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Organic versus conventional 'Prata-Anã' banana: effects on quality, bioactive compounds and oxidative markers

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ABSTRACT

Purpose: The objective of this work was to evaluate the effects of two systems of cultivation on the banana crop (*Musa spp.*) in the postharvest quality, bioactive compounds and phenylalanine ammonia-lyase during ripening process. **Research method:** Changes in physicochemical parameters, non-antioxidant, phenylalanine ammonia lyase (PAL) activity and oxidative markers were evaluated in banana cv. Prata-Anã from organic and conventional systems at three ripening stages: unripe, breaker and ripe. **Main findings:** The weight of conventional fruit was 48% greater at the ripe stage. The fruit size was reduced in fruits from organic farming while titratable acidity and the soluble solids content were respectively 82% and 58% higher at breaker stage in conventional bananas. The organic bananas have an increase of 58% in the phenolics at the unripe stage. The PAL activity was observed throughout banana development from organic farming, however the same was not observed for the conventional farming. Dismutase superoxide activity was also dramatically higher in matures and ripe fruits from organic farming. The lipid peroxidation degree of the cell membrane was 40% higher in ripe bananas for both systems. **Research limitations:** No limitations were founded, since the methods were well established. **Originality/Value:** Our observations suggest that banana fruits presented little changes in the function of farming conditions with an accumulation of specific compounds in determined stages of ripening without remarkable difference among systems of cultivation.

INTRODUCTION

Bananas (*Musa* sp.) are the second most important fruit in Brazil and only oranges overcome banana production. Bananas are climacteric fruit and ripen quickly reducing postharvest shelf life (Passos et al., 2016). Banana is a rich source of important bioactive compounds, including vitamins and phenolic compounds, besides notably enriched with minerals, such as phosphorus, sodium, potassium, calcium, magnesium, iron, copper, zinc and manganese (Lim & Tee, 2007; Wall, 2006). This fruit is a staple food in many countries and due to their nutritive capacity has a positive effect on the health and well-being of many people. Several researchers have evidenced that bananas are an important source of health-promoting phytochemicals (Davey et al., 2007; Someya et al., 2002). Due to these bioactive compounds, bananas have a higher antioxidant capacity than some berries, herbs and vegetables and this capacity increases during fruit maturity (Singh et al., 2016).

Although for the banana tree the conventional production system stands out with an important role in increasing productivity, the dependence of chemical inputs generate environmental impacts (Holb et al., 2012), so the organic system appears as an alternative. Organic banana farming is considered a profitable alternative for generating income and employment in the rural environment, especially for the family farmer who thus has a way of reducing production costs and a better quality of life (Neta et al., 2016). The differences between conventional and organic production systems may influence the quality attributes and physiology of fruits (Oliveira et al., 2013; 2017; Peck et al., 2011).

Several studies have demonstrated that oxidative stress increases phytochemical concentrations in organically grown fruits and vegetables (Jin et al., 2011; Lester & Saftner, 2011; Oliveira et al., 2017) and are usually richer in phenolic compounds than those from conventional growing systems. Brandt et al. (2011) reported that organically grown leafy vegetables and potatoes exhibited higher phytochemicals, such as ascorbic acid, as well as higher antioxidant activity. The accumulation of valuable molecules such as ascorbic acid, β-carotene and α-tocopherol under organic cultivation was recurrent in most of the studies reviewed (Smith-Spangler et al., 2012).

Based on the information presented above, the aim of this study was to evaluate the changes in physiochemical attributes, non-enzymatic and enzymatic parameters during ripening of "Prata-Anã" banana cultivated under organic and conventional systems.

MATERIALS AND METHODS

Fruit material

Banana (*Musa spp.* cv. Prata-anã) cultivated organically and conventionally were obtained from local producers of Crato-CE, State at the northeastern part of Brazil (7º 14'03"S and 39º 24'34"W) at 426 m above sea level. The soil was classified as humic yellowish latosol with medium phosphate and potassium levels, medium-textured clay and 0–20 cm top layer with pH (H_2O) 6.2. The organic system used as biofertilizer, a compost of animal manure (10 t ha^{-1}), legume cocktail and sugar cane bagasse incorporated into the soil just before sowing; and every 10 days, 0.5% Bordo mix was used preventively as a fungicide. In the conventional crop, the commercial pesticide FASTACH®100 was applied at 0.01% and inorganic fertilizer was used as recommended by the Brazilian Agricultural Development Department.

Bananas from organic and conventional systems were evaluated at three developmental stages: unripe, mature and ripe (Fig. 1). Bananas were harvested from 30 plants for each system, and then, washed in tap water and carefully selected to ensure good uniformity in

maturity and size. After cleansing and selection, both fruits from each stage of development were divided into samples made up of four replicates consisting of five fruits. Fruit pulp was homogenized using an Omni-mixer (Ultraturrax IKA®, Germany), and then, stored at -80 ºC for further analysis.

