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Bioactive compounds and physico-chemical characteristics of guavas bagged with different materials

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Abstract

There are several alternatives to bags used for field fruit bagging but little is known about their management in the orchards and the influence of the materials on the phytochemicals and on the physicochemical properties of the fruits after harvest. This study aimed at evaluating fruit bagging with different materials regarding its management and interference in bioactive compounds and physico-chemical features of guava cultivars 'Paluma', 'Século XXI' and 'Pedro Sato', which were cultivated in an organic farming system. The experiment was carried in Brazilian Agricultural Research Corporation in 2014/2015 and 2015/2016 harvests. Guavas underwent the following treatments: no bagging (witness); non-woven fabric (TNT); kraft paper; white paper and transparent perforated polyethylene. The following fruit quality variables were analyzed: total phenols; antioxidant activity; carotenoids; peel color; soluble solids; pH; and titratable acidity. This study found that bagging materials interfered both in the phenol content and in the antioxidant activity of the three guava cultivars even though they did not affect pulp carotenoids. Fruit bagging with TNT and transparent perforated polyethylene provided more resistance against weather adversities. Bagging of guava cultivars 'Paluma', 'Século XXI' and 'Pedro Sato' changed the phytochemical and physicochemical features of the fruits.

Keywords: antioxidant activity, *Psidium guajava,* peel color, total phenols

Introduction

Brazil has a great diversity of fruits among which guava stands out because it is one of the most appreciated tropical fruits, mainly as a result of its aroma, flavor and nutritional value. Farmers prefer the red pulp guava since it can be both used by the processing industry and consumed *in natura* (Haida et al., 2015; Santos et al., 2020). In Brazil, guava production takes place mainly in tropical and subtropical regions located in the Southeast and in the Northeast, especially in São Paulo and Pernambuco states (IBGE, 2020). Most plantations of guava trees in these states have been owned by small farmers who have found an alternative in which there is income diversification and value aggregation.

Despite the rusticity of the guava tree and few requirements of chemical inputs, this culture has been it still needs some adjustments. Guava is among the most attacked fruit species by insects and pathogens, which leads to the use of pesticides for phytosanitary treatments, especially to control fruit flies in conventional cultivation systems. Guava bagging has been a common practice of farmers who aim at reducing pesticide use, mainly in organic farming systems, so as to avoid damage caused by insect pest (Neto et al,. 2020). Fruit farming has used several types of packaging for bagging fruits. The most common one is the paper bag, but fruit protection also employs kraft paper, TNT, polypropylene and perforated polyethylene (Azevedo et al., 2016; Neto et al., 2020; Sharma et al. 2020). Fruit bagging practices have already been investigated with different cultures, such as apple (Santos et al., 2015; Azevedo et al., 2016) and guava (Abbasi et al., 2014; Azevedo et al., 2016; Neto et al., 2020; Sharma et al. 2020) trees. Despite the benefits of bagging, the high cost of manpower needed to carry out this task, which is also affected by weather adversities, ends up increasing production cost. As a result, these facts hinder

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its use and lower its competitiveness.

Even though the control of insect pests and even diseases is efficient (Azevedo et al., 2016; Sharma et al., 2020), bagging ends up creating a physical barrier against the incidence of sun rays, besides developing an environment which interferes in the fruit quality by affecting fruit temperature and gas exchange, i. e., fruit metabolism (Hossain et al., 2018). In this way, the bagging of the fruits can affect the phytochemical and physicochemical characteristics of the fruits. It is evident that bagging influences the quality of the fruit, such as weight gain, changes in color (Abbasi et al., 2014; Sharma et al., 2020), soluble solids (Meena et al., 2016; Sharma et al., 2020) and increase in vitamin C (Hossain et al., 2018). However, there is little information about the management of different packaging used for bagging guavas in the weather conditions found in the south of Brazil and its interference in the concentration of bioactive compounds and physico-chemical quality.

Therefore, this study aimed at assessing the effect of bagging with different materials on the phytochemical and physicochemical features of guava cultivars ‘Paluma’, ‘Século XXI’ and ‘Pedro Sato’ which were cultivated in an organic farming system in Rio Grande do Sul.

