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Cientific Paper

Physical-chemical characteristics and sensorial analysis of pineapple "vitória" fertigated with vinasse

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Abstract

The improvement of agronomics aspects by the wastewater use in crops is already well established. However, there are low consumer's acceptance from products that was cultivated with wastewater. The objective of this study was to evaluate the physical-chemical and sensorial characteristics in pineapple plant cultivated with wastewater (vinasse) from sugar cane at greenhouse conditions in Piracicaba, SP, Brazil. The treatments were divided in: T1 - 0 m^3 ha^{-1}; T2 - 231 m^3 ha^{-1}; T3 - 347 m^3 ha^{-1}; T4 - 462 m^3 ha^{-1}; and T5 - 578 m^3 ha^{-1} of vinasse level. The fresh fruit weight, pulp and bark hardness, pH, soluble solids (SS), titratable acidity (TA), and SS/TA ratio parameters, plus sensorial analysis, were determined to classify the fruits consumer's acceptance. A quadratic negative correlation was found between yield (fruit weight) and pulp hardness with vinasse levels. While SS had a linear correlation with vinasse level, TA had a quadratic correlation with the increment of vinasse level. For all vinasse level, it was observed a positive acceptance by the consumers with most of the scores from "like slightly" to "like very" much for the appearance, texture, odor, flavor and general impressions parameters, demonstrating that Vitória variety cultivated with vinasse has high potential into the Brazilian market.

Key words: wastewater, consumer acceptance, potassium requirement.

Resumo

Características físico-químicas e análise sensorial do abacaxi vitória fertigado com vinasse

A melhoria dos aspectos agronômicos com uso de efluentes agroindustriais são bem estabelecidos. No entanto, ainda existe uma baixa aceitação por produtos que foram produzidos com o uso de efluentes agroindustriais. O objetivo deste trabalho foi avaliar as características físico-químicas e a aceitação por parte dos consumidores do abacaxizeiro Vitória fertirrigado com diferentes níveis de vinhaça em casa de vegetação em Piracicaba, SP, Brasil. Foram aplicados os tratamentos com níveis de vinhaça: T1 - 0 m^3 ha^{-1}; T2 - 231 m^3 ha^{-1}; T3 - 347 m^3 ha^{-1}; T4 - 462 m^3 ha^{-1}; T5 - 578 m^3 ha^{-1}. 10 frutos foram colhidos por tratamentos para determinação de massa fresca, firmeza de casca e polpa, pH, sólidos solúveis (SS), ácido titulável total (ATT), e razão entre SS e ATT, além da análise sensorial para classificar a aceitação dos frutos pelos consumidores. Foi encontrado uma correlação quadrática negativa entre a produtividade (peso do fruto) e os diferentes níveis de vinhaça. Enquanto SS apresentou correlação linear, ATT apresentou uma correlação quadrática com o aumento dos níveis de vinhaça. Para todos os níveis de vinhaça, foi observado uma aceitação positiva pelos consumidores

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com a maioria das notas entre "gostei um pouco" e "gostei muito" para os parâmetros aparência, textura, cheiro, sabor e impressão geral, demonstrando que a variedade Vitória cultivada com vinhaça tem grande potencial no mercado Brasileiro.

Palavras chave: reuso de água; aceitação do consumidor; requerimento de potássio.

Resumen

Características fisicoquímicas y análisis sensorial de la piña Victoria en fertirriego con vinaza

La mejora de los aspectos agronómicos con el uso de efluentes agroindustriales están bien establecidos. Sin embargo, todavía existe una baja aceptación por productos que se produjeron con el uso de efluentes agroindustriales. El objetivo de este trabajo fue evaluar las características físico-químicas y la aceptación por parte de los consumidores del de la piña Victoria fertirrigado con diferentes niveles de vinaza en casa de vegetación en Piracicaba, SP, Brasil. Se aplicaron los tratamientos con niveles de vinaza: T1 - 0 m^3 ha^{-1}; T2 – 231 m^3 ha^{-1}; T3 - 347 m^3 ha^{-1}; T4 - 462 m^3 ha^{-1}; T5 - 578 m^3 ha^{-1}. 10 frutos fueran cosechados en cada tratamiento para la determinación de la masa fresca, firmeza de cáscara y pulpa, pH, sólidos solubles (SS), ácido titulable total (ATT), y razón entre SS y ATT, además del análisis sensorial para clasificar la aceptación de los frutos por los consumidores. Se encontró una correlación cuadrática negativa entre la productividad (peso del fruto) y los diferentes niveles de vinaza. Mientras SS presentó correlación lineal, ATT presentó una correlación cuadrática con el aumento de los niveles de vinaza. Para todos los niveles de vinaza, se observó una aceptación positiva por los consumidores con la mayoría de las notas entre "me gustó un poco" y "me gustó mucho" para los parámetros de apariencia, textura, olor, sabor e impresión general, demostrando que la variedad Victoria cultivada con vinaza tiene gran potencial en el mercado brasileño.

