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QUALITY OF 'TAINUNG NO. 1' PAPAYA IN FUNCTION OF PRODUCTION TIMES AND IRRIGATION MANAGEMENTS

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ABSTRACT

This study evaluates the quality of 'Tainung no. 1' papaya cultivated by partial rootzone drying (PRD) at summer and winter seasons, in Mocambinho, Jaíba, Minas Gerais, Brazil. The ten treatments resulted from the combination of four PRD forms and one with full irrigation (FI), without water deficit, during two production seasons. The experiments were set up in an entirely randomized. The treatments using PRD were based on the reduction of the calculated irrigation water level by 50%, alternating the side of the irrigated row with only one lateral line irrigation per row. The alternating frequencies (AF - changing of sides) were 7, 14 and 21 days and a fixed side without alternation. The FI was composed per two lateral lines per row of plants. The quality and sensorial evaluations were performed on ripe fruits (totally yellow peel). Papayas produced in summer were larger, firmer, with an orange and more acidic pulp. Irrigation managements interfered with the purchase intention and the sensorial attributes of fruits produced in summer and winter. Consumers liked the overall appearance and the color of papaya pulp produced in the summer, with the exception of PRD AF 7 days. The acceptance of texture and flavor varied depending on irrigation management.

Keywords: *Carica papaya* L., water deficit, partial rootzone drying, postharvest.

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QUALIDADE DE MAMÃO 'TAINUNG Nº1' EM FUNÇÃO DE ÉPOCAS DE PRODUÇÃO E MANEJO DE IRRIGAÇÃO

ABSTRACT

Este estudo avaliou a qualidade do mamão 'Tainung nº 1 ' cultivado sob secamento parcial do sistema radicular (SPR) nas estações de verão e inverno, em Mocambinho, Jaíba, Minas Gerais, Brasil. Os tratamentos resultaram da combinação de quatro formas de SPR e um com irrigação plena (IP), sem déficit hídrico, durante duas safras de produção. O delineamento experimental foi o inteiramente casualizado. Os tratamentos com SPR basearam-se na redução do nível da água de irrigação calculada em 50%, alternando o lado da fileira irrigada, com apenas uma linha de irrigação por fileira. As freqüências alternadas (FA - troca de lados) foram 7, 14 e 21 dias e um lado fixo sem alternância. A IP foi composta por duas linhas laterais por fileira de plantas. As avaliações de qualidade e sensorial foram realizadas nos frutos maduros (casca totalmente amarela). Mamões produzidos no verão foram maiores, mais firmes, mais ácidos e com polpa alaranjada. Os manejos de irrigação interferiram na intenção de compra e nos atributos sensoriais dos frutos produzidos no verão e no inverno. Os consumidores gostaram mais da aparência e cor da polpa do mamão produzido no verão, exceto para SPR FA 7 dias. A aceitação da textura e sabor variou dependendo do manejo da irrigação.

Palavras-chave: *Carica papaya* L., déficit hídrico, secamento parcial do sistema radicular, pós-colheita.

INTRODUCTION

The papaya (*Carica papaya* L.) is an important fruit tree grown in tropical and subtropical areas around the world. India, Brazil and Mexico are the main producers (FAOSTAT, 2018).

According to data from IBGE (2020), Brazil produced 1,060,392 tons of papaya in 2018, with an emphasis on the northeast and southeast regions, responsible for about 92% of the national production. Minas Gerais ranks sixth among the largest producers, producing 50.061 thousand tons of fruit, and 61% of this production comes from the northern region of the state.

The hybrid 'Tainung no. 1' is the most cultivated Formosa genotype in Brazil, with fruits presenting an average weight between 800 and 1,100 g, and a red-orange pulp with a pleasant flavor. The fruits present a good durability and resistance to transport (COSTA et al., 2013).

Because it is a typically tropical plant, it is possible that papaya produces high-quality fruits in regions with high insolation and temperatures varying between 22ºC and 28ºC (SANCHES, 2012). According to the author, the plant is demanding in water, which can be supplied with an annual distribution of 1,800-2,000 mm per year of rainfalls, or in semi-arid places with little rainfall through irrigation.

