

RESEARCH ARTICLE

Potassium fertilization in the quality improvement and centesimal composition of pitaya

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ABSTRACT

Pitaya stands out in the market for presenting exotic appearance species, high water content, vitamins and minerals, low calories, and bioactive compounds that makes it attractive for consumption. However, the composition of this fruit may change according from the place of cultivation, orchard management and harvesting season. Regarding orchards management, variations have been observed in the fact that the pitaya species are considered rustic, able of tolerating adverse conditions of low availability of water and nutrients, and mainly because lack information on fertilization. Thus, the research was carried out to evaluate the potassium fertilization in the quality and in the centesimal composition in pitayas of the species *Hylocereus undatus* and *Hylocereus polyrhizus*. The evaluations were carried out during two harvests, in pitayas harvested mature from plants that received different fertilizations. The fruits of the pitaya species reach larger sizes and better flavor with the potassium fertilization. The fruits centesimal composition is altered with the management of the fertilization of the orchards. The fruits produced by plants with higher availability of potassium oxide (K_2O) present higher contents of dry matter, fiber, ashes, carbohydrates and energetic value and lower moisture content, allowing conservation for longer if stored properly. The increase of these constituents in the fruit pulp is related to the function of potassium (K) in the enzyme's activation, which are fundamental in the metabolic processes and the transport of photoassimilates, evidencing their role in improving fruit quality characteristics. Orchards that are fertilized with potassium produce fruits with better composition and final quality, increasing the acceptance by consumers, size classification and market prices.

Keywords: Chemical composition; Nutritional composition; Physicochemical properties

INTRODUCTION

Pitaya is a new one in the world, this because until 1994, only scarce research existed on these fruits, however the worldwide interest in this novel fruit crop is evident, as numbers of pitaya-related publications have grown rapidly, especially during the past decade (Mizrahi, 2014). These researches attracted the attention of consumers, due to the potential beneficial to health and of producers, by their economic value in the market.

The studies related to the characterization evidenced that the pitayas are rich in vitamins, minerals, linoleic acid and oleic acid and antioxidant potential (Nurul and Asmah, 2014; Cordeiro et al., 2015; Jerônimo et al., 2015). They are similar to other fruits, most of its composition is water, the moisture content in the pulp varies between 85% and 89.9% (Sato et al., 2014; Nurul; Asmah, 2014; Jerônimo

et al.; 2015). Regarding the levels of proteins, fruits of the species *H. undatus* and *H. polyrhizus* purchased at a CEASA unit in Brazil, the contents evaluated ranged from 0.87 g 100 g⁻¹ and 2.26 g 100 g⁻¹ of pulp (Abreu et al., 2012; Jerônimo et al., 2015).

Pitayas have low levels of lipids. Results published in fruits produced in Brazil showed levels ranging from 0.3 g 100 g⁻¹ to 0.47 g 100 g⁻¹, for *H. undatus* and *H. polyrhizus* (Abreu et al., 2012, Santos et al., 2016) and rich in fibers with values ranging from 2.14 mg 100 g⁻¹, in pitayas produced by *H. undatus* and from 3.26 mg 100 g⁻¹ to 11.35g 100 g⁻¹, in fruits of the species *H. polyrhizus* (Cordeiro et al., 2015).

As for ash contents, results published in the characterization carried out in pitayas produced in Brazil report values from 0.33 g 100 g⁻¹ to 0.75 g 100 g⁻¹ in the fruit pulp of *H. undatus*

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Received: 21 March 2020; Accepted: 12 August 2020

and *H. polyrhizus* (Abreu et al., 2012; Jerônimo et al., 2015). Among the constituents in the composition of pitayas, the levels of carbohydrates are also variable. *H. polyrhizus* fruits harvested in Malaysia showed levels of 12.9 g 100 g⁻¹ and 8.4 g 100 g⁻¹, for those harvested in Australia. In Brazil, in fruits of the species *H. undatus*, a content of 10.79 g 100 g⁻¹ has been reported (Jerônimo et al., 2015).