Palabras clave: reuso de agua, aceptación del consumidor, requerimiento de potasio.

Introduction

The world population is continuously increasing, which are demanding higher water consumption and, consequently, producing high amounts of wastewater. The low investment by the governments on wastewater treatment, collection, and destination are the main reason that watershed has been constantly polluted, mainly those that are resource for human consumption (BERTONCINI, 2008).

According to FAO (2011), irrigation is the most fresh water consumptive activity, representing around 70% worldwide use. Although only 28% of total area is cultivated under irrigation, it represents 45% of total food production (CHRISTOFIDIS, 2002), and, additionally, the improvement of irrigation technology that occurred in the past years foster a higher food production and a reduction of water and energy consumption. One example of these improvement is fertigation, which consists in a technic that provides nutrients to the plant by irrigation (by chemical fertilizing or by agro-industrial wastewater) that has been widely used in many crops. Fertigation has the advantage of reducing energy consumption and improve the plants nutrient availability.

Vinasse is a wastewater from sugarcane alcohol-based production that is widely used in fertigation due to its high amount of nutrient composition. Fertigation with vinasse can also improve the chemicals and physicals soil characteristics, as observed by many authors with different crops (QUEIROZ et al., 2004; BARROS et al., 2005; SANTOS et al., 2006). One of the main components presented in vinasse is potassium. This element is part of carbohydrate synthesis, degradation, translocation, protein synthesis, and organic acid neutralization. For sugarcane crop production, it can also increase the sugar concentration and improve the volume of photosynthate in the phloem (KUMAR and KUMAR, 2007).

Vinasse fertigation in pineapple may increase yield and fruit quality, reduce cost during crop production since it can replace conventional nutrient application, and can watershed pollution. However, still there are many miss concepts about fruit quality when produced with any wastewater, which reflects on low acceptance from consumers. For pineapple, consumers correlate fruit quality with color, pulp hardness, size, and general aspects. Also, the high fruit acidity is considered the main reason low acceptance (MIGUEL et al., 2007). Investigating the benefits of vinasse fertigation in pineapple on yield and fruit quality characteristics is extremely important since these questions have not been completely understood yet.

The pineapple varieties such as Smooth Cayenne, Pérola, Hawaii, and Gold are the main cultivated in Brazil and worldwide. The high amount of research with these varieties was essential to improve its acceptance by the consumers (BENGOZI et al., 2007). The variety Pérola is the most accepted by the internal Brazilian market (BERILLI et al., 2011). The variety Vitória, object of this study, was recently introduced at the Brazilian market and its acceptance is not well defined yet, especially when cultivated under vinasse fertigation.

The main characteristic of Vitória variety is the fusariosis resistance. Additionally, it has some similar characteristics to Pérola variety such as fruit weight around 1,550 g, crown about 130 g, fruit average diameter of 12 cm, central axis diameter of 1.2 cm, white pulp, 15.8 °Brix soluble solids, and titratable acidity of 0.8% (VENTURA et at., 2009). Evaluating general fruit quality, Berilli et al. (2014) conclude that the Vitória variety has high potential for the Brazilian marketing, due to fruit visual aspect, flavor, texture, and global impression, with some characteristics better than Pérola and Gold varieties.

The objective of this study was to determine the influence of different vinasse fertigation in pineapple Vitoria variety on the physical-chemical characteristics and the consumer's acceptance.

Material and Methods

The study was performed under greenhouse conditions at Piracicaba, SP, Brazil (22° 43′ 31″ S, 47° 38′ 57″ W and 547 m altitude), during pineapple growing season from early-March 2012 to late-August 2013 (18 months). It was used the Vitória pineapple variety, with seedlings transplanted to the greenhouse when they were with 25 cm height (late-May-2012). The seedling was cultivated at 40 cm interval from each other, and at 50 cm interval between treatments, with 16 plants per treatment plot (Fig. 1).