The lack of rainfalls in some fruit producing regions has been a reality in the country for some years. The optimization in the use of water resources is necessary, especially in semi-arid regions, which, in addition to low rainfalls, their distribution occurs in a few months of the year, as is the case of the northern region of Minas Gerais. Thus, it is necessary to use techniques that increase the efficiency of the use of water by crops without losing production and fruit quality.

The PRD (partial rootzone drying) irrigates part of the root system of the plant. The other part is subjected to soil drying, in which factors such as plant species, soil type and climatic conditions determine the alternation of frequency of irrigation sides (SAMPAIO et al., 2014). It is a method that advocates increasing the efficiency of water

use and has been studied in different crops, such as cotton, citrus, papaya, wheat and corn (LI et al., 2017; KUSAKABE et al., 2016; DE LIMA et al., 2015; SAMPAIO et al., 2014; EL-SADEK, 2014). These studies confirm this technique as a good alternative for semiarid regions. The good responses obtained by PRD are through the signaling of abscisic acid (ABA) at the root, inducing stomatal closure with consequent water saving (EL-SADEK, 2014).

According to Aular e Natale (2013), external characteristics such as size, shape, appearance, color, texture and firmness uniformity, in addition to the internal ones such as aroma, flavor, nutritional value, acidity and soluble solids, determine the quality of the fruits. Information on the use of PRD for papaya cultivation in the literature is still scarce, and it is therefore important to investigate possible changes in the characteristics mentioned above. This study evaluates the quality of 'Tainung no. 1' papaya produced under different irrigation managements cultivated at different times.

MATERIALS AND METHODS

The papaya garden was implanted and conducted in an Experimental Field located in Mocambinho, in the district of Jaíba, North of Minas Gerais, Brazil. Its geographical coordinates are 43°29' S and 14°33' W, average altitude of 515 m and annual average rainfall of 938 mm. The climate of the region is AW (tropical rainy, savannah with a dry winter), according to Köppen. The soil is classified as Eutrophic Red Latosol. The 'Tainung no. 1' papaya cultivar was used. The plants were planted in a 3.0 m x 1.7 m spacing, and irrigated by drip irrigation with two lateral lines per row of plants containing six water emitters of 4 L h^{-1} per plant, three per lateral line.

Treatments consisting of the irrigation water management by partial rootzone drying (PRD) were distributed in the field in experimental plots containing ten plants in two rows, with six useful plants per plot. The quality of fruits produced in summer or winter, in different managements by PRD, was also evaluated.

The PRD was based on a reduction of the calculated irrigation water level by 50%, i.e., alternating the irrigated row side by three alternating frequencies (AF): 7, 14 and 21 days. The water managements, therefore, were Management 1 - PRD with a reduction of the calculated water level by 50% and 7 days AF (PRD-AF - 7 days); Management 2 - PRD with a reduction of the calculated water level by 50% and 14 days AF (PRD-AF - 14 days); Management 3 - PRD with a reduction of the calculated water level by 50% and AF of 21 days (PRD-AF - 21 days); Management 4 - PRD with a reduction of the calculated water level by 50% by irrigating only one side of the row of plants, without alternating; and Management 5 - full irrigation (the calculated level is applied integrally with two lateral lines, one on each side of the plant). The minimum and maximum temperature, rainfall and minimum and maximum relative air humidity at the time of flower opening until the harvest of the summer fruits (December 2016 to May 2017) were, respectively, 25.3°C and 26.8°C, 404.2 mm, 59.4 and 66.9%; in the winter (May to October 2017): 23.2°C and 25.0°C, 14.4 mm, 47.6% and 54.1% (http://www.inmet.gov.br/portal/index.php?r=estacoes/estacoesAutomaticas).

The fruits were harvested when they showed the first signs of yellowing that did not cover more than 15% of the peel, classified according to Companhia de Entrepostos e Armazéns Gerais de São Paulo - CEAGESP into "subgroup 1", which normally occurs four to six months after flower opening. The harvests began in May 2017 (production season: summer) and in October 2017 (production season: winter).

After harvesting, the fruits were subjected to physical, chemical and sensory evaluations.

