

Quality of ‘Tainung 1’ papaya produced by partial root zone drying

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Abstract – A significant portion of papaya production in the state of Minas Gerais originates from irrigated crops, and irrigation management using the partial root zone drying technique (PRD) is a fundamental alternative to reduce water waste. This study aimed to evaluate the quality of ‘Tainung 1’ papaya produced under PRD in semi-arid conditions of northern state of Minas Gerais. PRD treatments were composed of reduction of the calculated irrigation water (CIW) by 50%, applied on one side of the irrigation line, with alternation of 7, 14 and 21 days or without alternation and full irrigation, applying 100 % CIW in both lateral plant rows. Each experimental plot consisted of ten plants, and from six plants, fruits were harvested for evaluations at harvest point and when ripe. At harvest point, fruits had peel color, titratable acidity, ratio, pulp size and thickness similar to those produced without water deficit. Firmness, soluble solids content, fresh mass and central cavity diameter are distinct as a function of PRD condition. When ripe, only firmness varied according to PRD treatments. The quality of ‘Tainung 1’ papaya produced by partial root zone drying in semi-arid conditions was not compromised.

Index Terms: *Carica papaya* L., irrigation management, postharvest.

Qualidade de mamão ‘Tainung 1’ produzido sob secamento parcial radicular

Resumo – Importante parcela da produção de mamão de Minas Gerais origina-se de cultivos irrigados, sendo o manejo da irrigação com uso da técnica de secamento parcial radicular (SPR) uma alternativa fundamental para redução de desperdício da água. Objetivou-se avaliar a qualidade de mamão ‘Tainung 1’ produzido sob SPR em condições semiáridas do norte Minas Gerais. Os tratamentos por SPR foram constituídos pela redução da lâmina calculada de irrigação (lci) em 50%, aplicada em um dos lados da linha de irrigação, com alternância de 7; 14 e 21 dias ou sem alternância e irrigação plena, aplicando-se 100% da lci. Cada parcela experimental foi constituída por dez plantas, sendo que das seis centrais se colheram os frutos para as avaliações no ponto de colheita e quando maduros. No ponto de colheita, os frutos têm cor da casca, acidez titulável, ratio, tamanho e espessura da polpa semelhantes àqueles produzidos sem déficit hídrico. A firmeza, o teor de sólidos solúveis, a massa fresca e o diâmetro da cavidade central são distintos em função da condição de SPR. Quando maduros, somente a firmeza varia em função dos tratamentos por SPR. A qualidade do mamão ‘Tainung 1’, produzido por secamento parcial do sistema radicular, em condições semiáridas, não foi comprometida.

Termos para indexação: *Carica papaya* L., manejo da irrigação, pós-colheita.

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Introduction

Brazilian papaya production in 2017 was 1,057.101 tons, and the northeastern region was the largest producer, followed by the southeastern region. The state of Minas Gerais occupies the fifth position in production in Brazil, and 71.37% of its production comes from the northern region of the state (IBGE, 2019).

Climatic uncertainties have caused prolonged drought periods in semi-arid regions such as northern Minas Gerais, associated with unstable availability of water sources such as river flows and irregular rainfall are challenges to irrigated agriculture. Adequate irrigation is essential to maintain or increase production in current production areas, where there is increasing competition for water resources, demanding higher water use efficiency and reduced environmental impact (LIMA et al., 2015). Optimization of water resources is necessary in the planning of irrigation models that allow greater efficiency of water use in papaya crops.

An alternative for optimizing water use efficiency is irrigation water management by partial root zone drying (PRD). This technique saves 50% of calculated irrigation water because the irrigation time is applied to only one irrigation line, alternating the irrigated side of the plant row, and not both as under normal irrigation conditions.

In Jaíba, a semi-arid area in northern Minas Gerais, papaya crops are irrigated because the average annual rainfall of 894 mm is insufficient for full crop production. In regions with rainfall less than 1000 mm / year, the use of irrigation is fundamental for the rational and economic cultivation of papaya, with increased productivity and improved fruit quality (REIS et al. (2013).

The permanent challenge for papaya production is to increase the production of high quality fruits in marginal places where the abiotic environment is limiting (CAMPOSTRINI;GLENN, 2007). Super-optimum temperatures and water deficits are the environmental factors most likely to limit production.