Material And Methods

The experiment was carried out in the orchard at the Brazilian Agricultural Research Corporation in a suburb called Cascata, Pelotas, RS, Brazil. This region has humid temperate climate with hot summers, in agreement with the Köppen climate classification Cfa. The mean annual temperature and rainfall in the region are 17.9°C and 1500 mm, respectively.

Guava tree cultivars ‘Paluma’, ‘Pedro Sato’ and ‘Século XXI’, which were 7 years old, had been managed in an organic farming system since their implantation, spaced at 5 x 4 m and open-vase shaped. The following treatments were used in the 2014/2015 and 2015/2016 harvests: with no bagging (NB), non-woven fabric (TNT), kraft paper (KP), white paper (WP) and transparent perforated polyethylene (TPP). All materials were 13.5 cm in width x 26.0 cm in length. They were observed weekly and restored, in case they had undergone some damage due to climatic events.

The experimental design was carried out as randomized blocks in which treatments were applied to all quadrants of every plant. Six plants from each cultivar were selected to compose three blocks in two experimental units and from each block to collect ten fruits for evaluations of fruit quality. Bagging took place when fruits were from 2,0 a 3,0 cm (Azevedo et al., 2016). Cultivars ‘Paluma’ and ‘Século XXI’ had their fruits picked on March 16th, 2015 and on April 10th, 2016, whereas cultivar ‘Pedro Sato’ had them harvested on April 1st, 2015 and April 24th, 2016. In the bioactive compounds analysis, guava pulp with seeds was macerated with liquid nitrogen by a ball mill so as to yield the samples. Phenolic compounds were assessed in agreement with the methodology described by Singleton and Rossi (1965) and results were expressed as mg gallic acid equivalent/100 g^{-1} fresh weight. The antioxidant activity was determined by the method adapted from Brand-Williams et al. (1995), which uses the free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH), and results were expressed as inhibition percentage of the radical DPPH. Carotenoids were evaluated in agreement with the AOAC method 970.64 (2005), with some modifications, and results were expressed as mg β-carotene equivalent/100 g^{-1} fresh weight.

In order to determine the physico-chemical features of the fruit, the epidermis color was analyzed by a colorimeter through the CIE LAB system (with parameters L*, a*, b*). Values of a* and b* were used for calculating °Hue (°Hue = tan^{-1} b*/a*). Soluble solids (SS) were obtained by a digital refractometer, expressed as °Brix of the juice. The pH was directly read by a pH Meter. In order to determine titratable acidity (TA), 10 mL juice was diluted in 90 mL distilled water and titrated up to pH 8.1 with a solution of NaOH 0.1 mol/L. Results were expressed as percentage of citric acid.

Resulting data were subject to the Analysis of Variance and means were compared by the Tukey’s Test at 5% probability by the SISVAR statistical program version 5.6 (Ferreira, 2014).

Results and Discussion

Concentrations of the main groups of phytochemical compounds (total phenols and antioxidant activity) varied due to the bagging material (**Table 1**). Total phenolic compounds were altered by the type of bagging used with all three guava cultivars in both crops. The lowest total phenol concentrations were found in ‘Paluma’ fruits that were bagged with kraft paper and TPP, compared to guavas with no bagging. Cultivars ‘Século XXI’ and ‘Pedro Sato’ had the lowest concentrations in fruits bagged with TNT in the 2014/2015 harvest. While in the 2015/2016 harvest, fruits of all three cultivars had low total phenol concentrations when bagged with TPP and TNT in relation to guavas with no bagging. Regardless of the cultivar, non-bagged fruits had the highest total phenolic compound concentrations in both crops.