The design was completely randomized with four replications of two fruits per plot in

a 5 x 2 factorial design, with water management by PRD and fruit production times, respectively.

When the fruits reached 50-75% of yellow peel (subgroup 5, according to the CEAGESP classification), they were submitted to physical, chemical and sensorial evaluations.

The length and diameter were measured using a manual caliper, and the values were expressed in centimeters (cm). For firmness, a manual penetrometer was used, with readings in the equatorial region of the fruits with peels. The results were expressed in N.

The instrumental color (°hue) of the peel and pulp was measured by a Minolta colorimeter. The hue angle indicates the hue angle or the true color, which varies between 0° and 360°; the angle 0° corresponds to the red color, 90° to yellow, 180° or -90° to green and 270° or -180° to blue. The determination of total carotenoids was made by spectrophotometry, whose concentration was obtained according to the methodology described by Lichtenthaler (1987), with results expressed in μg/mL.

The soluble solids content was obtained by grinding and homogenizing the fruit pulp, with a subsequent reading in a digital refractometer. The results were expressed in ºBrix, according to the Adolfo Lutz Institute (2008). For titratable acidity, titration with 0.1 N NaOH, according to the Adolfo Lutz Institute (2008), was used in a homogeneous sample, expressed in grams of citric acid/100g of pulp.

The sensory evaluation was performed with 81 participants aged between 18 and 60 years consuming papaya. The samples were presented monadically following a balanced design according to Dutcovisy (2013). Upon receiving the samples, participants evaluated the whole fruits and answered based on the overall appearance, whether or not they would buy the product, using a five-point scale, ranging from "definitely would not buy" to "definitely would buy."

In the product acceptance test, consumers were asked to observe the fruit and express how much they liked its appearance. Then, they received a sample (a ± 7 cm piece) and evaluated the pulp color, tasted the sample and expressed how much they liked the texture and flavor. This evaluation was performed through a hedonic scale of 9 points, which ranged from 1 (extremely did not like it) to 9 (I liked it extremely) (MEILGAARD, 1999).

For statistical analysis, the physical and chemical evaluation data were submitted to analysis of variance, considering as sources of variation the partial rootzone drying, production times and the interaction partial rootzone drying with production times. The design of subdivided plots was adopted: in plots, the partial rootzone drying; in subplots, the production times. The test was completely randomized with four replications.

The interaction was unfolded or not according to its significance. The levels of production times were compared by the F test and the effects of the partial were evaluated by Tukey test. The coefficients of variation for the plot (CV a) and the subplot (CV b) were calculated. For all conclusions, an α = 0.05 was considered.

The statistical model adopted for the analysis was as follows:

$$Y_{ijk} = \mu + \delta_k + \alpha_i + (\alpha\delta_{ik}) + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

where: Y_{ijk} = dependent variables; μ = population mean; α_i = plot effect, i = 1, 2, 3, 4, 5; $(\alpha\delta)_{ij}$ = experimental plot error; β_j = subplot effect, j = 1, 2; $(\alpha\beta)_{ij}$ = interaction; ε_{ijk} = random, normal and independent error distributed with mean 0 and variance σ^2.

For sensory tests, the data obtained were submitted to the tests of homogeneity and normality. As the parameters did not obey the respective criteria, nonparametric statistics was applied, submitting the data of each irrigation in isolation in both production periods to Wilcoxon test at a 5% level of significance ($p < 0.05$).

RESULTS AND DISCUSSION

There was no significant interaction nbetween irrigation management and studied times (p> 0.05) for fruit diameter and length (Table 1). There was no difference between fruits produced under different types of irrigation (p > 0.05). However, there was an effect of the production period analyzed separately (p <0.05), in which fruits produced in winter were smaller than those produced in the summer (Table 1). Berilli et al. (2007) monitored the growth rate of 'UENF/CALIMAN 01 (UC01)' papaya in relation to the accumulation of degree-days at three different times of the year, and observed that the fruits produced in August were shorter, assuming, therefore, that warmer periods during fruit development provide longer lengths in papaya, corroborating with what occurred in this study. In contrast, Barros et al. (2017) did not observe differences in the length of Tainung no. 1 papaya from different crops (winter and summer) cultivated in Espírito Santo state, Brazil. In relation to the firmness of the fruits (Table 1), the interaction between the different irrigation managements and fruit growing times was not significant, showing an independence between the factors. In addition, the irrigation management in isolation did not interfere with the firmness of the fruits. However, between periods of production, there was a significant difference, in which the papayas whose period between flowering and harvest occurred in summer were firmer than those of winter.