Papaya trees irrigated with the use of water management by the partial root zone drying (PRD) are subject to moderate soil water deficit. Papaya is likely to tolerate moderate water deficits without significant reduction in yield components (LIMA et al., 2015). But when the water stress situation is not properly managed, it results in significant reductions in fruit yield and quality parameters (KRUGER and MOESTERT, 1999; SARWAR et al., 2001; LIMA et al., 2015; MAHOUACHI et al., 2007).

The PRD technique saves 50% of the calculated irrigation water because the irrigation time is partially applied in only one irrigation line, alternating the irrigated side, and not in both as under normal irrigation conditions.

Regarding fruit quality, there are positive

responses to water availability, as verified by Silva et al. (2013), where the largest cross-sectional and longitudinal diameters of UENF / Caliman 01 hybrid were obtained from irrigation depths of about 108% of ETo, and can be grown in the state of Paraíba hinterland with replacement rate of 100% of ETo, without compromising fruit quality. However, information on the quality of ‘Tainung 1’ papaya, which is a commercial variety produced under PRD conditions, is scarce.

The present study aimed to evaluate the quality of ‘Tainung 1’ papaya produced under partial root zone drying, under semi-arid conditions of northern Minas Gerais.

Material and methods

‘Tainung 1’ papaya plantation was implanted in the Experimental Field of Mocambinho (CEMO), which belongs to “Epamig Norte” and is located in the Irrigated Perimeter of Jaíba - MG. Because it is a semi-arid region of northern Minas Gerais, irrigation is indispensable to crops. The geographical coordinates of the central cultivation point area are 15°12’98” S and 43°45’01”W and 515 m a.s.l. and annual average rainfall around 800mm. The climate is classified as AW (tropical winter dry season) according to Köppen. The soil is Red-Yellow Latosol according to the Brazilian Soil Classification System.

In the field, treatments were based on the reduction of the calculated irrigation water (CIW) from the Reference Evapotranspiration (ETo) obtained by the modified Penman-Monteith method (ALLEN et al., 1998). The irrigation water management method by partial root zone drying (PRD) consisted of 50% CIW reduction by alternating the irrigated side of the planting row, between the two lateral irrigation lines per row in time and irrigation corresponding to CIW. The alternation frequencies (change of irrigation side) were 7, 14 and 21 days, which resulted in the following treatments: T1 - reduction of calculated irrigation water by 50%, with alternation frequency of 7 days; T2 - reduction of calculated irrigation water by 50%, with alternation frequency of 14 days; T3 - reduction of calculated irrigation water by 50%, with alternation frequency of 21 days; T4 - reduction of calculated irrigation water by 50%, fixing only one side of irrigated row and T5 - Full irrigation, ie using CIW with both lateral rows open during irrigation.

Planting spacing of 3.0 mx 1.5 m and drip irrigation with two lateral lines per plant row were used, with continuous drip-emitters spaced 0.50 m from each other along the lateral line.

Each experimental plot consisted of ten plants, in two rows of five plants, six plants in useful area, from which fruits were harvested for postharvest evaluations.

Plants were conducted with fertilization, weed

and pest management, according to recommendations for papaya cultivation of the Agricultural Report (CASTRICINI; RODRIGUES, 2013). Planting took place in May 2016 and fruits were harvested on 03/17/2017, when they showed streaks or bands with 50% yellow color, usually four to six months after flowering, which is the appropriate time for harvest. According to Yamanishi et al. (2005), the most appropriate harvest point is from the 126th day after effective fruiting, when fruits have low chlorophyll content and physical and chemical characteristics with average values suitable for marketing.

After harvesting at CEMO, fruits were transported to the "Epamig Norte" Postharvest Laboratory, at Gorutuba Experimental Field (CEGR), Nova Porteirinha - MG, where they were evaluated at harvest point (50% green peel) and when ripe (all yellow peel). During the days to peel color change, they remained in an environment with temperature of $24 \pm 1^\circ\text{C}$ in the postharvest laboratory.