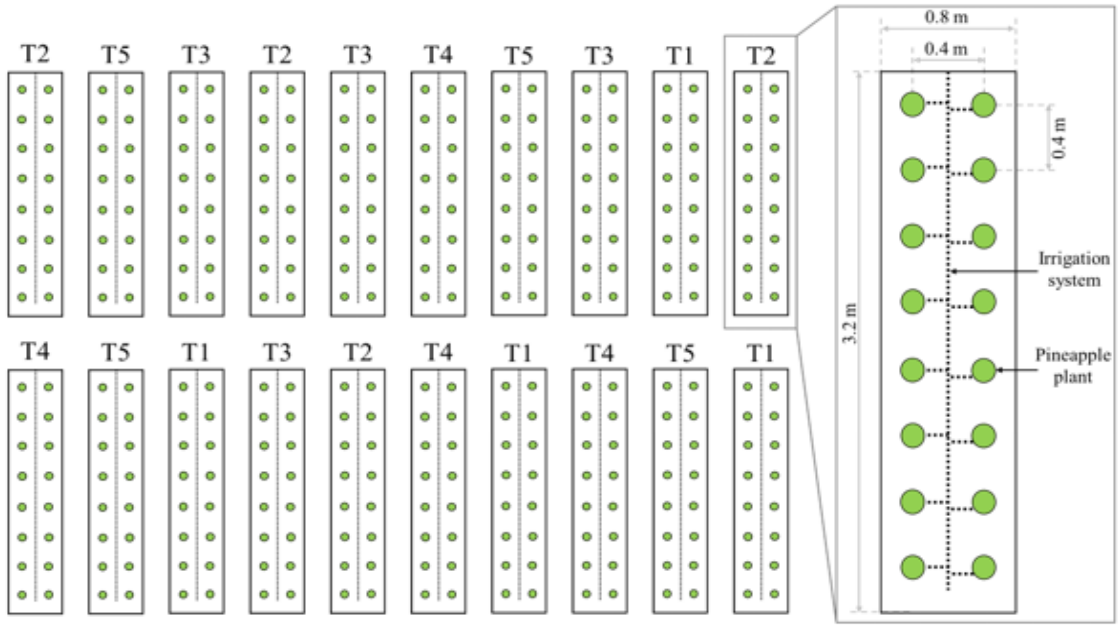

Figure 1. Experiment layout with treatments design.

Each treatments plot was previously constructed before experiment period. The soil was removed at 0.5 cm depth, and at 3.2 and 0.8 cm length and width, respectively. Before soil reconstruction, the trenches were isolated with a plastic film and filled with soil (Fig. 2A to C). The soil was classified as loamy sand, with 74.8% of sand, 17.1% of clay and 8.1% of silt with 1.49 g cm^{-3} soil density. Soil field capacity and permanent wilting point was 0.230 cm^3 cm^{-3} and 0.107 cm^3 cm^{-3}, respectively, resulting a water holding storage capacity of 73.3 mm at 0.4 m depth. After soil reconstruction, the pineapple was cultivated and irrigation system installed (Fig. 2D).

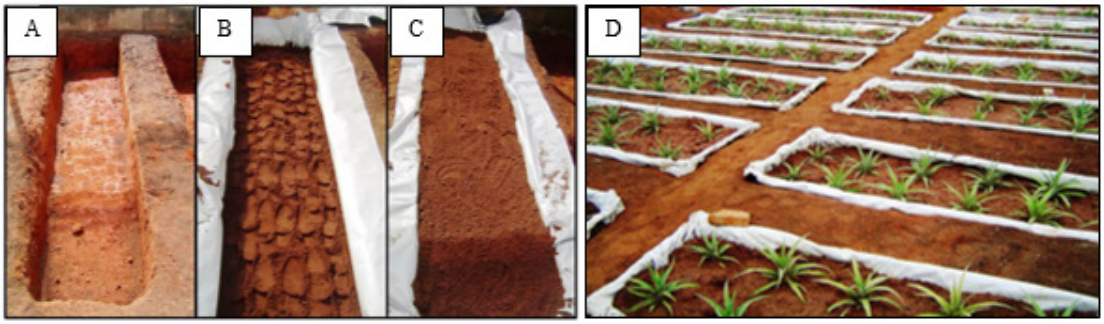

Figure 2. Soil excavation (A), reconstructed (B and C), and the experimental view of the treatments after seedling (D).