It is possible to note that the composition of the pitayas can vary between species, soil and climatic conditions of the place cultivation and with the conditions of orchards management. Further, the conditions during storage may also influence the composition and final quality of these fruit (Freitas et al., 2013, and Duarte et al., 2017).

Research relating the composition and quality of pitayas with orchard management are still scarce. Regarding fertilization, the studies carried out by Duarte et al. (2017) with management of organic fertilization and Fernandes et al. (2018) with the management of potassium fertilization showed that fertilization is one of the factors that directly interferes in the quality of these fruits, but specifically in the centesimal composition no information has been disclosed yet.

Quality is important for commercialization because it involves characteristics related to fruit size and flavor, such as the sugars concentration and the acidity in its pulp, variables that characterize the smooth-flavored pitayas, which may hinder its acceptance in the consumer market.

To improve the quality and composition of the pitayas produced, plant nutrition is determinant, considering the nutrients' participation in the flavor, color, aroma, form, size, appearance, resistance to pests and diseases, and preservation during post-harvest storage of fruit (Aular and Natale, 2013), because in addition to the nutritional value of fruit, consumers are demanding more in relation to quality.

Potassium (K) is one of the essential mineral nutrients to plants, which participates in biochemical and physiological functions as the activation enzymes, which are fundamental in the metabolic processes, for the proteins and sugars production; and in the transport of sugars produced by photosynthesis to the fruits (Senapati and Santra, 2009; IPI, 2013).

In this context, the research was conducted with the objective of evaluated the effect of potassic fertilization on the quality and in the centesimal composition of pitayas of the species *Hylocereus undatus* and *Hylocereus polyrhizus*.

MATERIALS AND METHODS

The evaluated pitayas were harvested in an orchard located at 18° 04' 15"S latitude and 43° 28' 15"W longitude at an altitude of 726 meters. The region has an Aw climate type, classified as high-altitude tropical, with a mean temperature of 21.5 °C and precipitation of 1,246 mm per year.

The soil of the orchard is the Yellow-Dystrophic Latosol, with following characteristics: pH = 4.1; phosphor (P) = 52.3 mg dm⁻³; potassium (K) = 40.7 mg dm⁻³; calcium (Ca) = 1.2 cmolc dm⁻³; magnesium (Mg) = 0.7 cmolc dm⁻³; aluminum (Al) = 1.13 cmolc dm⁻³; organic matter = 0.4 dag kg⁻¹; base saturation = 25% and cation exchange capacity at pH 7 = 9.4 cmolc dm⁻³.

Experimental design and complementary fertilization

For the application of the doses of potassium oxide (K₂O) tested the 2 x 4 factorial scheme was used, the factors are related to two pitaya species, *Hylocereus undatus* (Haw.) and *Hylocereus polyrhizus* (Web.) Britton & Rose and four doses of K₂O, 0; 50; 100 and 200 g per plant, distributed in randomized blocks, composed of four blocks and three plants per plot.

Complementary fertilization of the orchard was carried out with nitrogen (N), P, Ca, Mg and bovine manure. Before planting, the soil was prepared with limestone that provides Ca and Mg and raise the bases saturation to 60% and fertilized with 50 g of P and 10 liters of bovine manure. After planting, 100 g of N were applied per plant, divided into three applications, in all production cycles evaluated.

Analyses

The fruits were harvested when the peel color was completely red, during the summer in the growing region, between the months of December and March. The analyzes were in two productive cycles, in the third and fourth harvest after the orchard implantation. After harvest as pitayas were carried out at the Laboratory of fruit analysis for sample preparation and analysis. In Laboratory the fruits were washed in water and allowed to air-dry.

To assess the fruits quality were analyzed for longitudinal diameter, transverse diameter, mass, soluble solids content (°Brix), titratable acidity (% of malic acid equivalents) soluble solids/titratable acidity ratio and the concentration of total sugars.