Table 1. Contents of total phenols (TP), antioxidant activity (AA) and total carotenoids (TC) of 'Paluma', 'Século XXI' and 'Pedro Sato' organic guavas with no bagging (NB), non-woven fabric (TNT), kraft paper (KP), white paper (WP) and transparent perforated polyethylene (TPP) in Pelotas, RS, Brazil, in 2014/2015 and 2015/2016 harvests

	2014/2015						2015/2016					
Treatments	TP[1]		AA[2]		TC[3]		TP[1]		AA[2]		TC[3]	
							'Paluma'					
NB	154.3	a	302.93	b	18.64	ns	115.40	a	263.17	b	13.98	ns
TNT	138.3	ab	527.75	a	15.78		102.66	b	311.08	a	17.77	
TPP	103.5	b	438.56	ab	16.52		90.89	b	263.66	b	16.36	
KP	121.5	ab	360.81	ab	18.58		-		-		-	
WP	112.6	b	429.37	ab	18.49		-		-		-	
CV (%)	10.83		14.52		8.41		6.8		13.92		12.89	
							'Século XXI'					
NB	189.3	a	209.39	ns	20.04	ns	176.82	a	268.87	ns	19.64	ns
TNT	141.9	b	186.83		22.00		121.16	c	275.37		23.48	
TPP	198.6	a	267.90		19.81		156.36	b	274.54		17.00	
KP	185.3	a	248.29		18.32		-		-		-	
WP	173.9	a	187.44		22.79		-		-		-	
CV (%)	10.84		32.72		20.02		1.56		14.74		18.7	
							'Pedro Sato'					
NB	141.6	a	327.83	ns	16.06	ns	112.19	a	204.41	ns	24.25	ns
TNT	89.08	b	468.27		15.31		88.21	b	225.97		22.48	
TPP	124.4	a	421.38		15.54		83.08	b	284.71		20.79	
KP	109.4	ab	358.19		14.46		-		-		-	
WP	120.0	a	464.86		15.46		-		-		-	
CV (%)	11.15		17.42		7.25		4.59		18.49		10.87	

[1] mg equivalent gallic acid $100g^{-1}$ fresh weight; [2] mg trolox equivalent $100g^{-1}$ fresh weight; [3] mg equivalent β-carotene $100g^{-1}$ fresh weight; * Mean values followed by the same letter in a column do not differ at 5% by Tukey test; - Not evaluated by exclusion of the type of bagging material.

Bagging material did not influence the antioxidant activity of guava cultivars 'Século XXI' and 'Pedro Sato' in both crops under assessment (Table 1). However, cultivar 'Paluma' fruits showed changes in the antioxidant activity concentration. In general, non-bagged 'Paluma' guavas had low antioxidant activity concentration whereas the use of TNT led to higher concentrations in both crops under study.

In both 2014/2015 and 2015/2016 harvests, bagging materials had no significant effect on carotenoid concentration of guava cultivars 'Paluma', 'Pedro Sato' and 'Século XXI' (Table 1). In the first crop, fruits bagged with kraft paper and white paper were observed to need bags to be replaced more than four times, from development to harvest, due to the weather conditions in the region, mainly frequent rainfall and strong winds. As a result, in the 2015/2016 harvest, there was an adjustment in the treatments, i e., kraft paper and white paper were eliminated but the other bagging materials were kept.

Luminosity values (L*) characterize lighter colors since they are closer to pure white. The bagging material in any crop did not influence luminosity in the epidermis of 'Pedro Sato' and 'Século XXI' guavas. However, it interfered in the values found in 'Paluma' fruits in the 2014/2015 harvest (**Table 2**).

The more negative coordinate a* is the greener the rind; thus, TNT provided a greener color to the rind of 'Paluma' guavas in 2014/2015 and 2015/2016 harvests and to 'Pedro Sato' ones in the 2015/2016 harvest (Table 2). Regarding 'Século XXI' guavas, the materials did not influence coordinate a*, i. e., the green color of the rind in both crops. When coordinate b* is positive, it indicates a stronger shade of yellow on the rind and all materials used for bagging influenced b* of the three guava cultivars in both crops (Table 2).

The material used for bagging guavas in both crops (**Table 3**) influenced soluble solids, pH and titratable acidity in cultivar 'Século XXI'. Non-bagged guavas of cultivar 'Século XXI' had high content of soluble solids, even though they did not differ from fruits bagged with TNT and TPP in the 2014/2015 harvest. However, unbagged 'Século XXI' and 'Paluma' guavas also had high soluble solid contents in the 2015/2016 harvest.