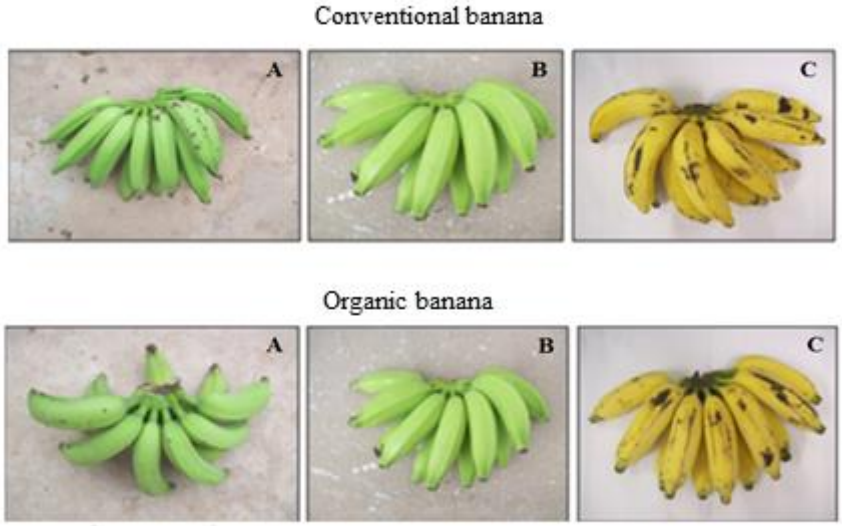

Fig. 1. Ripening stages of 'Prata-Anã' banana cultivated under conventional and organic systems. (**A**) Unripe, (**B**) Mature, and (**C**) Ripe.

Quality

The weight of the whole banana was measured individually using a semi-analytical scale (Tecnal®) and results expressed in grams (g). Bananas sizes were made with a pachymeter and result expressed as centimeters (cm). The pH was evaluated using an automatic pH meter (Labmeter PHS-3B®, São Paulo-Brazil) according to AOAC (2005). Titratable acidity (TA) was measured using an automatic titrator (Mettler-Toledo® DL12, Columbus-USA) as determined by AOAC (2005), and results were expressed as percent of malic acid. Soluble solids content (SSC) was determined by refractometry using a digital refractometer (Atago® model N1) as recommended by AOAC (2005) and results expressed in ºBrix.

Antioxidant metabolism and phenylalanine ammonia lyase (PAL) activity

Total phenolics were measured by a colorimetric assay according to the method described by Obanda and Owuor (1997) while extracts were prepared as described by Larrauri et al. (1997). Banana samples (1 g) were homogenized in 4 mL methanol [50% (*v/v*)] and kept in the dark at room conditions for 1 hour, before centrifugation at 4,000 *g* for 30 min at 4 ºC. The precipitate was extracted with 4 mL acetone [70% (*v/v*)] under similar conditions as previously described. After centrifugation, supernatants were joined and the total volume was raised to 10 mL with distilled water. Extracts (100 µL) were added to 100 µL Folin Ciocalteu, 1 mL Na_2CO_3 (20%) and 100 µL of distilled water and allowed to stand for 30 min in the dark. Absorbance was measured at 700 nm and results were expressed as Gallic Acid Equivalents (GAEs) mg 100 g^{-1} FW.

Total anthocyanins and yellow flavonoids were determined according to Francis (1982). One gram of pulp was extracted with a 95% ethanol-1.5 M HCl (85:15) solution, vortexed for 5 min and then, brought to 50 mL with the extracting solution. Absorbance was measured at 535 nm for the total anthocyanin content using an absorption coefficient of 98.2 mol cm^{-1} and

at 374 nm for the yellow flavonoid content using an absorption coefficient of 76.6 mol cm^{-1}. Both results were expressed as mg 100 g^{-1} FW. The total vitamin C was determined by titration with a 0.02% 2.6-dichloroindophenol solution (AOAC, 2005). The banana pulp was diluted to 50 mL of 0.5% oxalic acid, homogenized and, then, 2 mL of this solution was diluted to 50 mL with distilled water and titrated. Results were expressed as mg 100 g^{-1} FW.

The total antioxidant activity was determined according to Re et al. (1999)**.** The banana pulp was subjected to extraction procedure according to Larrauri et al. (1997). Once the radical was formed, the reaction was started by adding 30 µL of the extract in 3 mL of radical solution; after 6 min, absorbance was measured at 734 nm. A calibration curve was prepared with standard trolox solutions ranging from 100 to 2.000 µM. Antioxidant activity was expressed as Trolox Equivalent Antioxidant Capacity (TEAC), µM trolox g^{-1} FW.

The phenylalanine ammonialyase (PAL, EC 4.3.1.24) extraction was evaluated by a method developed by Mori et al. (2001). The banana sample was homogenized with 2 mL of 0.1 M Tris-HCl buffer solution (pH 8.0), 1 mM EDTA and 0.5 g PVP for 3 min at 4 ºC, and centrifuged at 5,000*g* for 20 min. The supernatant was used to determine the PAL activity according to El-Shora (2002). The reaction mixture contained 100 mM Tris-HCl buffer (pH 8.4), 40 mM L-phenylalanine and extract and 6 M of HCl to start the reaction. The absorbance was measured at 290 nm and activity of PAL expressed as µmol of trans-cinnamic acid g^{-1} protein.

Oxidative markers

Antioxidant enzyme activities were measured from 2 g of fruit pulp homogenized in 4 mL of 100 mM potassium phosphate buffer (pH 7.0) and 0.1 mM of ethylenediaminetetracetic acid (EDTA) for 2 min, followed by centrifugation at 12,000*g* for 40 min at 4 ºC (Yang et al., 2009). The supernatant fraction was used as a crude extract and all the procedures above were performed at 4 ºC. Results were also taken as specific enzyme activity considering the total protein content of sample quantified according to Bradford (1976).

