th day of storage. It is important to note that 50% N fertilization + 10% Bio was the one that still showed growth in the °brix at the 12th day of storage, demonstrating that these fruits had not yet reached full maturation during the maximum storage period.

Table 1. Soluble solids (SS), titratable acidity (TA), ratio (SS/TA), vitamin C (Vit. C), pH, % of pulp with seed, firmness (Firm.) and loss of weight (LW) of ‘Paluma’ guavas as a function of storage days (DPH), nitrogen fertilization (N) and biofertilizer doses (Bio.).

| DPH (‘F’ value) | SS (°Brix) | TA | SS/TA | Vit. C | pH | Firm. | LW (%) |
|-----------------|------------|----|-------|--------|-----|-------|--------|
| Msd             | 6459.271 **| 2913.225 **| 4635.684 **| 263.482 **| 604.264** | 8.770 ** | 33.281 **|
| CV. % (DPH)     | 0.37       | 1.6 | 1.64  | 7.98   | 0.83 | 101.64 | 40.38  |
| N (‘F’ value)   | 19489.080 **| 49.829 **| 602.332 **| 7.234 **| 63.649** | 15.364 * | 13.64 * |
| 50%             | 9.186 b    | 0.654 b | 1.450.597 b | 79.940 a | 3.71547 a | 32.041 | 13.361 b |
| 100%            | 9.992 a    | 0.665 a | 1.533.612 a | 78.192 b | 3.644 b | 39.602 a | 15.190 a |
| Msd             | 0.0128     | 0.0036 | 0.07534 | 0.04748 | 0.0198 | 0.0309 | 0.04748 |
| CV. % (N)       | 0.37       | 1.52 | 1.39  | 5.03   | 1.48  | 46.62  | 17.95  |
| Bio (‘F’ value) | 2937.299 **| 103.511 **| 264.727 **| 6.4267 **| 11.852** | 1.695 ns | 18.457 **|
| 50% N            | 0.0208     | 0.00562 | 0.140 | 241.541 | 0.0264 | 14.4012 | 2.829  |
| CV. % (Bio)     | 0.28       | 1.37 | 1.30  | 4.24   | 1.07  | 55.75  | 24.44  |

Interaction (‘F’ value)

| Interaction (‘F’ value) | SS (°Brix) | TA | SS/TA | Vit. C | pH | Firm. | LW (%) |
|-------------------------|------------|----|-------|--------|-----|-------|--------|
| N x Bio                 | 11027.844 **| 136.979 **| 347.371 **| 7.217 **| 70.477** | 3.947 ** | 3.783 **|
| DPH x Bio               | 14128.284 **| 80.272 **| 202.167 **| 19.248 **| 6.920* | 0.649 ns | 0.172 **|
| DPH x N                 | 727.476 ** | 50.425 **| 115.715**| 6.942 **| 4.735* | 1.450 ns | 0.488 ns |
| DPH x N x Bio           | 2439.472 **| 25.063 **| 69.173 **| 16.048 **| 7.656** | 1.573 ns | 0.066 **|

** Significant at the 1% probability level (p <0.01); * Significant at the 5% probability level (p <0.05); ns: not significant (p> 0.05), by Tukey’s test. msd = minimum significant difference. CV. = coefficient of variance.

Figure 1. ‘Paluma’ guava soluble solids in function of post-harvest time, doses of biofertilizer and nitrogen fertilization 50 % (A) and 100% (B).

Titratable acidity

Fruits from fertigated plants with 100% N had average titratable acidity between 0.71 and 0.64 g citric acid 100 g of pulp (Figure 2B) and in the fertilization with 50% N, the values found was between 0.72 and 0.59 g citric acid 100 g of pulp (Figure 2A). The values are higher than those reported by Malta et al. (2013) that ranged between 0.41 and 0.53 g citric acid 100 g of pulp in ‘Paluma’ guava under organic and mineral fertilization. In general, fruits titratable acidity decreased over the post-harvest times (Figure 2A and B) in consequence of fruit maturation. This
behavior is expected because the reduction of organic acids presents in the fruits are result of fruits respiration (Andrade Júnior et al., 2016). In the fertilization with 100% N, there was increase in the TA directly proportional to the doses of biofertilizer (Figure 2B), which may be linked to biofertilizer chemical composition, because the organic acids present in biofertilizer can improve fruits titratable acidity (Santos et al., 2014). For treatments associated to 50% of N fertilization, it was verified more pronounced decrease of acid values when compared to those with 100% N fertilization (Figure 2). All the average values of TA found are higher than the minimum value required by current legislation in Brazil, which is 0.4% (MAPA, 2000).