Soluble solids contents were quantified using a digital refractometer. For titratable acidity in 0.1 M NaOH, according to methodology of the IAL (2008). Determination of the total soluble sugars adapted by McCready (1950). From the results of the soluble solids concentration and

acidity titratable, the soluble solids and titratable acidity e ratio was calculated.

To evaluate the centesimal composition, pulp samples of 40 fruits harvested in the plants of each fertilization, at each harvest season, were withdrawn. The samples were placed in Petri dishes to dry in a forced circulation oven at 65 °C until reaching a constant mass.

Moisture content; ash; crude fiber, lipids; and protein were determined according to standard IAL (2008) in mature fruits (Fig. 1). All samples were analyzed in triplicate and were expressed as mg 100⁻¹ g dry matter. Carbohydrates concentration were determined by the difference of water, protein, lipid and ashes contents, according the methodology proposed by Brazil (2003).

Statistical analyses

The data were submitted to analysis of variance and the variables with significant differences between the K₂O doses tested were submitted to regression analysis, considering a $p < 0.05$.

The multivariate analysis was performed by means of the canonical variable (HAIR et al., 2009), for the joint analysis

of the doses of K₂O in the two pitaya species and in the two harvests evaluated.

From the equation obtained, the dose of K₂O was estimated for the highest value of the canonical variable that was used in the regression equations of the quality and the centesimal composition variables of the pitayas.

RESULTS

The quadratic equation was the one that best explained the variation of the canonical variable as a function of the K₂O doses, for the quality and the centesimal composition variables of the pitayas, in the two productive cycles (Fig. 2).

According to the adjusted model, the dose of K₂O that provides the fruits production of better quality and centesimal composition is 144 g of K₂O per plant. Potassium fertilization increases fruit size, soluble solids, fiber, ash, carbohydrate and dry matter (Table 1).

Fruit quality

The mass and the diameters in the pitayas of the *H. undatus* species increased with the greater availability of potassium



Fig 1. Preparation of samples for analysis of lipids, ashes, carbohydrates, protein and sugars, of white pitaya *H. undatus* and red pitaya *H. polyrhizus*.

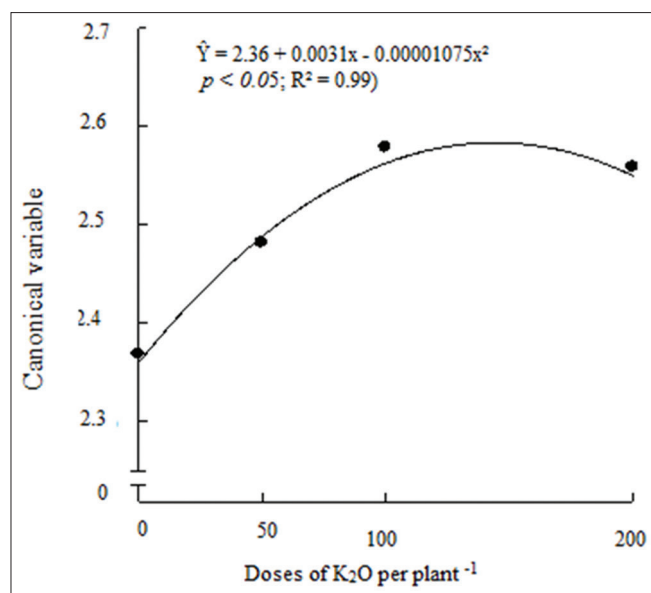


Fig 2. Score of the canonical variable of the multivariate analysis as a function of the doses of K_2O for the variables of quality and centesimal composition of the pitayas, in the third and fourth productive cycles.