Non-bagged guavas increased their pH in the three guava cultivars in both crops (Table 3). There was no difference between the titratable acidity of 'Paluma' and 'Pedro Sato' cultivars with the bagging materials in the 2014/2015 harvest, but in the second harvest, titratable acidity was lower in fruits with TNT and TPP (Table 3). Titratable acidity was lower in 'Século XXI' fruits with TNT and TPP bags in both crops.

Non-bagged fruits had the highest total phenolic compound concentrations in both crops. It may have happened due to exposure to climate adversities and attacks of both insect pests and pathogenic fungi.

Table 2. Luminosity (L*), a* and b* of the rind of 'Paluma', 'Século XXI' and 'Pedro Sato' Sato' organic guavas with no bagging (NB), non-woven fabric (TNT), kraft paper (KP), white paper (WP) and transparent perforated polyethylene (TPP) in Pelotas, RS, Brazil, in 2014/2015 and 2015/2016 harvests

	2014/2015						2015/2016					
Treatments	L*		a*		b*		L*		a*		b*	
							'Paluma'					
NB	76.26	a	-3.37	b	49.71	a	75.92	ns	-2.37	b	46.22	a
TNT	65.48	b	-10.08	a	39.33	bc	74.93		-9.49	a	40.05	b
TPP	75.95	a	-1.62	b	41.18	bc	75.37		-5.00	ab	41.37	b
KP	68.44	ab	-5.72	b	37.28	c	-		-		-	
WP	72.21	ab	-3.81	b	42.88	bc	-		-		-	
CV (%)	4.52		20.7		4.29		2.96		11.01		2.8	
							'Século XXI'					
NB	70.04	ns	-8.21	ns	51.14	a	68.92	ns	-6.53	ns	47.87	a
TNT	59.93		-14.07		36.11	c	74.44		-6.22		44.37	b
TPP	71.55		-6.92		49.16	ab	75.28		-6.96		43.22	b
KP	68.94		-5.13		43.29	ab	-		-		-	
WP	61.06		-11.43		40.83	bc	-		-		-	
CV (%)	7.52		20.96		7.1		3.41		2.56		5.48	
							'Pedro Sato'					
NB	69.89	ns	-11.32	ns	42.74	a	58.70	ns	-8.28	c	35.03	a
TNT	60.94		-14.57		34.51	b	59.12		-15.7	a	33.64	b
TPP	65.39		-12.83		37.40	ab	61.54		-12.1	b	33.19	b
KP	64.32		-14.24		37.02	ab	-		-		-	
WP	60.24		-14.28		33.33	b	-		-		-	
CV (%)	6.68		12.21		6.88		1.15		6.72		0.94	

* Mean values followed by the same letter in a column do not differ at 5% by Tukey test.

Table 3. Soluble solids (SS), pH and titratable acidity (TA) of 'Paluma', 'Século XXI' and 'Pedro Sato' organic guavas with no bagging (NB), non-woven fabric (TNT), kraft paper (KP), white paper (WP) and transparent perforated polyethylene (TPP) in Pelotas, RS, Brazil, in 2014/2015 and 2015/2016 harvests

	2014/2015						2015/2016					
Treatments	SS		pH		TA		SS		pH		TA	
							'Paluma'					
NB	10.36	ns	3.74	a	0.42	ns	10.46	a	4.60	a	0.48	a
TNT	10.00		3.48	bc	0.39		9.83	b	3.23	b	0.33	b
TPP	10.56		3.58	abc	0.42		9.20	b	3.80	b	0.30	b
KP	10.40		3.69	abc	0.37		-		-		-	
WP	10.50		3.43	c	0.30		-		-		-	
CV (%)	4.06		2.27		11.6		5.01		2.69		3.69	
							'Século XXI'					
NB	11.13	a	4.19	a	0.21	ab	9.50	a	4.03	a	0.34	a
TNT	10.53	ab	4.08	ab	0.16	b	9.10	b	4.08	a	0.26	b
TPP	10.90	ab	4.03	abc	0.16	b	9.22	b	3.69	b	0.32	b
KP	10.26	b	3.95	bc	0.25	a	-		-		-	
WP	10.30	b	3.85	c	0.28	a	-		-		-	
CV (%)	2.31		1.61		12.5		2.12		1.31		9.01	
							'Pedro Sato'					
NB	9.56	ns	4.25	a	0.25	ns	9.15	ns	3.93	a	0.35	a
TNT	9.43		4.15	b	0.21		9.30		3.70	b	0.32	b
TPP	10.03		4.06	c	0.23		9.80		3.73	b	0.31	b
KP	10.06		4.15	b	0.23		-		-		-	
WP	10.10		4.08	ac	0.21		-		-		-	
CV (%)	5.66		0.61		9.24		2.51		1.41		2.8	