**Figure 2.** ‘Paluma’ guava titratable acidity in function of post-harvest time, doses of biofertilizer and nitrogen fertilization 50 % (A) and 100% (B) and ratio post-harvest times, doses of biofertilizer and nitrogen fertilization 50 % (C) and 100% (D).

**Ratio (SS/TA)**

The fruits from plants grown under 100% N fertilization and biofertilizer presented superiority over 50% N fertilization (Table 1). Ratio average recorded for treatments with 50 and 100% N ranged from 13.12 to 16.23 and from 13.58 to 17.00, respectively (Figure 2C and D) and they are lower than those reported by Batista et al. (2015) that was 18.87 when evaluating guava fruits quality. For treatments with 50 and 100% of N fertilization there was a linear increase to the ratio. About biofertilizer rates, the highest ratio values were record to 10% concentration and on the twelfth day of evaluation, proving that there was an increase in the SS content and reduction of TA over the time. Any of the treatments applied provided the guava Ratio values close to the minimum required by the current Brazil legislation, which is 17.5 (MAPA, 2000).

**Vitamin C**

The highest value was found to 50% of N (Table 1), whose average ranged from 69.86 to 92.24 mg of ascorbic acid 100 mL of pulp\(^{-1}\) (Figure 3A), and for 100% N fertilization the values ranged between 67.9 and 86.36 mg of ascorbic acid 100 mL of pulp\(^{-1}\) (Figure 3B). The values are close to those found by Lima et al. (2008) who reported a value of 89.78 mg of ascorbic acid 100 mL of pulp\(^{-1}\), and Santana et al. (2017) whose values ranged from 70.08 to 79.88 mg of ascorbic acid.100 mL of pulp\(^{-1}\), both working with ‘Paluma’ guavas variety.

In general, vitamin C increased over the days reaching maximum mean values between the ninth and eleventh evaluation days. According to Machado et al. (2019) in the first maturation stage of guavas there is a tendency to increase the vitamin C content as the
maturation proceeds until it stabilizes and begins to decrease. Concerning the interaction among DPH \( \times \) N \( \times \) Bio with 100\% of N (Figure 3B), the best biofertilizer rate was 7.5\%, increase 2.55\% in relation to the control, but only in the twelfth day of evaluation. The association between 50\% of N and 7.5\% is responsible for the highest concentration of ascorbic acid on the ninth day of evaluation, increasing to 24.82\% ascorbic acid content in relation to the control. Application of bovine biofertilizer has a positive influence on the vitamin C (Nascimento et al., 2015), this probably happens due to organic acids and sugars that are present in organic sources and can increase the vitamin C content in the fruits.

**Figure 3.** ‘Paluma’ guavas Ascorbic acid depending to days post-harvest, nitrogen fertilization 50\% (A) and 100\% (B) and dose of biofertilizer; pH depending to days post-harvest, nitrogen fertilization 50\% (C) and 100\% (D) and dose of biofertilizer.

The treatment with 50\% N and biofertilizer presented higher pH values (Table 1). The averages recorded for 100\% and 50\% N with biofertilizer varied from 3.59 to 3.73 and from 3.62 to 3.84, respectively (Figure 3C and D). These values are close to those found by Amorim et al. (2015) which were between 3.72 and 3.88 but are lower than values reported by Batista et al. (2015) between 3.92 and 4.0 to the same variety.

The treatments with biofertilizer increased the fruits pH in relation to the control, however, it was verified oscillation in the pH values with the rise of the doses. Only the treatment with 100\% N and 10\% of biofertilizer provided the lowest values and pH variation from the first until the last day of evaluation. This behavior is connected to higher titratable acidity for the same biofertilizer dose, as seen previously, been these parameters inversely proportional (Amarante et al., 2013). Regardless of the treatment applied, all fruits presented pH values under limit value of Brazilian legislation, which is 4.2 (MAPA, 2000). The lowest values of pH indicate that the fruit has a higher content of organic acids and, hence, it will reflect in the fruit conservation, making it less susceptible to this consequently will deterioration in post-harvest (Amarante et al., 2013).