Table 1. Diameter (cm), length (cm) and firmness (N) of mature 'Tainung no. 1' papaya fruits produced with a reduction of the irrigation water level in two production periods.

	Diameter (cm)		
Irrigation management	Period between flowering and harvest		
	summer	winter	MEAN
PRD - AF - 7 days	9.09	9.31	9.06 a
PRD - AF - 14 days	10.19	10.69	10.44 a
PRD - AF - 21 days	8.93	11.84	10.38 a
PRD - Partial Irrigation	10.01	11.23	10.63 a
Full irrigation	9.93	9.59	9.76 a
MEAN	9.63 A	10.48 A	
CV (%) plot	19.85		
CV (%) subplot	17.66		
	Length (cm)		
	summer	winter	MEAN
PRD - AF - 7 days	21.81	18.31	20.06 a
PRD - AF - 14 days	22.25	17.88	20.07 a
PRD - AF - 21 days	23.49	19.44	21.47 a
PRD - Partial Irrigation	22.86	20.82	21.84 a
Full irrigation	20.54	22.70	21.70 a
MEAN	22.19 A	19.83 B	
CV (%) plot	10.89		9.16 a
CV (%) subplot	13.58		7.14 a
	Firmness (N)		
	summer	winter	MEAN
PRD - AF - 7 days	12.40	5.83	9.11 a
PRD - AF - 14 days	8.26	6.03	7.14 a
PRD - AF - 21 days	9.26	3.25	6.25 a
PRD - Partial Irrigation	7.27	4.05	5.66 a
Full irrigation	9.32	5.65	7.48 a
MEAN	9.30 A	4.96 B	
CV (%) plot	32.12		
CV (%) subplot	44.10		

Means followed by uppercase letters in rows and lowercase in columns differ significantly from each other at 5% probability by F test and Tukey test, respectively.

This may have been due to the low temperatures and relative humidity recorded between flowering and harvesting of winter fruits since, according to Chitarra and Chitarra (2005), temperature has a direct influence on metabolism, changing the structure of components of the cell wall and other compounds and modifying the texture and firmness.

The color of the pulp evaluated in an instrumental way pointed to a more reddish coloration in the fruits produced in the winter. However, in the chemical evaluation of carotenoids, which are the predominant pigments in the pulp, there was a higher concentration in summer fruits (Table 2). Studies on papayas from the 'Formosa', 'Golden' and 'Sunrise' groups indicate that the attractive orange color of papaya is due to some carotenoids present in the chemical composition of this fruit, mainly lycopene (first major), β-cryptoxanthin and β-carotene (SENTANIN; AMAYA, 2007). The relative concentrations of the pigments may impart different color nuances, and thus promote small differences in the results obtained by the different methods. This result suggests that there may have been a higher concentration of β-cryptoxanthin in fruits produced in the summer, yielding fruits with an orange pulp. According to SETIAWAN et al. (2001), the carotenoid content in fruits may vary according to the conditions of cultivation, maturation, varieties or cultivars, geographic locations and seasons.

Table 2. °hue (of peel and pulp) and total carotenoids (of the pulp) of mature 'Tainung no. 1' papaya fruits produced with a reduction of the irrigation water level in two production periods.