The experiment was composed by five treatments and four replications. The treatments (T) were classified according to the vinasse levels recommendation: T1 – 0 m^3 ha^{-1}; T2 – 231 m^3 ha^{-1}; T3 – 347 m^3 ha^{-1}; T4 – 462 m^3 ha^{-1}; T5 – 578 m^3 ha^{-1}. The standard CETESB P4.231 (CETESB, 2015) recommendations was used to calculate the vinasse volume, considering T1, T2, T3, T4, and T5 with 0, 50, 75, 100 and, 125% for potassium requirement in pineapple, respectively. As the objective was to evaluate only the vinasse levels, for T1, T2, and T3 it was provided additional chemical potassium to guarantee 100% of plant requirement. The vinasse was applied using a drip irrigation system with 4 L h^{-1} emitter flow with 40 cm spacing. The vinasse application was performed from seedling to the artificial floral induction in mid-February 2013 (9 months) every 20 days (14 applications total). In each application, it was applied 1/14 of the vinasse recommendation level for pineapple. The pineapple water requirement was determined according the results of soil water retention from tow tensiometers installed at 0.2 and 0.4 cm depth in each plot. According to the vinasse physical-chemical characteristics, it had god potassium level (Table 1). The vinasse composition was used to determine the potassium fertigation requirement for pineapple, as well was to adequate the plant requirement for other nutrients.

Table 1. Characterization of the vinasse used.

Chemical oxygen demand	Biological oxygen demand	Total solids	Electrical conductivity	pH	Nitrate	Potassium	Sodium
(mg L^{-1})	(mg L^{-1})	(mg L^{-1})	(mS cm^{-1})	-	(mg L^{-1})	(mg L^{-1})	(mg L^{-1})
36,845.7	6,683.7	33,434.5	7,110.00	4.08	124.0	3,568.5	49.0

The artificially flowering induction was performed in early-February 2013 and, six months later (in late-August 2013) plans were at harvest point. At this point, fruits were at the beginning of maturation process and presenting an increment of spacing between fruitlets. The analysis for each

treatment was performed by ten fruits per treatments that were manually harvested. Firstly, all fruits were weighted and, then, sent to Fruit and Vegetable Lab at the Food Science Department of ESALQ/USP to perform the chemical and sensorial analysis.

The chemical variable analyzed were: the pulp and bark hardness (using a penetrometer with 6 mm pointer with four readings per fruit at 90º, results in N cm^{-2}); pH (using a pH meter TECNAL model Tec-3MP and liquefied samples (CUNNIFF, 1995)); soluble solids (SS, using ATAGO optical refractometer model N1-0-32, results in °Brix (CHEMISTS, 1995)); titratable acidity (TA, by NaOH 0.1N titulation until 8.2 (pH at the changing color of indicator phenolphthalein), results in grams of citric acid per 100 g of pulp (g $(100\ g)^{-1}$) (CHEMISTS, 1995)) and; ratio between SS and TA.

The sensorial analysis was conducted by the seven points hedonic scale (CHAVES and SPROESSER, 1993) using fruit samples for each treatments. The evaluated attributes were appearance, odor, texture, flavor, and general impression, scaling from 1 to 7, where 1 was "dislike very much", 2 was "dislike moderately", 3 was "dislike slightly", 4 was "neither like nor dislike", 5 was "like slightly", 6 was "like moderately", and 7 was "like very much". Using individual cabins, every costumer had one pineapple fruit sample of each treatment to provide individual attribute numbers. Each sample had 70 g for each treatment, which was taken by 3 cm thick pieces form the top, bottom, and center part of the pineapple fruit.

The data results were previously evaluated to determine its normality and homoscedasticity using the Shapiro-Wilk ($P > 0.01$) and Levene ($P > 0.01$) statistical analysis. The variance analysis was evaluated by the quantitative effects in orthogonal polynomials with the F test results, choosing the model with highest significance. The variance and regression analysis were determined by the Statistical Analysis System 9.3 software. All sensorial analysis results were evaluated with frequency distribution by the consumer answer results.

Results and Discussion

The Shapiro-Wilk and Levene tests showed data normality and homoscedasticity, which was not necessary to apply data transformation. Different vinasse levels significantly affected (1%) the fresh fruit weight. The plotted results was best correlated by a quadratic polynomial equation, with decrease of fruit weight when vinasse level was increased (Fig. 3). Paula et al., (1999), studying the Smooth Cayenne variety, found a linear correlation between vinasse levels and fresh fruit weight at maximum of 1,353.6 g with 400 $m^3\ ha^{-1}$ of vinasse level, indicating that Vitoria variety fruit weight has an opposite characteristic when compared to Smooth Cayenne variety under vinasse fertigation.