Ascorbate peroxidase activity (APX, EC 1.11.1.1) was determined according to Nakano and Asada (1981). The reaction was started by adding ascorbic acid and ascorbate oxidation was measured by absorbance at 290 nm. Enzyme activity was measured using the molar extinction coefficient for ascorbate (2.8 mM cm^{-1}) and the results expressed in µmol H_2O_2 mg^{-1} protein min^{-1}, considering 1 mol of ascorbate for a reduction of 1 mol H_2O_2. Catalase (CAT, EC 1.11.1.6) activity was measured according to Beers and Sizer (1952). The reaction started by adding the enzyme extract and then, the decrease in H_2O_2 was monitored through absorbance at 240 nm, and quantified by its molar extinction coefficient (36 M^{-1} cm^{-1}). One unit of CAT activity was defined as the amount of enzyme required to decompose H_2O_2 on a protein basis, and the results were expressed as µmol H_2O_2 mg^{-1} protein min^{-1}. Superoxide dismutase (SOD, EC 1.15.1.1) activity was determined according to Giannopolitis and Ries (1977). The reaction mixture absorbance was measured at 560 nm, and one unit of SOD activity was defined as the amount of enzyme required capable to reduce 50% in the NBT photo-reduction rate on protein basis. Results were expressed as UA mg^{-1} protein min^{-1}. The lipid peroxidation degree was measured according to protocol developed by Zhu et al. (2008) with modifications. Fruit pulp was mixed in 0.1% trichloroacetic acid (TCA) followed by centrifugation at 3,000*g* at 4 ºC, for 20 min. The supernatant collected was added to 0.5% thiobarbituric acid (TBA) in 20% TCA and incubated at 95 ºC, for 30 min. After incubation, samples were centrifuged at 3,000*g* for 10 min at 4 ºC. Absorbance was measured at 532 nm and corrections were made for unspecific turbidity subtracting the absorbance at 600 nm. Thiobarbituric acids were calculated using an extinction coefficient of 155 $mMol^{-1}$ cm^{-1} and results expressed as nmol MDA equivalents g^{-1} FW.

Statistical analysis

The experiment was conducted as a factorial design (2 x 3), (cultivation system and developmental stage). Data were subjected to analysis of variance (ANOVA) and significant differences were determined by Tukey's test, at 5% significance level.

RESULTS AND DISCUSSION

Organic and conventional bananas were evaluated for quality parameters (Table 1). Both cultivation system and development influenced the increase in weight of bananas, which was 48% greater in the ripe conventional fruit (Table 1). The most significant difference observed for banana size was greater length +70% of ripe conventional fruit (Table 1). The fruit's length and diameter characteristics are important for fruit classification and consumption at purchase time. During the development of banana a significant decrease was observed in pH to 4.18 and to 4.15 in ripe organic and conventional fruit, respectively, without statistical difference between systems (Table 1). Thereby, titratable acidity showed an opposite pattern increasing of 0.11 to 0.62% and 0.08% to 0.51% in organic and conventional banana, respectively (Table 1). This increase in acidity was explained by Ferreira et al. (2010) as result of a reduction in malate oxidase enzyme activity leading to an accumulation of malic acid and similar results were obtained for different banana cultivars. The SSC increased significantly from 1.23 to 24.7 ºBrix and 1.43 to 24.2 ºBrix for organic and conventional fruit, respectively (Table 1), due mainly to starch hydrolysis into sugar.

The bioactive compounds are shown in Table 2. The total phenolic increased significantly during development from 23.3 to 53.1 mg 100 g^{-1} FW and from 39.2 to 54.7 mg 100 g^{-1} FW in organic and conventional fruit, respectively. The organic cultivation system only affected phenol content in the unripe bananas, which was 58% greater if compared to the conventional fruit (Table 2). Bananas are rich in phenolic compounds that polymerize during ripening reducing its astringency and its content may vary according to different factors such as cultivar, growing conditions and maturity state (Silva et al., 2015).

The total anthocyanin content was low and no significant differences were observed between farming systems or development (Table 2). The flavonoid content differed between organic and conventional bananas during development (Table 2). The organic bananas showed higher values until physiological maturity (breaker) (2.0 mg 100 g^{-1}) and then, declined during ripening (1.19 mg 100 g^{-1}), meanwhile, conventional fruit showed an increase all through development so that when ripe, it was higher than organic (1.43 mg 100 g^{-1}). These discrepancies indicated that organic farming had the effect of modifying the levels of transcripts or the activities of enzymes controlling intermediary steps of the biosynthetic pathway of phenolic compounds.

The vitamin C content differed during ripening only in conventional bananas, which decreased by 65% (Table 2). A reduction in vitamin C content during ripening of bananas was also observed by Hernández et al. (2006). Vinha et al. (2014) in a study with organic tomatoes demonstrated that they were richer in vitamin C, lycopene, total phenolics and flavonoids compared to conventional ones. Greater accumulation of ascorbic acid in organic crops has been associated with stress response pathways (Vallverdú-Queralt et al., 2012). Based on several cases so far described, we may agree that oxidative stress increases phytochemical concentrations in organically grown fruits and vegetables (Jin et al., 2011; Oliveira et al., 2013; 2017).