Common physical and chemical assessments for harvest point and / or ripe fruits: 1 - Peel and pulp color (in ripe fruits): assessed by colorimeter in the CIELab system (Konica Minolta, Osaka, Japan), which expresses color by means of three parameters, lightness (L^*), chromaticity (C^*) and color tone / angle ($^\circ$ hue); 2 - pulp firmness (N): obtained with manual penetrometer, with conical tip, which measurements were performed at three points of the fruit surface, at the extremities and in the equatorial region, after peeling; 3 - soluble solids (SS): measured by refractometry using a field refractometer (Atago, model N-1 α , reading in the range from 0 to 95 $^\circ$ Brix), and results expressed in $^\circ$ Brix; 4 - titratable acidity (TA): determined by titrating an aliquot of pulp with agitation with 0.1N NaOH, using 1% phenolphthalein as indicator, resulting in % citric acid (IAL, 2008). ; 5 - soluble solids / titratable acidity (Ratio): obtained by dividing SS / TA variables and 6 - Ascorbic acid (in ripe fruits): determined by titration, by the modified Tillmans method, as described in the Manual of Analytical Methods for Beverages and Vinegars (MAPA, 2019), with values expressed in mg of ascorbic acid in 100g of pulp.

Evaluations performed at harvest point: 1 - fresh fruit mass - expressed in grams (g); 2 - fruit diameter (df) - measurements made in the equatorial region, expressed in mm; 3 - fruit length (cf) - measurements made longitudinally, expressed in mm; 4 - average fruit pulp thickness (espolpa) - expressed in mm, was obtained by measuring the mesocarp after fruit cross section, measuring the pulp thickness in two points (greater and smaller thickness), with the aid of a ruler and calculation made using the formula: $(\text{greater} + \text{smaller}) / 2 = \text{espolpa (cm)} \times 10 = (\text{mm})$ and 5 - diameter of the fruit central cavity (dcav) - determined by the following formula: $\text{dcav} = \text{df} - 2 (\text{espolpa})$, expressed in mm. Fruit dimensions were determined with the aid of a caliper, and weighing was made using a semi - analytical scale. Formulas used

for 'espolpa' and 'dcav' calculations are found in Macedo (2012).

A completely randomized design with four replicates of two fruits per plot was used to evaluate fruits produced in the 5 treatments. Data were statistically interpreted by analysis of variance preceded by the Lilliefors test and means compared by the Tukey test at 5% probability using the SAEG 9.1 statistical software - System for Statistical and Genetic Analyses (2007).

Results and discussion

According to the Lilliefors test ($P = 0.05$), whose tabulated value under experimental conditions was 0.190, all variables presented normal distribution of errors, as calculated values were lower than tabulated values. According to the analysis of variance, there was no significant difference ($P \geq 0.05$) among treatments for the following variables evaluated in fruits at harvest point: peel color, L^* , C^* and $^\circ$ hue parameters, titratable acidity, soluble solids / titratable acidity ratio, fruit diameter, fruit length and pulp thickness. For ripe fruits, only firmness varied according to treatments ($P \leq 0.05$). The mean values of the analyzed variables are presented in Table 1 and are among those obtained by Fernandes et al., (2010) and Viana et al. (2015).

The reduction in the average $^\circ$ hue value from 123.66 $^\circ$ to 80.89 $^\circ$ of fruits at the harvest point in relation to ripe fruits shows the natural tendency of peel yellowing during ripening. The other components that characterize color, i.e., lightness and chroma, increased in ripe fruits, indicating higher lightness and peel color intensity, respectively, when peel becomes yellow. Fruit pulp is orange-red, according to the observed mean $^\circ$ hue value of 58.83 $^\circ$, being an important sensory characteristic, as verified by Viana et al. (2015), and consumers prefer fruits of red pulp varieties.

The titratable acidity in ripe fruits was 0.32% citric acid, being higher than papaya at harvest point, which was 0.19% citric acid. According to Souza et al. (2009), the predominant organic acid in papaya is citric and, with maturation, there is a slight increase in acidity. The average soluble solids content of fruits (13.38 $^\circ$ Brix) was higher than that found by Viana et al. (2015) (11.80 $^\circ$ Brix), which is likely to provide greater sweetness to fruits. Cultivation conditions that allow fruits to be sweeter at harvest are desirable for papaya, as there are no significant changes in soluble solids content after harvesting, i.e., during ripening. This trend was observed by Souza et al. (2014), where from the first to the seventh day after harvest, there were no significant differences for this component. According to Souza et al. (2009), the maximum soluble solids contents after harvest are reached when fruits are harvested with 33% of the yellow surface

and, in the present work, harvest occurred with 50% of the yellow surface; thus, probably little or no variation occurred during ripening.