Table 1: Mean values of quality and centesimal composition variables of pitayas, resulting from analysis of variance and canonical variable (CV), as a function of the doses of K_2O

Variables	Doses of K_2O (g plant ⁻¹)			
	0	50	100	200
Mass (g)	146.8	178.05	190.7	196.4
Transverse diameter (mm)	59.5	70.5	74.5	70.7
Longitudinal diameter (mm)	61.4	70.4	74.1	72.5
Soluble solids (°Brix)	17.1	19.1	19.5	18.6
Titrateable acidity (TA) (%)	0.3	0.28	0.27	0.28
Total sugars (%)	7.2	7.5	8.6	8.7
SS/TA Ratio	72.1	80.6	86.6	80.7
Proteins (%)	1.0	0.99	0.87	0.99
Lipids (%)	1.54	1.13	1.20	1.33
Fibers (%)	2.39	2.37	3.22	3.09
Ashes (%)	0.39	0.50	0.56	0.63
Moisture (%)	86.9	85.2	84.4	83.7
Carbohydrates (%)	10.3	12.4	12.9	13.4
Dry matter (%)	13.2	14.9	15.5	16.0
Canonical variable (CV) ^{1/}	2.37	2.48	2.58	2.56

^{1/}CV=0.01083612 * protein - 0.02334588 * lipids+0.06523551 * fibers+0.73489504 * ashes+0.01667250 * moisture+0.00761084 * carbohydrates - 0.01376635 * sugars - 0.00032907 * dough total mass+0.00593143 * transverse diameter - 0.00224888 * longitudinal diameter+0.01588613 * Soluble solids+0.21979416 * Acidity+0.00199253 * SS/TA ratio - 0.01062828 * dry mass with auto value=83%

for the plants (Table 2). Maximum values for the fruit quality variables were calculated from the 144 g dose of K_2O per plant (Fig. 1).

The results observed in relation to the size of the fruit show increases in mass and diameters in the pitayas of the two species, in the two harvests evaluated (Tables 2).

The mass is one of the important variables to classify the fruits for commercialization, the size observed in

the fruits of the plants that did not receive potassium fertilization masses changed from 136 to 165 g, while the fruits produced by the plants fertilized with 144 g of K_2O presented mass of 191 to 203 g, representing increments of 17% and 36% (Table 2).

In the *H. polyrhizus* species, fertilization with 144 g of K_2O per plant provided the production of fruits with a transverse diameter of 78.5 mm and longitudinal diameter between 78.5 mm to 81.72 mm, and mass of 195 g to 200 g, 25% higher than fruit of plants that were not fertilized with K (Table 2).

In relation to the chemical characteristics evaluated, the fruits of *H. undatus* fertilized with K_2O showed differences in relation to soluble solids and total sugars and titrateable acidity (Table 2), soluble solids contents at 17.7 ° Brix and total sugars 6.4% to 8.9% with the dose of 144 g of K_2O per plant, whereas in the fruits of the non-fertilized plants the values of soluble solids observed ranged from 16.3 ° Brix to 16.7 ° Brix and 5.4% to 7.4% of sugars, in the two cycles evaluated and acidity reduction from 0.23% to 0.18%. In the *H. polyrhizus* fruits fertilized with the 144 g dose of K_2O , soluble solids contents reached 22.1 ° Brix to 20.2 ° Brix, and 7.4% and 11.6% sugars, and the acidity ranged from 0.24% to 0.17% (Table 2), in the third and fourth cycle, respectively.

The titrateable acidity ranged from 0.51% to 0.19% in the fruits of *H. undatus* and from 0.24% to 0.17% in the fruits of *H. polyrhizus* in the two harvests evaluated. The SS / TA ratio varied from 34.4 and 81.7, in the fruits of *H. undatus* and from 88.3 to 123, in the fruits of *H. polyrhizus* (Table 2).

Centesimal composition

For the protein and lipid contents, no differences were observed in the fruits, in the harvests evaluated (Table 3).

Fibers contents increased in the two harvests evaluated, from 2.3% to 3.3% and 3.01% to 3.6%, in the pitayas of the *H. undatus* species and from 1.5% to 2.2% and 2.2% to 2.8%, in the pitayas of the *H. polyrhizus* (Table 3).