* Mean values followed by the same letter in a column do not differ at 5% by Tukey test.
- Not evaluated by exclusion of the type of bagging material.

Phenolic compounds are formed in stress conditions (Kabtni et al., 2020) and pathogens (Deus et al., 2019). Variation in phenolic compound concentrations results from responses to environmental stress, such as temperature, transpiration, oxygen and attacks of phytopathogens and pests.

Considering that, in this study, soil and climate conditions, plant management system and fruit maturity at harvest were the same, differences observed among cultivars in terms of results of total phenolic compounds and antioxidant activity may be due to fruit genetic differences (Amarante et al., 2017) and bagging (Sharma et al. 2020). Farming systems, such as organic ones, may also influence phenolic compound concentrations. According to Filho et al. (2017), changes in phenol concentrations result from climate conditions and plant management. Few studies have aimed at evaluating the influence of farming systems on fruit antioxidant activity (Deus et al. 2019). However, Vallverdú-Queralt et al. (2012) stated that organic fruit may have high polyphenol concentrations due to high phosphorus absorption and restricted nitrogen availability.

In this study, a difference in antioxidant activity was observed of guavas bagged with different materials, a fact that was also reported by Sharma et al. (2020). The use of TNT in 'Paluma' guavas had led to higher concentrations of antioxidant activity. Similar result was replaced by Sharma et al. (2020).

It should be highligh ted that bags made of TNT and TPP were resistant to weather factors (wind, rain, sun). The bagging materials used resisted climatic variations throughout the experiment, without breaking, guaranteeing the integrity of the bagging. Plastic bags and TNT are efficient and resistant to rain and winds, however, paper bags are the most used due to their low cost (Meena et al., 2016; Hossain et al,. 2018). The treatments with TNT fabric and transparent plastic bags proved to be more resistant than the others (Neto et al., 2020)

'Paluma' had higher luminosity values in non-bagged fruits and in the ones with TPP, a fact that attributed light luminosity to the rind. It may be the result of higher exposure of the fruits to solar radiation. Fruit color is an attribute that consumers take into account when they are buying fruits. According Abassi et al. (2014) and Sharma et al. (2020), this variable may be affected by bagging.

'Paluma' (2014/2015 and 2015/2016) and 'Pedro Sato' (2015/2016) showed at greener color to the rind with the use of TNT, due to dense thickness, it may favor less passage of light to the fruit. It was also observed by Teixeira et al. (2011) who reported reduction in the red color of apples bagged with TNT, due to the low passage of light.

In the three guava cultivars, non-bagged fruits had a stronger shade of yellow on the rind. It may be due to early maturity, provoked by the attack of fruit flies in this treatment. Due to the damage, these fruits may increase ethylene concentration, which is related to fruit maturity and senescence, as an answer to stress caused by the mechanical action of biotic agents.

Titratable acidity varied according to the bagging material and seasons. The effect of the decrease in the titratable acidity may be related to changes in the environment that the bagging material offers to the fruit. Santos et al. (2015) reported that the titratable acidity of apples was lower in bagged fruits than in non-bagged ones.

Conclusions

Bagging interferes in the bioactive compounds and physico-chemical of guavas, mainly the cultivar 'Século XXI'.

Carotenoids are not affected by different materials used in the bagging of the three guava cultivars.

Guavas bagged with TNT showed the best physico-chemical but also resisted well to inclement weather.

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