The tendency of lower fruit acidity at harvest point provided higher soluble solids / titratable acidity ratio, since, on average, the soluble solids content was very similar among fruits at different degrees of ripeness. According to Viana et al. (2015), the SS / TA ratio represents the balance between sugars and acids and directly contributes to flavor and aroma formation. Generally, fruits with higher SS / TA values have more pronounced sweetness and lower acidity, being preferred by consumers.

The ascorbic acid content of ripe fruits was 38.25 mg 100g⁻¹, lower than those verified by Reis et al. (2015), where 'Tainung 1', L33 and H36.45 papayas, from the 'Formosa' group, presented Vitamin C concentrations of 70.09 mg100g⁻¹, 85.45 mg100g⁻¹ and 93.64 mg100g⁻¹, respectively. However, as mentioned by Manica (2006), ascorbic acid concentrations in pulp range from 35 mg 100g⁻¹ to 84 mg 100g⁻¹.

Fruits of the present study presented 105.01 mm in diameter, 27.27 cm in length and 25.73 mm in pulp thickness, being similar to those characterized by Rodolfo Júnior et al. (2007), who concluded that these values are adequate for the requirements of the domestic market of 'Formosa' papaya; however, the choice for size of fresh fruits depends on the consumer market.

Treatments significantly influenced firmness, soluble solids content, fresh mass and the central cavity diameter of fruits at harvest point. Comparisons of means, made by Tukey test, are presented in Table 2.

Papayas produced under PRD with alternating frequency of 14 days (T2) were firmer than those produced under full irrigation (T5), but did not differ with respect to soluble solids content, fresh mass and central cavity diameter. Firmness is an important quality attribute for both fruit management and consumer acceptance (CUQUEL et al., 2012), providing greater transport resistance and longer shelf life, as the firmer the fruit at harvest, the greater its susceptibility to mechanical damage and rot.

Higher soluble solids content occurred in fruits produced under PRD with alternation frequency of 7 days (T1), compared to those produced by fixing an irrigated side (T4). However, for all treatments, values of this quality component were satisfactory, being above 10.8 ° Brix, a feature cited by Costa et al. (2013) for 'Tainung 1' papaya. As in the present study, Silva et al. (2013) found that higher soluble solids contents were obtained in UENF / Caliman 01 papayas when produced under water deficit conditions, i.e., with 50% and 75% ETo.

Fruits produced under full irrigation (T5) presented higher fresh mass, but statistically equal to those produced under PRD with alternation frequency of 14 days (T2)

and those produced without irrigated side alternation (T4), indicating that reduction of water availability by 50% does not affect the weight of fruits, provided that the alternation conditions of the irrigated side are observed. Costa et al. (2013) reported that the weight of 'Tainung 1' fruits varies from 900 to 1,100 g, therefore, the average weight of fruits produced under T2, T4 and T5 conditions was higher. According to Dias et al. (2011), the diameter of the inner cavity is related to the quality of fruits, and those with smaller diameter usually have larger amount of pulp. Papaya produced under PRD conditions with alternating frequency of 21 (T3) days presented smaller central cavity diameter, but without statistical difference compared to those with alternating frequency of 14 (T2) days and under full irrigation (T5). However, the proportion of the central cavity diameter of papaya produced with alternation of 21 days, in relation to fruit diameter was 35.65%, being the lowest proportion observed, since for the other fruits, values were 60.85 %, 50.54%, 51.78% and 50.22% for T1, T2, T4 and T5, respectively.

Ripe fruits showed firmness variation according to treatments, being those produced by PRD with 14 days alternation frequency (T2) firmer than those produced with 7 days alternation frequency (T1) or when only one irrigated side was fixed (T4) (Figure 1). Higher firmness observed in papaya produced with alternation frequency of 14 days (T2), at harvest point, remained until they were fully ripe, being an important aspect for conservation and fruit quality.

Table 1. Means of variables with non-significant differences evaluated in 'Tainung 1' papayas at harvest point and / or ripe produced under partial root zone drying.