The ash contents increased in the pitayas with potassium fertilization, varying from 0.5% to 0.68% and 0.3%, to 0.55%, in the *H. undatus* species, in the productive cycles, respectively. In the pitayas of the *H. polyrhizus* the contents varied from 0.49% to 0.60% and 0.33% 0.48% (Table 3), comparing fruit harvested in plants that did not receive potassium fertilization and fruits of plants fertilized with the dose of 144 g of K_2O .

Carbohydrates increased with availability of K_2O for plants. In the fruits of the *H. undatus*, concentrations increased

Table 2: Equation of Regression and determination coefficients (R²) for mean total fruit mass, transverse diameter, longitudinal diameter, soluble solids content, titratable acidity (TA), total sugars and the SS/TA ratio, in function of the K₂O doses in pitayas of the species *Hylocereus undatus* and *Hylocereus polyrhizus* in the second and third productive cycles

Variables	Equation	R ²	Maximum value	Equation	R ²	Maximum value
	<i>H. undatus</i>			<i>H. polyrhizus</i>		
	Third cycle of production					
Mass (g)	$\hat{Y} = 165.3+0.181571x^{**}$	94	191.4	$\hat{Y} = 157.38+0.638x - 0.00259x^{2**}$	86	195.7
Transverse diameter (mm)	$\hat{Y} = 58.76+0.0691x^{**}$	85	68.7	$\hat{Y}=71,7115+0.202x - 0.0011x^{2**}$	98	78.5
Longitudinal diameter (mm)	$\hat{Y} = 62.72+0.1078x^{**}$	96	78.2	$\hat{Y} = 69.6778+0.282x - 0.0014x^{2**}$	99	84.1
Soluble solids (°Brix)	$\hat{Y} = 16.34+0.00959x^{*}$	88	17.7	$\hat{Y} = 19.77+0.0393x - 0.00017x^{2**}$	99	22.1
Titrateable acidity (TA) (%)	$\hat{Y} = 0.51^{ns}$	-	0.5	$\hat{Y} = 0.24^{ns}$	-	0.24
Total Sugars	$\hat{Y} = 5.407+0.00698x^{**}$	94	6.4	$\hat{Y} = 6.42+0.00742x^{**}$	91	7.5
SS/TA Ratio	$= 34.41^{ns}$	-	34.4	$\hat{Y} = 88.28^{ns}$	-	88.3
Productivity (t ha ⁻¹)	$\hat{Y}=5.6545+0.01536x^{**}$	84	8.7	$\hat{Y} = 6.3470+0.00754x^{**}$	97	7.9
Fourth cycle of production						
Mass (g)	$\hat{Y}=136.623+0.4637x^{**}$	92	203.4	$\hat{Y} = 137.67+1.119x - 0.00476x^{2**}$	97	200.8
Transverse diameter (mm)	$\hat{Y}= 60.71+0.09278x^{**}$	79	74.1	$\hat{Y} = 52.985+0.364x - 0,0013x^{2**}$	92	78.5
Longitudinal diameter (mm)	$\hat{Y}= 61.96+0.045194x^{**}$	81	68.5	$\hat{Y} = 54.085+0.3043x - 0.0012x^{**}$	91	78.5
Soluble solids (°Brix)	$\hat{Y}= 17,02^{ns}$	-	17.0	$\hat{Y} = 19.26^{ns}$	-	19.3
Titrateable acidity (TA) (%)	$\hat{Y} = 0.237 - 0.000286x$	75	0.19	$\hat{Y} = 0.17^{ns}$	-	0.17
Total Sugars	$\hat{Y} = 7.163+0.03348x - 0.000136x^{2**}$	96	9.2	$\hat{Y} = 9.141+0.0401x - 0.00016x^{2**}$	90	11.6
SS/TA Ratio	$\hat{Y} = 81.77^{ns}$	-	81.8	$\hat{Y} = 113.23^{ns}$	-	113.2
Productivity (t ha ⁻¹)	$\hat{Y} = 1.2151+0.079x - 0,00025x^{2**}$	95	7.5	$\hat{Y} = 2.1105+0.02913x^{**}$	81	7.9