Table 1. Quality properties during ripening of 'Prata-anã' banana cultivated in organic and conventional systems

Properties	Ripening stage	Cultivation system	
		Organic	Conventional
Weight (g)	Unripe	71.36 ± 4.68 Ab	69.09 ± 4.39 Ac
	Breaker	80.86 ± 6.14 Ba	109.19 ± 9.98 Ab
	Ripe	78.49 ± 4.73 Bab	160.01 ± 13.56 Aa
Diameter (cm)	Unripe	3.13 ± 0.21 Ab	3.01 ± 0.10 Ac
	Breaker	3.32 ± 0.15 Aa	3.33 ± 0.22 Ab
	Ripe	3.68 ± 0.26 Aa	3.78 ± 0.20 Aa
Length (cm)	Unripe	10.65 ± 0.51 Ab	10.48 ± 0.45 Ac
	Breaker	11.66 ± 0.21 Ba	13.53 ± 0.78 Ab
	Ripe	11.72 ± 0.53 Ba	16.78 ± 1.03 Aa
pH	Unripe	5.48 ± 0.04 Ba	5.59 ± 0.01 Aa
	Breaker	4.31 ± 0.01 Bb	4.61 ± 0.02 Ab
	Ripe	4.18 ± 0.08 Ac	4.15 ± 0.05 Ac
Titratable acidity (% malic acid)	Unripe	0.11 ± 0.00 Ac	0.08 ± 0.00 Ac
	Breaker	0.53 ± 0.01 Ab	0.40 ± 0.01 Bb
	Ripe	0.62 ± 0.03 Aa	0.51 ± 0.03 Ba
Soluble solid content (°Brix)	Unripe	1.23 ± 0.12 Ac	1.43 ± 0.15 Ac
	Breaker	17.23 ± 0.40 Ab	10.00 ± 0.36 Bb
	Ripe	24.70 ± 0.66 Aa	24.20 ± 0.44 Aa

Means in the same column followed by the same lowercase not differed significantly between ripening stages, by Tukey's test at 5% level. Means in the same line followed by the same uppercase not differed significantly between the crop systems, by Tukey's test at 5% level. Results are expressed as means ± standard deviation (SD).

Table 2. Changes in non-enzymatic antioxidants, total antioxidant activity and PAL activity during ripening of 'Prata-anã' banana cultivated in organic and conventional systems

Properties	Ripening stage	Cultivation system	
		Organic	Conventional
Total phenolics (mg GAE 100 g^{-1})	Unripe	23.36 ± 1.42 Bc	39.21 ± 5.13 Ab
	Mature	38.56 ± 0.64 Ab	39.97 ± 2.25 Ab
	Ripe	53.12 ± 6.71 Aa	54.74 ± 6.89 Aa
Total anthocyanins (mg 100 g^{-1})	Unripe	0.15 ± 0.09 Aa	0.08 ± 0.03 Aa
	Breaker	0.22 ± 0.06 Aa	0.13 ± 0.06 Aa
	Ripe	0.10 ± 0.05 Aa	0.12 ± 0.03 Aa
Yellow Flavonoids (mg 100 g^{-1})	Unripe	2.00 ± 0.08 Ab	0.85 ± 0.13 Bb
	Breaker	2.39 ± 0.50 Ab	1.15 ± 0.50 Bab
	Ripe	1.19 ± 0.04 Ba	1.43 ± 0.04 Aa
Vitamin C (mg 100 g^{-1})	Unripe	8.77 ± 0.18 Ba	13.03 ± 0.39 Aa
	Breaker	8.68 ± 0.19 Aa	8.69 ± 0.34 Ab
	Ripe	8.53 ± 0.38 Aa	8.52 ± 0.20 Ab
Total antioxidant Activity (µMol Trolox g^{-1})	Unripe	90.20 ± 5.70 Aa	98.18 ± 10.42 Ab
	Breaker	93.04 ± 4.67 Aa	130.08 ± 8.85 Aab
	Ripe	134.97 ± 44.52 Aa	179.62 ± 36.86 Aa
PAL Activity (µmol trans-cin. acid g^{-1} protein)	Unripe	35.33 ± 1.42 Bc	55.29 ± 1.41 Aa
	Breaker	58.20 ± 2.98 Ab	5.38 ± 1.57 Bb
	Ripe	82.75 ± 4.17 Aa	2.39 ± 0.07 Bb

Means in the same column followed by the same lowercase not differed significantly between ripening stages, by Tukey's test at 5% level. Means in the same line followed by the same uppercase not differed significantly between the crop systems, by Tukey's test at 5% level. Results are expressed as means ± standard deviation (SD).

According to Deshmukh et al. (2011), the concentration of antioxidant compounds in plant organisms is strongly influenced by genetics, cultivar, ontology and environment as climate and soil conditions, among other factors. Thus, the cultivation practices, i.e. conventional vs. organic farming, may also influence the composition of phytochemicals in fruits and vegetables (Vinha et al., 2014). In conventional bananas, the total antioxidant activity increased from 98.18 to 179.62 μM Trolox g^{-1} FW during development without statistical difference between cropping systems. This result corroborates with those found for phenols and vitamin C, on Table 2 and indicates that banana antioxidant metabolism was not significantly affected by the organic cultivation system. Thaiphanit and Anprung (2010) also observed an increase in antioxidant activity of conventional bananas during ripening, but not for organic fruit, although when ripe, they were not statistically different. Lower values of antioxidant activity were found by Faller and Fialho et al. (2010) for ripe banana (*Musa acuminate* L.), but there were also no significant differences under farming systems. Higher phenolic concentrations in organic crops may be due to lower mineral nitrogen fertilizer inputs under organic systems (Barański et al., 2014). Organic and conventional bananas showed significantly different behavior regarding PAL activity (Table 2). Conventional fruits had higher activity levels when unripe (55.29 μmol trans-cinnamic acid h^{-1} mg^{-1} P) which declined when the fruit ripened (2.39 μmol trans-cinnamic acid h^{-1} mg^{-1} P). Meanwhile, the organic bananas showed an increase in PAL activity all through the development (Table 2). The increase in PAL activity in organic bananas probably explains the significant increase of total phenols (Table 2). Thus, the organic cropping system interfered in the secondary metabolism of bananas. Similar results have been reported by Jin et al. (2011) who hypothesized that because environmental stress affects more organic plants and induce the activity of PAL, organic farming may activate higher antioxidant capacities and flavonoid contents than those produced with conventional cultivation (Baranski et al., 2014). This data indicate that organic bananas do suffer oxidative stress and thereby, explains the higher PAL activity as either Reactive Oxygen Species (ROS) or nitric oxide (NO) may enhance PAL activity for secondary metabolism and antioxidative protection (Kováčik et al., 2010). In spite of the stress signals in organic bananas, their nutritional quality parameters are not affected by the cropping system.