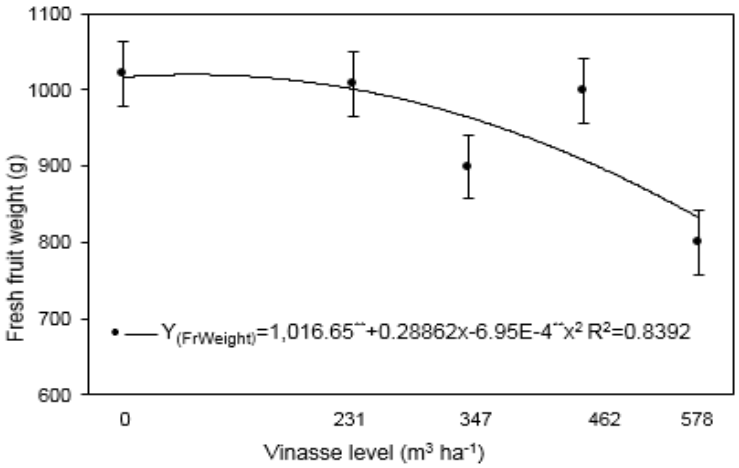

Figure 3. Scatter and correlation between vinasse levels and fresh fruit weight.

The minimum and maximum fruit weight was observed for T1 (760 g) and T5 (1,276 g), respectively. The results for all vinasse levels were within the standard fresh fruit weight (from 700 to 1,500 g) presented by Coelho and Cunha (1982), however, below the Brazilian market preference of 1,500 g per fresh fruit presented by Santana et al., (2001). It is important to mention that the plants were cultivated under greenhouse conditions, which might have reduced the plant development when compared to the conventional conditions. Studies with different vinasse levels for Vitória variety under conventional conditions is necessary to obtain reliable information about pineapple plant development and yield.

The correlation of the pulp hardness and vinasse levels were similar to fruit weight correlation (Fig. 4). Adding more vinasse promoted an increment of pulp hardness until T3 (75%) with a subsequent reduction pulp hardness for T4 and T5. The vinasse levels have affected this parameter significantly (1%) and presented a quadratic polynomial correlation with 32.6 (for T5) and 42.9 (for T3) N cm^{-2} of minimum and maximum, respectivel

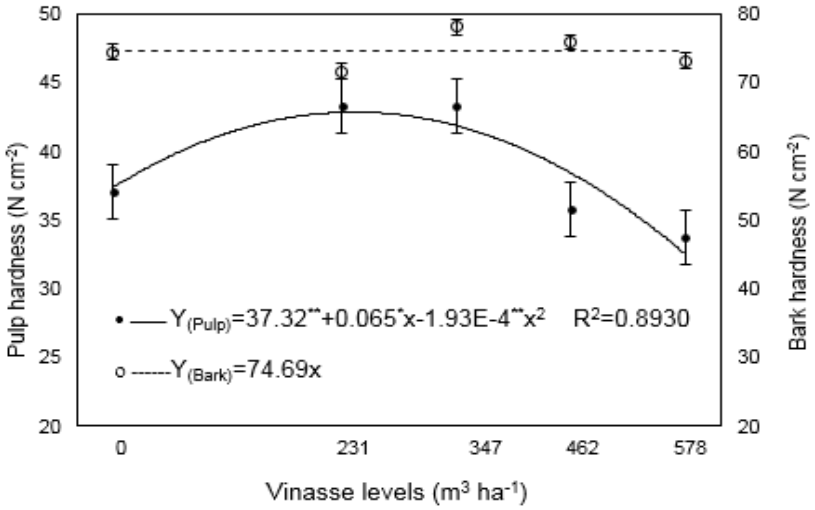

Figure 4. Scatter and correlation between vinasse levels and pulp and bark hardness.

The treatments that receive just vinasse as source of potassium presented negative correlation of the pulp hardness, i.e., the increment of vinasse levels have resulted at lower pulp hardness. Ramos et al. (2010) explain that cell turgor of pineapple is directly associated to potassium activity, which explains the reduction in the pulp hardness with the increment potassium.

It can be observed in Fig. 5 that the best correlation between vinasse levels and pH was represented by a quadratic polynomial equation, varying from 3.88 (T5) and 4.24 (T1). This parameter was significantly affected by the vinasse levels (1%). Potassium is related to organic acids neutralization in pineapple plants, in which pH values can be higher in the absence of this nutrient (TAIZ and ZEIGER, 2007). The pH values observed in this study were very similar to those by Bengozi et al. (2007), presenting pH values ranging for 3.37 to 4.13 for Smooth Cayenne variety, from 3.53 to 4.32 for and Pérola variety.