** = significant, at 1% and ns=not significant $p < 0.05$ **Table 3: Regression equations and determination coefficient (R²) for protein, lipid, fiber, ash, carbohydrate, moisture, dry matter (g 100g⁻¹) and energy value (kcal), as a function of the doses of K₂O in pitayas of the *Hylocereus undatus* and *Hylocereus polyrhizus* species, in the second and third productive cycles**

Variables	Equation	R ²	Maximum value	Equation	R ²	Maximum value
	<i>H. undatus</i>			<i>H. polyrhizus</i>		
	Third cycle of production					
Proteins (%)	$\hat{Y}= 1.2137^{ns}$	-	1.2	$\hat{Y} = 0.864^{ns}$	-	0.86
Lipids (%)	$\hat{Y}= 1.1356^{ns}$	-	1.1	$\hat{Y} = 1.11^{ns}$	-	1.1
Fibers (%)	$\hat{Y}= 2.263+0.00714x^{**}$	92	3.3	$\hat{Y} = 1.541+0.00493x^{**}$	96	2.2
Ashes (%)	$\hat{Y}= 0.5+0.001293x^{**}$	94	0.68	$\hat{Y} = 0.4905+0.000766x^{**}$	91	0.6
Carbohydrates	$\hat{Y}= 10.403+0.00914x^{**}$	87	11.7	$\hat{Y} = 12.3055+0.008023x^{**}$	92	13.5
Energy value (kcal)	$\hat{Y}= 60.17^{ns}$	-	60.2	$\hat{Y}=57.3867+0.2495x - 0.001x^{2**}$	99	72.6
Moisture	$\hat{Y}= 86.509 - 0.00667x^{**}$	75	85.5	$\hat{Y} = 85.621 - 0.01511x^{**}$	95	83.4
Dry matter	$\hat{Y}= 13.441+0.00697x^{**}$	95	14.4	$\hat{Y} = 13.269+0.01561x^{**}$	94	15.5
Fourth cycle of production						
Proteins (%)	$\hat{Y}= 1.0512^{ns}$	-	1.05	$\hat{Y} = 0.71^{ns}$	-	0,71
Lipids (%)	$\hat{Y}= 1.3287^{ns}$	-	1.3	$\hat{Y} = 1.547^{ns}$	-	1.55
Fibers (%)	$\hat{Y}= 3.0185+0.00389x^{**}$	83	3.6	$\hat{Y} = 2.263+0.00361x^{*}$	85	2.78
Ashes (%)	$\hat{Y}= 0.352+0.00141x^{**}$	84	0.55	$\hat{Y} = 0.3365+0.001004x^{**}$	90	0.48
Carbohydrates	$\hat{Y}= 10.061+0.07112x - 0.00028x^{2**}$	94	14.5	$\hat{Y} = 8.16664+0.09494x - 0.00035x^{2**}$	93	14.5
energy value (kcal)	$\hat{Y}=60.706+0.0668x^{**}$	94	70.3	$\hat{Y} = 53,4465+0,3241x - 0,0013x^{2**}$	94	73.2
Moisture	$\hat{Y}= 85.9665 - 0.023x^{**}$	76	82.6	$\hat{Y} = 87.185 - 0,0226x^{*}$	88	83.9
Dry matter	$\hat{Y}= 12.985+0.0658x - 0.00025x^{2**}$	95	17.3	$\hat{Y} = 11.1908+0.0917x - 0.00035x^{2**}$	91	17.0

** = significant, at 1%; * = significant, at 5%; and ns=not significant $p < 0.05$

from 10.4% and 11.7% to 11.7% and 14.5%, when the plants received the dose of 144 g of K₂O, and in fruits of the *H. polyrhizus* species, from 12.3% and 8.1% to 13.4% and 14.4%, in the third and fourth cycles, respectively (Table 3).