**Weight loss**

The mass losses were increasing over evaluation days (Figure 4A and B) and the fertilization with 100\% N promoted higher loss of fresh mass than 50\% of N (Table 1). The treatments with 50 and 100\% N associated to 7.5\% biofertilizer dose were that promoted the lower losses of...
fruit fresh mass in the ninth days of evaluation (9.97%) and
(13.73%), respectively. It is probable that the components
present in the biofertilizer contributed to a delay in the loss
of fresh guava as Calcium (0.20 mg dm$^{-3}$). The calcium
reduces the respiration rates, pectin degradation and
changes in fruit tissues (Bouzo et al., 2018). Although fresh
mass loss has been 20.10% (50% N) and (100% N) on the
twelfth day of storage, the values presented are close
than those reported by Onias et al. (2018) that was up to
25% in ‘Paluma’ guavas stored in ambient condition and
by Cavalini et al. (2015) in work on harvesting point and
quality of ’Kumagai’ and ’Paluma’.

Figure 5. ‘Paluma’ guavas firmness of pulp under nitrogen
fertilization and doses of biofertilizer

**Firmness of pulp**

It was observed superiority of the treatments with
100% N, whose values ranged from 43.69 (control) to 47.69
N (10% biofertilizer) (Figure 5). These values are lower than that found by Pérez-
Barraza et al. (2015), that ranging from 86.5 to 191.2 N for
‘Paluma’ guava. On the other hand, Batista et al. (2015)
found lower pulp firmness values, approximately 20 N
for mature guavas, maintained in the same condition
of this experiment. As can be seen in Figure 4, from the
5% biofertilizer dose and 100% of N there was increase
in firmness of the pulp, while at the rate of 50% of N it
was observed reverse effect. Nascimento et al. (2015)
in a study with biofertilizer and mineral fertilization in the
quality of passion fruit found the highest values of pulp
firmness in the treatments where mineral fertilization was
supplied with NPK and firmness tended to increase with
the growing biofertilizer dose.

The superior performance for the 100% N
treatment may have influenced by the presence of
high levels of potassium and calcium in the biofertilizer
used in this experiment (0.50 mg dm$^{-3}$ and 0.20 mg dm$^{-3}$
respectively). The potassium promotes, as result of the
translocation of sugars, increase in mass, flavor, and
aroma due to maintenance of cellular turgescence
and also contributes to the fruits resistance (Rogier et al.,
2017). In addition, calcium also has an influence on the
firmness because is part of the middle lamella cellular,
thus, reduction of water loss, leading to better fruit quality
and longer post-harvest storage period (Bouzo, et al.,
2018). These aspects may have favored increasing the
firmness of the pulp as the biofertilizer growing doses, with
a maximum value recorded for the 10% biofertilizer (47.69
N).

In addition to this, the ‘Paluma’ guava fruits
trated with fertilization of 50% and 100% and doses of
biofertilizer, presented better appearance compared
with control treatment (Figure 6A and B). It is observed
that until the ninth day of evaluation, the fruits still had
a healthy aspect, and although ripe, they in natura be
consumed especially those treated with the highest

Figure 4. ‘Paluma’ guavas loss of weight post-harvest times, doses of biofertilizer, nitrogen fertilization 50% (A) and 100% (B).
doses of biofertilizer. This could be an indicator that the combination of nitrogen fertilization and biofertilizer can favor the conservation of the fruits of ‘Paluma’ guava, even under storage conditions at room temperature.

Conclusions
The results of this research indicate that: i) the quality of ‘Paluma’ guava fruit stored under ambient temperature is influenced by the bovine biofertilizer and nitrogen fertilization; ii) the bovine biofertilizer increased the chemical parameters (soluble solids, titratable acidity, ratio, vitamin C and pH) and physical (firmness of pulp and decreases weight loss), of guavas; iii) In general, the 10% biofertilizer dose provides the best post-harvest, mainly when associated with 50% N fertilization. Furthermore, this combination reduces the synthetic fertilization; iv) the combination of biofertilizer and nitrogen fertilization conduced the guavas to nine days of shelf-life under environment condition.

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