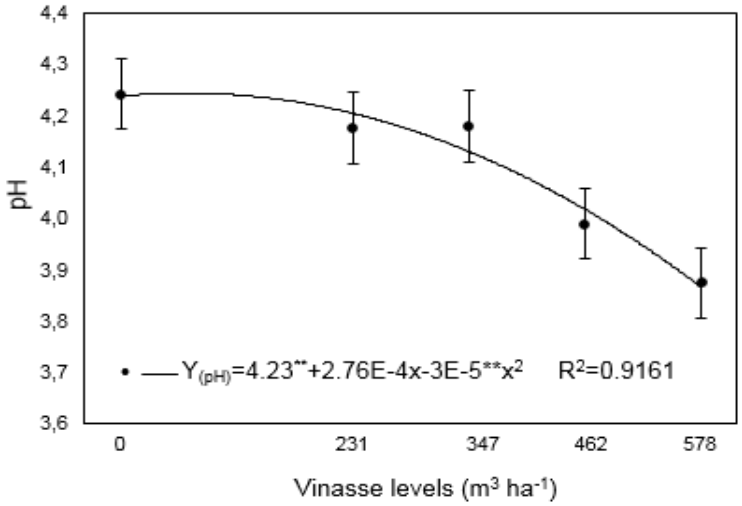

Figure 5. Scattergram and correlation equations between vinasse levels and pH.

SS and the TA were significantly affected (1%) by the vinasse levels (Fig. 6). Positive linear and quadratic polynomial correlation presented the best adjustment for SS and TA, respectively. The results ranged from 12.90 to 13.97 ºBrix for SS and from 0.71 to 0.91 g (100 g)$^{-1}$ for TA. The Brazilian Institute of Horticulture Quality (HORTIBRASIL, 2013) considers unripe pineapple fruit when SS is lower than 12 ºBrix. However, for the European market prefer fruits with at least 14 ºBrix (SOLER, 1992). SS results observed in this study with Vitória variety were in the range accepted by Brazilian market, but not the European market. Similar SS values were observed by other authors, with increment of SS when vinasse levels was increased (PAULA et al., 1999), lower percentage of SS in plants with potassium deficiency (PAULA et al., 1998), and negative and positive correlation between nitrogen and potassium, respectively, for SS in pineapple fruits (SPIRONELLO et al., 2004).

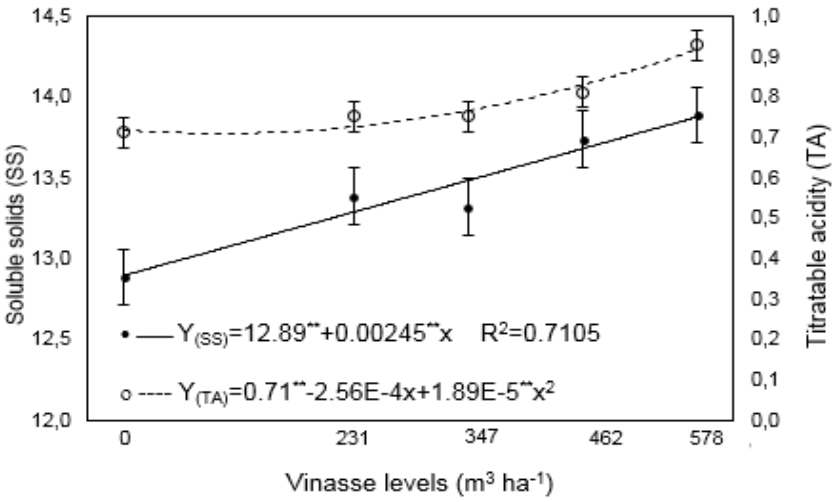

Figure 6. Scatter and correlation between vinasse levels and soluble solids and titratable acidity.

The increment of vinasse levels have resulted increment in the fruit TA. Similar results were found by Paula et al. (1999) that showed TA of 0.63 g (100 g)$^{-1}$ for 400 m^3 ha^{-1} of vinasse for Pérola variety. Souza et al. (1999) mention that the fruit acidity is related with plant nutrition, in which the potassium levels increase the fruit acidity. Reinhardt (1980) observed a positive correlation between TA and potassium level and negative between TA and nitrogen level. However, Veloso et al. (2001) have verified that TA decreased with potassium levels increment for both Smooth Cayenne and Pérola varieties. The values found in this study are higher than those found by Reinhardt and Medina (1992) and Costa (2009). However, it was observed in the literature a divergent results for TA levels: 0.35 g (100 g)$^{-1}$ (CUNHA et al., 2007) and from 0.38 to 0.59 g (100 g)$^{-1}$ (BENGOZI et al., 2007).