Irrigation management	Period between flowering and harvest		
	summer	Winter	MEAN
	°hue of peel		
PRD - AF - 7 days	76.89	74.55	75.72 a
PRD - AF - 14 days	71.39	75.20	73.29 a
PRD - AF - 21 days	77.98	73.98	75.98 a
PRD - Partial Irrigation	75.20	78.12	76.66 a
Full irrigation	77.67	74.34	76.00 a
MEAN	75.82 A	75.24 A	
CV (%) plot	6.12		
CV (%) subplot	4.88		
	°hue of pulp		
PRD - AF - 7 days	65.48	45.87	51.17 a
PRD - AF - 14 days	60.21	48.08	54.15 a
PRD - AF - 21 days	58.02	48.31	53.17 a
PRD - Partial Irrigation	57.56	45.96	51.76 a
Full irrigation	55.32	51.40	53.36 a
MEAN	57.52 A	47.92 B	
CV (%) plot	5.51		
CV (%) subplot	6.53		
	Total carotenoids of the pulp (μg/mL)		
PRD - AF - 7 days	76.25 a	69.86 a	73.05 a
PRD - AF - 14 days	79.77 a	67.17 a	73.47 a
PRD - AF - 21 days	73.10 a	66.99 a	70.04 a
PRD - Partial Irrigation	76.66 a	66.97 a	71.82 a
Full irrigation	76.66 a	69.41 a	73.03 a
MEAN	76.49 A	68.08 B	
CV (%) plot	5.46		
CV (%) subplot	7.11		

Means followed by uppercase letters in rows and lowercase in columns differ significantly from each other at 5% probability by F test and Tukey test, respectively.

Chen et al. (2017), in a work with 'Cabernet Sauvignon' grapes produced in two distinct regions of China, observed a greater accumulation of carotenoids (especially lycopene) in grapes coming from a vineyard cultivated in a climate characterized by hot, dry summers and cold, arid winters, harvested as berries in the size of peas and berries at the beginning of veraison (phase of color change of the grapes in which they enter the final phase of ripening).

There was no significant interaction between the factors nor between their isolated effects ($p>0.05$) for soluble solids content (Table 3). Fillipou (2011) reported that plants subjected to water stress induce an accumulation of sugars in order to increase their osmotic potential. In this study, however, the different irrigation managements did not influence the content of soluble solids in papaya. As for production at different times, as opposed to this study, Mota et al. (2010) observed that grapes of different varieties harvested in winter (July) had a higher concentration of soluble solids and reducing sugars than in berries harvested in summer (January). This can be attributed, according to the authors, to a reduction in berry diameter and a lower rainfall in winter.

In terms of titratable acidity (Table 3), the interaction between irrigation management and fruit growing times was not significant ($p> 0.05$), but irrigation and growing seasons, analyzed independently, was indeed significant ($p <0.05$). The titratable acidity of the fruits irrigated with alternation of the seven-day irrigated line was higher ($p <0.05$) than that of the fruits with alternation of 21 days, indicating that the longer the water stress, the lower the titratable acidity of papaya 'Tainung no. 1'.

Regarding the growing season, fruits grown in summer were more acidic than those grown in winter ($p <0.05$). According to Cavichioli et al. (2008), temperature influences the most the accumulation of citric acid in the fruit, in that the higher the temperature during ripening, the greater the decrease in acid concentration. The authors, who evaluated some physical-chemical characteristics of yellow passion fruit fruits subjected to artificial lighting, irrigation and shading, observed a higher acidity in fruits harvested in August. They justified the lower acidity in fruits harvested in December by the high temperatures of October and November, which may have exceeded the compensation point when respiratory demand is high, thereby decreasing the citric acid reserve of juice cells. However, the papaya did not follow this tendency, evidencing an influence of the climate on the quality of the fruits. Less acidic fruits had the color of the pulp more attractive - reddish (lower ^{o}hue) when produced in the winter.

Yamanishi et al. (2006), in their study on papaya from the Formosa group harvested at different times, observed an acidity of the 'Tainung no. 1' fruits harvested in the spring (September) of 0.044 g of citric acid, close to the fruits of this study produced in the summer (0.040 g citric acid) and higher than that produced in winter (0.026 g citric acid) (Table 3). For sensory analysis, this project was submitted to the Ethics and Research Committee of the State University of Montes Claros, and accepted under opinion number 2,254,931.

Table 3. Soluble solids and titratable acidity in mature 'Tainung no. 1' papaya fruits produced with a reduced irrigation water level in two production periods.