Table 3. Oxidative markers during ripening of 'Prata-anã' banana cultivated in organic and conventional systems

Properties	Ripening stage	Cultivation system	
		Organic	Conventional
Peroxidase ascorbate activity (H_2O_2 mg^{-1} protein min^{-1})	Unripe	0.29 ± 0.14 Ba	2.98 ± 0.40 Aa
	Breaker	0.26 ± 0.08 Ba	1.15 ± 0.19 Ab
	Ripe	0.12 ± 0.03 Ba	0.49 ± 0.05 Ab
Catalase activity (H_2O_2 mg^{-1} protein min^{-1})	Unripe	8.76 ± 1.51 Ba	26.41 ± 8.18 Aa
	Breaker	4.97 ± 1.38 Aa	9.04 ± 4.26 Ab
	Ripe	4.11 ± 1.34 Aa	10.45 ± 8.31 Ab
Dismutase superoxide activity (UA mg^{-1} protein min^{-1})	Unripe	310.49 ± 15.38 Ba	1207.08 ± 215.55 Aa
	Breaker	172.57 ± 16.24 Ab	76.05 ± 5.28 Bb
	Ripe	155.17 ± 18.26 Ab	32.41 ± 1.12 Bc
Lipid peroxidation (nmol MDA g^{-1})	Unripe	3.01 ± 6.65 Ac	3.71 ± 0.74 Ac
	Breaker	22.58 ± 2.44 Ab	14.57 ± 2.82 Ab
	Ripe	46.18 ± 8.66 Aa	44.52 ± 6.10 Aa

Means in the same column followed by the same lowercase not differed significantly between ripening stages, by Tukey's test at 5% level. Means in the same line followed by the same uppercase not differed significantly between the crop systems, by Tukey's test at 5% level. Results are expressed as means ± standard deviation (SD).

Oxidative markers

The APX activity decreased significantly during the development of conventional bananas (Table 3). Meanwhile, APX activity was inhibited by the organic cultivation system and was constantly low during development. Similar behavior was observed for CAT, as the activity declined during maturation of conventional fruit and was lower and constant for organic fruit (Table 3). These results show that the organic cropping system exerts influence on the ROS, H_2O_2, neutralization pathways through inhibition of CAT and APX activities mainly at earlier stages of banana development, but not at ripening. The SOD activity decreased during the development of bananas, although its decline was steeper for conventional fruit. Differently, from APX and CAT, SOD activity was significantly higher at the breaker for unripe organic bananas indicating a greater production and accumulation of H_2O_2 due to the inhibition of the scavenging enzymes. Organically grown tomato fruits experienced stress conditions that resulted in oxidative stress based on higher SOD and PAL activity (Oliveira et al., 2013). The latter is a key enzyme in both plant defense and development and also controls a rate-determining step of the biosynthetic pathway of phenolic compounds in plants.

During development, there was observed an increase of membrane lipid peroxidation (LP) without significant difference between organic and conventional bananas (Table 3). The lipid peroxidation degree of the cell membrane was 40% higher in ripe bananas for both systems. These results indicate the greater LP values were mainly due to the oxidative imbalance characteristic of ripening and senescence, but not to an oxidative stress induced by crop system.

The effect of agricultural practices on the accumulation of these molecules in organic farming will require more in-depth studies in order to elucidate the links between biotic/abiotic stress, oxidative stress, secondary metabolism, and other underexplored physiological and molecular determinants that may enhance the nutritional value of organic vegetables.

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CONCLUSION

This work approaches the influence of organic versus conventional cultivation systems from a unique point of view as it associates quality and metabolic stress parameters during the development of banana. Taken together, our observations suggest that banana fruits presented little changes in the function of farming conditions with an accumulation of specific compounds in determined stages of ripening without remarkable difference among cultivation systems. However, bananas presented oxidative stress signals and smaller size when cultivated organically, but their nutritional quality parameters were not affected by the cropping system.

REFERENCES

Alkarkhi, A.F.M., Bin-Ramli, S., Yong, Y.S., & Easa. (2011). Comparing physicochemical properties of banana pulp and peel flours prepared from green and ripe fruits. *Food Chemistry, 129*, 312-318. doi: 10.1016/j.foodchem.2011.04.060

Asami, D.K., Hong, Y.J., Barrett, D.M., & Mitchell, & A.E. (2003). Comparison of the total phenolic and ascorbic acid content of freeze-dried and air-dried marionberry, strawberry, and corn grown

using conventional, organic, and sustainable agricultural practices. *Journal of Agricultural and Food Chemistry*, 51, 1237-1241. doi: 10.1021/jf020635c

Association of Official Analytical Chemistry-AOAC. (2005). Official Methods of Analysis of AOAC International.