The ratio between SS and TA was best represented by a quadratic polynomial equation (Fig. 7) and it was statistically different at 1% level for different vinasse treatments. The minimum and maximum SS/TA was observer for T5 (15.1) and T1 (18.2), respectively. Authors have presented different values for this ratio: from 13.18 to 48.7 g (100 g)$^{-1}$ (MANICA, 2000), and 42.7, 30.8, and 30.6 g (100 g)$^{-1}$ respectively for Pérola, Jupi and Gold varieties (CUNHA et al., 2007).

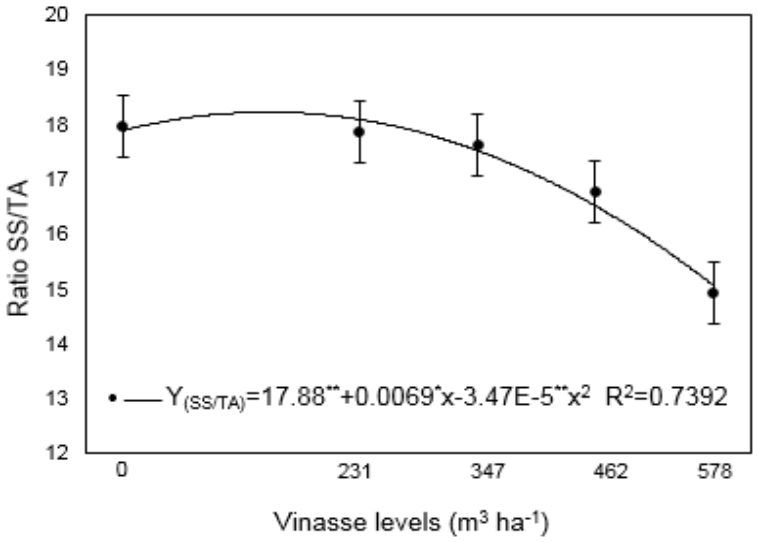

Figure 7. Scatter and correlation between vinasse levels and ratio SS/TA.

The international market and industry usually prefer SS/TA ratio around 12, but the Brazilian market requires higher ratio because of the preferences for sweeter fruits. SS/AT ratio is used to evaluate fruits flavor, representing the balance between sweet and acid ratio. However, Bartholomew et al. (2003) mention that fruits with 20 ^{o}Brix and 1 g (100 g)$^{-1}$ TA have the same ratio than a fruit with 10 ^{o}Brix and 0.5 g (100 g)$^{-1}$ TA, and the SS/TA ratio can also be function of variety, maturity, position of sample in the fruit, and development conditions. The values of SS/TA ratio presented by this author varied from 8 to 40 g (100 g)$^{-1}$.

The hedonic attributes analyzed did not preset statistically difference from the variance analysis results. Evaluating the consumer's answer frequency distribution (Fig. 8), it was observed higher concentration (from 60% to 85%, depending on the treatments) between "like slightly" to "like very much" for all five attributes. The most frequent answer to appearance attribute was "like moderately" for the treatment that receive only chemical fertilization (T1). Only two percent have answered "dislike very much" for the pineapple appearance for T1, T2, and T5. The odor for T2 was best evaluated, with 56% answers between "Like very much" and "Like moderately".