	Soluble Solids (ºBrix)		
	Period between flowering and harvest		
	Summer	Winter	MEAN
PRD - AF - 7 days	13.05	13.27	13.16 a
PRD - AF - 14 days	13.05	13.13	13.09 a
PRD - AF - 21 days	13.07	13.45	13.26 a
PRD - Partial Irrigation	12.82	13.77	13.30 a
Full irrigation	13.62	14.27	13.95 a
MEAN	13.13 A	13.58 A	
CV (%) plot	10.33		
CV (%) subplot	11.25		
	Titratable acidity (g citric acid/100g)		
PRD - AF - 7 days	0.045	0.030	0.037 a
PRD - AF - 14 days	0.041	0.024	0.032 ab
PRD - AF - 21 days	0.032	0.025	0.028 b
PRD - Partial Irrigation	0.038	0.027	0.033 ab
Full irrigation	0.042	0.027	0.034 ab
MEAN	0.040 A	0.026 B	
CV (%) plot	16.14		
CV (%) subplot	18.57		

Means followed by uppercase letters in rows and lowercase in columns differ significantly from each other at 5% probability by F test and Tukey test, respectively.

For purchase intention, all sensory attributes of the summer crop were more accepted ($p < 0.05$) by consumers than fruits produced in winter (Table 4). However, when the PRD-AF-7 irrigation was used, there was no difference in purchase intention, overall appearance and pulp color produced in summer or winter ($p > 0.05$). This tendency was also verified for texture and flavor of fruits produced with the PRD-AF-14 days and full irrigation.

As for pulp color, consumers were able to distinguish the difference in total carotenoid content of fruits from different growing seasons for all irrigations (with the exception of PRD-AF-7 days), indicating that these consumers prefer papaya orange pulp.

Consumers similarly enjoyed ($p > 0.05$) fruit flavor using PRD-AF-14, 21 days and full irrigation. This indicates that irrigation management should be specific for each productive period, under the conditions of Mocambinho, northern Minas Gerais, in order to ensure quality. In addition, the temperature during the productive period influenced the quality of papaya, since, according to Marin (2004), fruits harvested in the winter (May to August) have a rougher, lackluster peel with few external spots, besides a pulp with lower contents of sugars.

Table 4. Means of the scores attributed by the tasters (100) for purchase intention (a structured scale of 5 points, ranging from "definitely would not buy" (1) to "definitely would buy") and acceptance of papaya 'Tainung no. 1' (hedonic scale ranging from 1 = extremely did not like it to 9 = extremely liked it).

Irrigation management*	Sensory Attributes									
	Purchase Intention		General appearance		Pulp color		Texture		Flavor	
	Summer**	Winter**	Summer**	Winter**	Summer**	Winter**	Summer**	Winter**	Summer**	Winter**
PRD - AF - 7 days	3.81 a	3.77 a	6.69 a	6.72 a	6.98 a	6.72 a	7.11 a	6.65 b	6.69 a	5.80 b
PRD - AF - 14 days	3.85 a	3.49 b	6.68 a	5.70 b	7.41a	6.88 b	7.43 a	7.37 a	7.12 a	7.56 a
PRD - AF - 21 days	3.88 a	3.33 b	6.68 a	5.74 b	7.43 a	6.48 b	7.31 a	6.83 b	7.10 a	6.60 a
PRD - Partial Irrigation	3.94 a	2.94 b	7.17 a	4.85 b	7.47 a	6.28 b	7.52 a	6.88 b	7.73 a	6.64 b
Full irrigation	3.86 a	3.09 b	6.90 a	5.17 b	7.41 a	6.88 b	7.12 a	6.90 a	6.90 a	6.56 a

CONCLUSIONS

Papayas produced in summer are larger, firmer, with an orange and more acidic pulp.

Irrigation management interferes with the purchase intention and the sensorial attributes of fruits produced in summer and winter. In general, consumers like the overall appearance and the color of papaya pulp produced in the summer, with the exception of PRD with alternating frequency of 7 days. The acceptance of texture and flavor is the same for fruits produced in summer and winter provided that the irrigation be full or with an alternation frequency of fourteen days for both attributes and also of twenty-one days for flavor.

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