Barański, M., Średnicka-Tober, D., Volakakis, N., Seal, C., Sanderson, R., Stewart, G.B., Benbrook, C., Biavati, B., Markellou, E., & Giotis, C. (2014). Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systematic literature review and meta-analyses. *British Journal of Nutrition*, *112*, 794-811. doi: 10.1017/S0007114514001366

Beers, R.F. & Sizer, I.W. (1952). A spectrophotometric method for measuring the breakdown of hydrogen peroxide by catalase. *The Journal of Biological Chemistry*, *195*, 133-140.

Bradford, M.M. (1976). A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Analytical Biochemistry*, *72*, 248-254. doi: 10.1016/0003-2697(76)90527-3

Brandt, K., Leifert, C., Sanderson, R., & Seal, C.J. (2011). Agroecosystem management and nutritional quality of plant foods: the case of organic fruits and vegetables. *Critical Reviews in Plant Science*, 30 (1-2), 177-197. doi: 10.1080/07352689.2011.554417

Cardoso, P.C., Tomazini, A.P.B., Stringheta, P.C., Ribeiro, S.M., & Pinheiro-Sant'Ana, H.M. (2011). Vitamin C and carotenoids in organic and conventional fruits grown in Brazil. *Food Chemistry*, *126*, 411-416. doi: 10.1016/j.foodchem.2010.10.109

Chang, A., Lim, M-H., Lee, S-W., Robb, E.J., & Nazar, R.N. (2008). Tomato phenylalanine ammonia-lyase gene family, highly redundant but strongly underutilized. *The Journal of Biological Chemistry*, *283*, 33591-33601. doi: 10.1074/jbc.M804428200

Dangour, A.D., Dodhia, S.K., Hayter, A., Allen, E., Lock, K., & Uauy, R. (2009). Nutritional quality of organic foods: a systematic review. *The American Journal of Clinical Nutrition*, *90*, 680-685. doi: 10.3945/ajcn.2009.28041

Davey, M.W., Stals, E., Ngoh-Newilah, G., Tomekpe, K., Lusty, C., Markham, R., Swennen, R., & Keulemans, J. (2007). Sampling strategies and variability in fruit pulp micronutrient contents of West and Central African bananas and plantains (*Musa species*). *Journal of Agricultural and Food Chemistry*, 55, 2633-2644. doi:10.1021/jf063119l

Deshmukh, S., Wadegaonkar, V., Bhagat, R., & Wadegaonkar, P. (2011). Tissue specific expression of Anthraquinones, flavonoids and phenolics in leaf, fruit and root suspension cultures of Indian Mulberry (*Morinda citrifola* L.). *Plant Omics*, *4*, 6.

El-Mergawi, R.A. & Al-Redhaiman, K. (2010). Effect of organic and conventional production practices on antioxidant activity, antioxidant constituents and nutritional value of tomatoes and carrots in Saudi Arabia markets. *Journal of Food, Agriculture and Environment*, *8*, 253-258.

El-Shora, H. (2002). Properties of phenylalanine ammonia-lyase from marrow cotyledons. *Plant Science*, *162*, 1-7. doi: 10.1016/S0168-9452(01)00471-X

Faller, A. & Fialho, E. (2010). Polyphenol content and antioxidant capacity in organic and conventional plant foods. *Journal of Food Composition and Analysis*, *23*, 561-568. doi: 10.1016/j.jfca.2010.01.003

Fardet, A., Rock, E., & Rémésy, C. (2008). Is the in vitro antioxidant potential of whole-grain cereals and cereal products well reflected in vivo? *Journal of Cereal Science*, *48*, 258-276. doi: 10.1016/j.jcs.2008.01.002

Ferreira, S.M.R., Quadros, D.A., Karkle, E.N.L., Lima, J.J., Tullio, L.T., & Freitas, R.J.S. (2010). Qualidade pós-colheita do tomate de mesa convencional e orgânico. *Ciência e Tecnologia de Alimentos*, *30*, 858-864.

Francis, F.J. (1982). *Analysis of anthocyanins*. In Anthocyanins as food colors. Academic Press. 181-207. doi: 10.1016/j.foodchem.2003.08.011

Giannopolitis, C.N. & Ries, S.K. (1977). Superoxide dismutase In. Occurrence in higher plants. *Plant Physiology*, *59*, 309-314. doi: 10.1104/pp.59.2.309

Gil, M.I, Ferreres, F. & Tomas-Barberan, F. (1999). A. Effect of postharvest storage and processing on the antioxidant constituents (flavonoids and vitamin C) of fresh-cut spinach. *Journal of Agricultural and Food Chemistry*, *47*, 2213-2217. doi: 10.1021/jf981200l

Hernández, Y., Lobo, M.G., & González, M. (2006). Determination of vitamin C in tropical fruits: A comparative evaluation of methods. *Food Chemistry*, *96*, 654-664. doi: 0.1016/j.foodchem.2005.04.012

Holb, I.J., Dremák, P., Bitskey, K. & Gonda, I. (2012). Yield response, pest damage and fruit quality parameters of scab-resistant and scab-susceptible apple cultivars in integrated and organic production systems. *Scientia Horticulturae*, *145*, 109-117. doi: 10.1016/j.scienta.2012.08.003