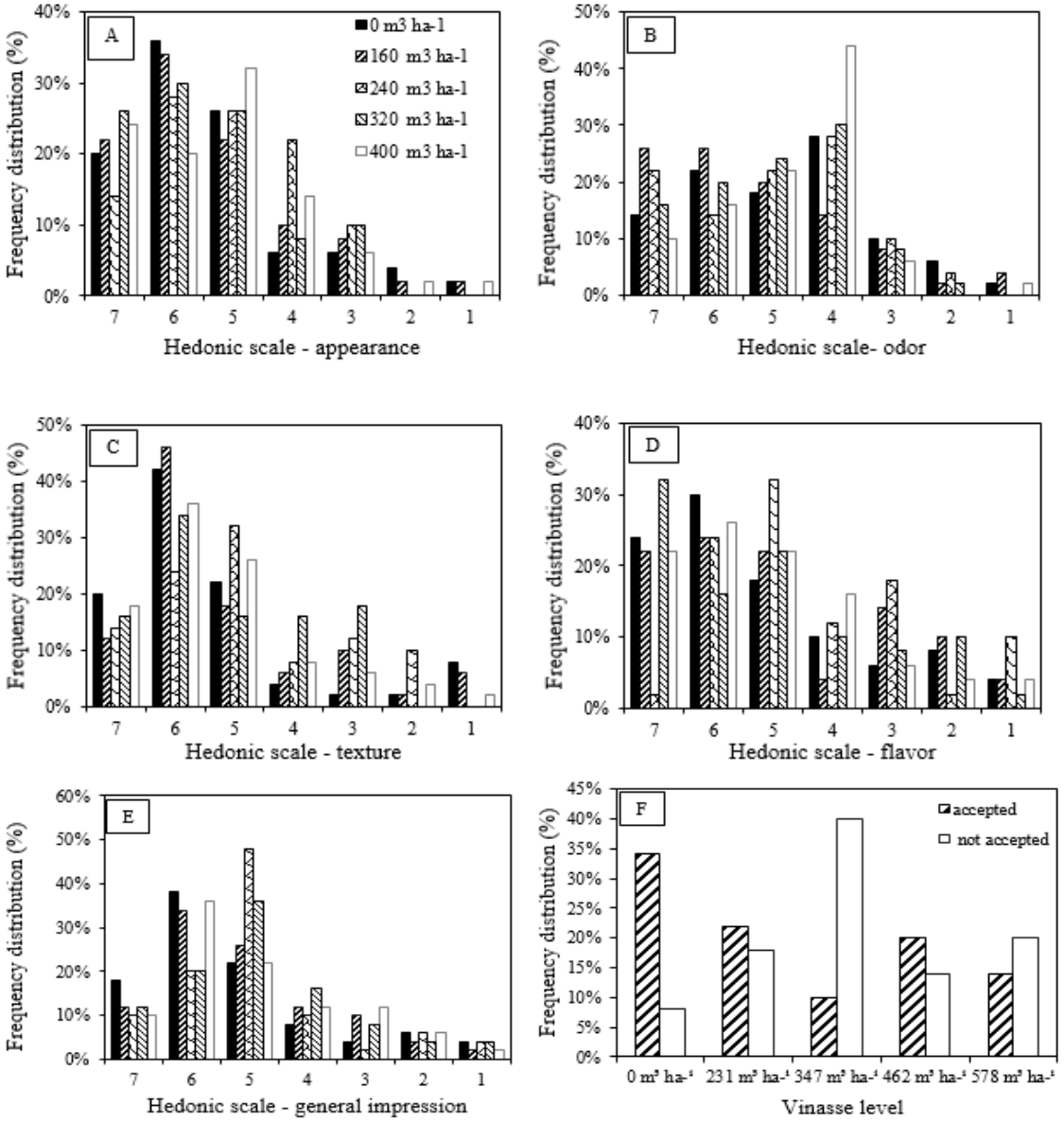

Figure 8. Consumers answers frequency distribution (%) for appearance (A), odor (B), texture (C), flavor (D), general impression (E), and treatment acceptance (F).

For texture attribute, the "like moderately" answer was the most rated, representing 42% and 46% for T1 and T2 respectively (Fig. 8C). Additionally, these treatments have received 8% and 6% answers of "dislike very much". Evaluating the distribution frequency for general impression (Fig. 8D), it was verified one correlation between the better answers ("like very much") with the higher ratio of SS/AT. This correlation indicates the Brazilian consumer's preference already mentioned. T4 received 32% of "like very much" for general impression and, although T3 received lower percentage as "like very much" (10%), this treatment received high percentage from "like slightly" to "like very much" (78%).

Considering the answers "like moderately" and "like very much" as indicative of high acceptance, T1 was considered the most accepted by the testers with 24% and 30%, respectively. It can be observed in Fig. 8F that T3 received the worst results in terms of acceptance. The high acceptance of T1 can be related with its high SS/TA ratio. Thus, considering authors as Medina (1992), Costa (2009), CUNHA et al., 2007) and (BENGOZI et al., 2007), these values can be used as indicative for the Vitória variety achieve good acceptance at the Brazilian internal market.

Conclusions

The sensorial test results have showed that is possible to use vinasse on fertigation for pineapple without affect the consumer acceptance. In addition, the utilization of vinasse resulted in improvement at the physical-chemical characteristics such as soluble solids and titratable acid although, however, reduced the fresh fruit weight.

Acknowledgment

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