Pitayas harvested in plants with potassium fertilization showed higher energy value (kcal). In fruits of the

H. undatus species, the energy value increased from 60 kcal to 70 kcal with the dose of 144 g K₂O. Similar results were observed in pitayas of the *H. polyrhizus*, values increased from 57 kcal and 53 kcal to 72 kcal and 73 kcal, in the two harvests, respectively (Table 3).

As for moisture, a reduction of the content in the pitayas was observed with the availability of K₂O, in the two

harvests evaluated (Table 3). The reduction varied from 86.5% to 85.5% and from 85.9% to 82.6%, in the fruits of *H. undatus* and from 85.1% to 83.4% and from 87.2% and 83.9% in fruit of the *H. polyrhizus* species.

The dry matter in the pitayas of the *H. undatus* and *H. polyrhizus* species increased with potassium fertilization, in the two cycles evaluated. The dry matter content increased from 13.4% to 14.4% and from 12.9% to 17.2% in fruits of the species *H. undatus* and from 13.2% to 15.5% and from 11, 1% to 17% in *H. polyrhizus* fruits.

DISCUSSION

The improvement of the variables related to the quality of pitayas is in agrees with what has been reported in relation to potassium fertilization in other fruit species, that is, that K is important in the production of good quality fruits. In other fruit species the action of K on fruit size increase is not exactly known, but it is admitted that it participates in the metabolic activities related to the synthesis and transport of carbohydrates and water to the fruits, resulting in an increase in fruit mass (Aular and Natale, 2013). For the pitaya, the increase in size was observed for three consecutive harvests, with the increase of orchard productivity, due to the increase of the K doses supplied to the plants, evidencing the action of K on the mass gain (Fernandes et al., 2018).

The improvement in the fruits composition with the availability of K_2O occurs because this nutrient participates in metabolic processes, such as synthesis of proteins and sugars, being responsible for transporting sugars and carbohydrates to fruits. In addition, plants adequately supplied with K_2O produce fruits with higher nutritional properties, such as, protein, oils and vitamins contents and flavor (Senapati and Santra, 2009; IPI, 2013). However, for the pitaya there were no studies correlating the fertilization of the plants with the composition of the fruits, being the results of this research pioneer.

The difference observed in the adjustment of the regression equations as a function of the doses of K_2O , mainly regarding the size variables, among the pitaya species in this work can be attributed to the vegetative vigor of the *H. undatus* species, which surpasses that of *H. polyrhizus*, with the emission of greater number and size of cladodes, which, possibly, increases the demand for nutrients.

The increase in the pitayas size is interesting for the marking, considering the classification of the fruits for the commercialization by the international standard. The pitayas produced with potassium fertilization are in class

B of the size table, while the fruits of the plants without fertilization are in class A (FAO, 2004), that is, they can reach higher prices in the market, considering that this characteristic associated to the other external variables that are responsible for the final quality.

Another important factor for the producer is that with the realize of the adequate potassium fertilization, more fruits per plant were harvested (Table 2), that is, a larger quantity of fruits with a standard for commercialization. This is important because size is one of the variables that are directly linked to productivity. In the results of the third and fourth harvests evaluated, this can be observed, mainly in *H. undatus* species (Table 2), because it is a species that presents greater vegetative growth, in which the size varied in the two harvests evaluated, as a function of productivity achieved.

The results related to soluble solids content, total sugars and titratable acidity observed in the present study indicate that the potassium fertilization improved the quality variables of the pitayas. This is because the concentration of soluble solids has been associated with the amount of sugars in the fruit and, therefore, is a desirable characteristic, because the high the content in the fruit, the higher its acceptance by the consumers.

Fruits with soluble solids content higher than 12 ° Brix or 13 ° Brix present better acceptance for consumption (Wanitchang et al., 2010). Fruits with higher sugar contents are more accepted because the soluble sugars are responsible for the sweetness and flavor of fruits, which constitutes the majority of soluble solids in the form of glucose, fructose and sucrose (Cordeiro et al., 2015).