Howard, L.R., Pandjaitan, N., Morelock, T., & Gil, M.I. (2002). Antioxidant capacity and phenolic content of spinach as affected by genetics and growing season. *Journal of Agricultural and Food Chemistry*, *50*, 5891-5896. doi: 10.1021/jf020507o

Jin, P., Wang, S.Y., Wang, C.Y., & Zheng, Y. (2011). Effect of cultural system and storage temperature on antioxidant capacity and phenolic compounds in strawberries. *Food Chemistry*, *124*, 262-270. doi: 1016/j.foodchem.2010.06.029

Kader, A.A. (2002). Postharvest technology of horticultural crops: UCANR Publications. In: Lima, G.P.P., Vianello, F., 2011. Review on the main differences between organic and conventional plant-based foods. *International Journal of Food Science and Technology*, *46*, 1-13.

Kováčik, J., Grúz, J., Klejdus, B., Štork, F., Marchiosi, R., & Ferrarese-Filho, O. (2010). Lignification and related parameters in copper-exposed Matricaria chamomilla roots: role of H_2O_2 and NO in this process. *Plant science*, *179*(4), 383-389. https://doi.org/10.1016/j.plantsci.2010.06.014

Larrauri, J.A., Rupérez, P., & Saura-Calixto, F. (1997). Effect of drying temperature on the stability of polyphenols and antioxidant activity of red grape pomace peels. *Journal of Agricultural and Food Chemistry*, *45*, 1390-1393. doi: 10.1021/jf960282f

Lester, G.E. & Saftner, R.A. (2011). Organically versus conventionally grown produce: common production inputs, nutritional quality, and nitrogen delivery between the two systems. *Journal of Agricultural and Food Chemistry*, *59*, 10401-10406.doi: 10.1021/jf202385x

Lim, Y., Lim, T., & Tee, J. (2007). Antioxidant properties of several tropical fruits: A comparative study. *Food Chemistry*, *103*, 1003-1008. doi: 10.1016/j.foodchem.2006.08.038

Mohapatra, D., Mishra, S., Singh, C.B., & Jayas, D.S. (2011). Post-harvest processing of banana: opportunities and challenges. *Food Bioprocess and Technology*, *4*, 327-339. doi: 10.1007/s11947-010-0377-6

Moore, J., Liu, J-G., Zhou, K., & Yu, L. (2006). Effects of genotype and environment on the antioxidant properties of hard winter wheat bran. *Journal of Agricultural and Food Chemistry*, *54*, 5313-5322. doi: 10.1021/jf060381l

Mori, T., Sakurai, M. & Sakuta, M. (2001). Effects of conditioned medium on activities of PAL, CHS, DAHP synthase (DS-Co and DS-Mn) and anthocyanin production in suspension cultures of *Fragaria ananassa*. *Plant Science*, *160*, 355-360. doi: 10.1016/S0168-9452(00)00399-X

Nakano, Y. & Asada, K. (1981). Hydrogen peroxide is scavenged by ascorbate-specific peroxidase in spinach chloroplasts. *Plant Cell Physiology*, *22*, 867-880. doi: 10.1093/oxfordjournals.pcp.a076232

Neta, M.N.A., Araújo, F.D., Rabelo, J.M., Almeida, T.S., & Cunha, L.M.V. (2016). Análise dos custos de produção de bananicultura orgânica com selo SAT-sem o uso de agrotóxico no norte de Minas Gerais. *Cadernos de Agroecologia*, 1-10.

Obanda, M., Owuor, P.O., & Taylor, S.J. (1997). Flavanol composition and caffeine content of green leaf as quality potential indicators of Kenyan black teas. *Journal of Food the Science of Food and Agriculture*, *74*, 209-215. doi: 10.1002/(SICI)1097

Oliveira, A.B., Lopes, M.M.A., Moura, C.F.H., Oliveira, L.S., Souza, K.O., Gomes-Filho, E., Urban, L., & Miranda, M.R.A. (2017). Effects of organic vs. conventional farming systems on quality and antioxidant metabolism of passion fruit during maturation. *Scientia Horticulturae*, *222*, 84-89.doi: 10.1016/j.scienta.2017.05.021

Oliveira, A.B., Moura, C.F., Gomes-Filho, E., Marco, C.A., Urban, L., & Miranda, M.R.A. (2013). The impact of organic farming on quality of tomatoes is associated to increased oxidative stress during fruit development. *Plos One*, *8*, e56354. doi: 10.1371/journal.pone.0056354

Passos, F.R., Mendes, F.Q., Cunha, M.C.D., Pigozzi, M.T., & Carvalho, A.M.X.D. (2016). Propolis extract in postharvest conservation banana 'prata'. *Revista Brasileira de Fruticultura*, *38*, 2. doi: 10.1590/0100-29452016931.

Peck, G.M., Merwin, I.A., Thies, J.E., Schindelbeck, R.R., & Brown, M.G. (2011). Soil properties change during the transition to integrated and organic apple production in a New York orchard. *Applied Soil Ecology*, *48*, 18-30. doi: 10.1016/j.apsoil.2011.02.008

Pimentel, R.A., Guimarães, F.N., Santos, V., & Resende, J. (2010). Qualidade pós-colheita dos genótipos de banana PA42-44 e Prata-Anã cultivados no norte de Minas Gerais. *Revista Brasileira de Fruticultura*, *32*, 407-413.

Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology & Medicine*, *26*, 1231-1237. doi: 1016/S0891-5849(98)00315-3

Silva, A.A., Junior, J.L.B., & Barbosa, M.I.M.J. (2015). Farinha de banana verde como ingrediente funcional em produtos alimentícios. *Ciência Rural*, *45*, 2252-2258. doi: 10.1590/0103-478cr20140332

Singh, B., Singh, J.P., Kaur, A., & Singh, N. (2016). Bioactive compounds in banana and their associated health benefits-A review. *Food Chemistry*, *206*, 1-11. doi: 10.1016/j.foodchem.2016.03.033

Smith-Spangler, C., Brandeau, M.L., Hunter, G.E., Bavinger, J.C., Pearson, M., Eschbach, P.J., Sundaram, V., Liu, H., Schirmer, P., Stave, C., Olkin, I., & Bravata, D.M. (2012). Are organic foods safer or healthier than conventional alternatives? A systematic review. *Annals of Internal Medicine*, *157*, 348-366. doi: 10.7326/0003-4819-157-5-201209040-00007

Someya, S., Yoshiki, Y., & Okubo, K. (2002). Antioxidant compounds from bananas (*Musa cavendish*). *Food Chemistry*, *79*, 351-354. doi: 10.1016/S0308-8146(02)00186-3

Thaiphanit, S. & Anprung, P. (2010). Physicochemical and flavor changes of fragrant banana (*Musa acuminata* AAA group 'Gross Michel') during ripening. *Journal of Food Processing and Preservation*, *34*, 366-382. doi: 10.1111/j.1745-4549.2008.00314.x

Vallverdú-Queralt, A., Jáuregui, O., Medina-Remón, A., & Lamuela-Raventós, R.M. (2012). Evaluation of a method to characterize the phenolic profile of organic and conventional tomatoes. *Journal of Agricultural and Food Chemistry*, *60*, 3373-3380. doi: 10.1021/jf204702f

Vinha, A.F., Barreira, S.V., Costa, A.S., Alves, R.C., & Oliveira, M.B.P. (2014). Organic versus conventional tomatoes: Influence on physicochemical parameters, bioactive compounds and sensorial attributes. *Food Chemistry and Toxicology*, *67*, 139-144. doi: 10.1016/j.fct.2014.02.018

Wall, M.M. (2006). Ascorbic acid, vitamin A, and mineral composition of banana (*Musa* sp.) and papaya (*Carica papaya*) cultivars grown in Hawaii. *Journal of Food Composition and Analysis*, *19*, 434-445. doi: 10.1016/j.jfca.2006.01.002

Yang, Z., Zheng, Y., & Cao, S. (2008). Effect of high oxygen atmosphere storage on quality, antioxidant enzymes, and DPPH-radical scavenging activity of Chinese bayberry fruit. *Journal of Agricultural and Food Chemistry*, *57*, 176-181. doi: 10.1021/jf803007j

Zhu, S., Sun, L., Liu, M., & Zhou, J. (2008). Effect of nitric oxide on reactive oxygen species and antioxidant enzymes in kiwifruit during storage. *Journal of the Science of Food and Agriculture*, *88*, 2324-2331. doi: /10.1002/jsfa.3353

تولید موز "پراتا آنا" ارگانیک و متداول: اثرات بر کیفیت، ترکیبات فعال زیستی و نشانگرهای اکسیداتیو

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چکیده:

هدف از این مطالعه ارزیابی اثرات دو سیستم کشت در کیفیت پس از برداشت، ترکیبات فعال زیستی و فنیل آلانین آمونیالاز در طی فرآیند رسیدگی محصول موز بود. تغییرات پارامترهای فیزیکوشیمیایی، غیر آنتی اکسیدانی، فعالیت فنیل آلانین آمونیالاز (PAL) و نشانگرهای اکسیداتیو در موز رقم Prata-Anã در سیستم های ارگانیک و متداول درسه مرحله رسیدگی نارس، تغییر رنگ و رسیده مورد ارزیابی قرار گرفت. وزن میوه در کشت معمول در مرحله رسیده ۴۸ درصد بیشتر بود. اندازه میوه در میوه‌های کشت ارگانیک کاهش یافت، در حالی که اسیدیته قابل تیتر و مواد جامد محلول به ترتیب ۸۲ و ۵۸ درصد در مرحله تغییر رنگ در موز های کشت معمول بیشتر شده بود. میزان فنول در موزهای ارگانیک در مرحله نارس ۵۸ درصد افزایش یافت. فعالیت PAL در طی نمو میوه موز در کشت ارگانیک مشاهده شد، اما در کشت معمول چنین مشاهده نشد. فعالیت سوپراکسید دیسموتاز نیز به طور چشمگیری در میوه بالغ و رسیده در کشت ارگانیک بیشتر بود. درجه پراکسیداسیون لیپید در غشای سلولی در موز رسیده در هر دو سیستم کشت ۴۰ درصد بیشتر بود. مشاهدات ما نشان می دهد که شرایط کشت تغییرات اندکی در کارکرد میوه موز داشت که با انباشت ترکیبات خاص در مراحل مشخص رسیدگی و فاقد تفاوت قابل ملاحظه بین سیستم های کشت همراه بود.

کلمات کلیدی: *Musa spp.*، فنولیک، فنیل آلانین آمونیالاز، متابولیسم ثانویه