In addition to the influence of fertilization, it is possible to observe that there was variation in these variables as a function of the harvest season in the two productive cycles evaluated, which can be attributed to the rainfall incidence and the temperatures when the samples were harvested. Because in the place of cultivation the period of production of the pitaya species coincides with the rainy season. Thus, depending on the volume of rainfall in the days preceding the harvest, dilution of soluble sugars occurs in the fruits, directly reflecting in these variables. During the third harvest there was a higher concentration of rain during the period of formation, growth and harvest of the fruits, and different temperature variations compared to fourth cycle productive.

The sugar content increases during the development of pitayas, reaching from 7% to 9% (Nerd et al., 2002; Osorio et al., 2013). In the present work, the content varied from 6.4% to 11.6% in the pitayas harvested in plants fertilized with K_2O .

The observed improvement in the quality of pitayas with potassium fertilization can be related to the enzymatic activation that is essential for the production and redistribution of sugars for fruits (IPI, 2013).

For titratable acidity, the results observed in relation to the low acid percentages, is a characteristic of pitayas, which makes them flavored smooth. The results reported for the pitayas vary from 0.07% to 0.51% (Moreira et al., 2011; Lima et al., 2013; Cordeiro et al., 2015; Fernandes et al., 2018). The variation in acidity may be related to the maturation stage at the time of harvest (Ortiz and Takahashi, 2015) and to the time and storage conditions, which can reduce the acidity rapidly as a function of the metabolic and physiological processes (Brunini and Cardoso, 2011; Duarte et al., 2017) that use organic acids as a substrate for respiration. In addition, the climatic conditions can influence this variable, since the occurrence of rains can cause the dilution of organic acids in the fruits.

The change SS / TA ratio in the pitayas is most often caused by the drastic reduction of acidity, so that the high SS / TA ratio does not always indicate satisfactory contents of soluble solids (Osuna Enciso et al., 2011). Some authors consider the ideal value of the SS / TA ratio in pitayas of approximately 40, which occurs in mature fruits with 0.4% acidity (To et al., 2002).

The increase in soluble solids contents and the reduction in acidity contribute to increase SS / TA ratio in fruits and consumer acceptance. Considering this variable, it is worth mentioning the pitayas of the *H. polyrhizus* species, which present a high relation, more than double the ideal value, between 88.1 and 123, indicating that the fruits of this species present a more attractive flavor compared to *H. undatus*.

For protein concentrations, the observed results show that the production of proteins in the plant depends of the N that is transported from the roots to the aerial part, and the K assists in this transport, since it determines the balance of salts and water in the plant. For the pitaya's species evaluated, the availability of N can had been lower than that of K. Thus, probably because of this reason the increase of the potassium doses did not interfere in the contents of protein.

In relation to lipids, the contents in the pitayas can be high if the methodology used to extract oil from the seeds, since they have high oil content, reaching yield of 18.33% to 28.37%. (Lim et al., 2010). Thus, the low lipids contents evaluated in this study may be related to the methodology used, since the analysis was done in the pulp containing the intact seeds.

CONCLUSIONS

Pitaya species fertilized with potassium produce larger fruits and better flavor, improving the final quality. The centesimal composition of pitayas is altered with the management of orchard fertilization.

The *Hylocereus undatus* and *Hylocereus polyrhizus* species with the availability of potassium produce fruits most rich in fibers, minerals, carbohydrates and energetic value, and with lower humidity, allowing the preservation for longer if properly stored.

ACKNOWLEDGMENT

This study was financed in part by the Coordination for the Improvement of Higher Education Personnel (CAPES) - Brazil - Finance Code 001. The Federal University of the Jequitinhonha and Mucuri Valley (UFVJM) provided the infrastructure needed to conduct this study.

Authors' contributions

Josimara Mendes Rabelo, Cíntia Gonçalves Sena and Letícia Alves Carvalho designed and performed experiments, in addition to analysed data. Maria do Céu Monteiro Cruz, Lílían de Araújo Pantoja and Alexandre Soares dos Santos supervised the research. Amanda Gonçalves Guimarães wrote the paper. All authors read and approved the final manuscript.

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