Variables	Fruits at harvest point	Ripe fruits
Lightness (L*) - peel	41.30	62.10
Chroma (C*) - peel	28.75	58.42
Hue Angle - peel	123.66	80.89
Titratable acidity (% citric acid)	0.19	0.32
Ratio (soluble solids / titratable acidity)	68.05	41.81
Diameter (mm)	105.01	-----
Length (cm)	27.27	-----
Pulp Thickness (mm)	25.73	-----
Lightness (L*) – pulp	-----	54.28
Chroma (C*) – pulp	-----	49.37
Hue Angle - pulp	-----	58.83
Soluble Solids (°Brix)	***	13.38
Ascorbic Acid (mg.100g ⁻¹)	-----	38.25

--- no evaluation at harvest point or ripe

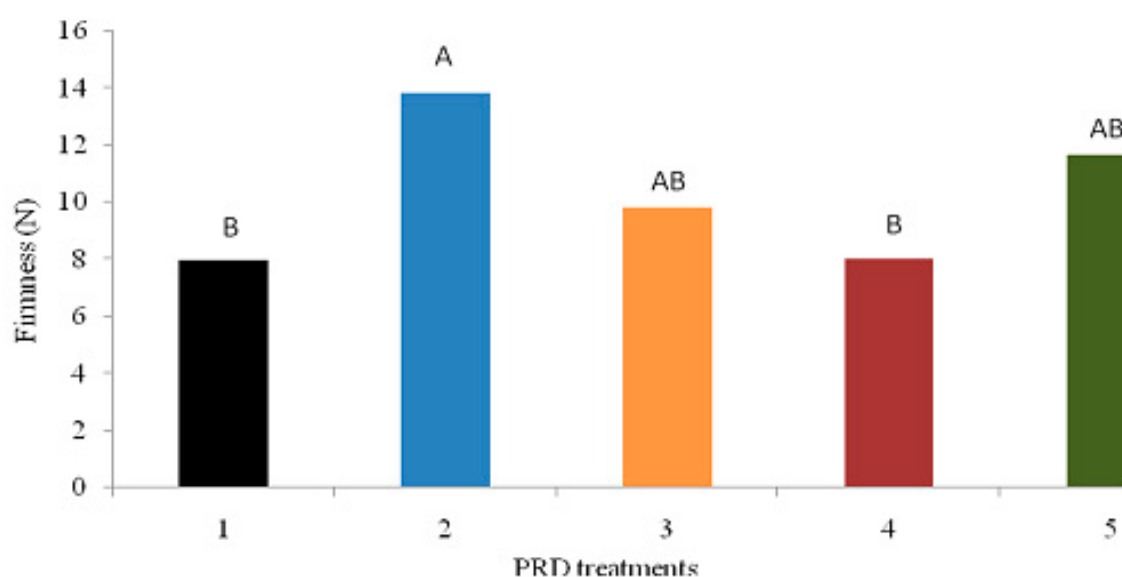
*** significant at harvest point

Table 2. Firmness, soluble solids, fresh mass and central cavity diameter of 'Tainung 1' papayas produced under partial root zone drying. Fruits at harvest point

Treatments	Firmness (N)	Soluble Solids (° Brix)	Fresh mass (g)	Central cavity diameter (mm)
T1	98.99 AB	13.95 A	888.57 B	63.90 A
T2	107.23 A	12.45 AB	1140.09 AB	53.07 AB
T3	89.50 ABC	12.80 AB	840.79 B	37.44 B
T4	70.94 BC	11.90 B	1115.61 AB	54.37 A
T5	66.55 C	13.55 AB	1281.53 A	52.74 AB

Means followed by the same letter in the column do not differ by the Tukey test at 5% significance.

T1 - PRD with alternation frequency of 7 days; T2 - PRD with alternation frequency of 14 days; T3 - PRD with alternation frequency of 21 days; T4 - PRD and fixing only one irrigated side and T5 - Full irrigation, corresponding to the calculated water, to replace the reference evapotranspiration, in two lateral lines per plant row.

**Figure 1.** Firmness of mature 'Tainung 1' papayas produced by partial root zone drying (PRD).

Bars above the same letter in the column do not differ by the Tukey test at 5% significance. T1 - PRD with alternation frequency of 7 days; T2 - PRD with alternation frequency of 14 days; T3 - PRD with alternation frequency of 21 days; T4 - PRD and fixing only one irrigated side and T5 - Full irrigation, corresponding to the calculated water, to replace the reference evapotranspiration, in two lateral lines per plant row.

Conclusion

At harvest point, the quality of ‘Tainung 1’ papaya produced by partial root zone drying under semi-arid conditions of northern Minas Gerais was not compromised.

At harvest point, fruits have peel color, titratable acidity, pulp ratio, size and thickness similar to those produced without water deficit. Firmness, soluble solids content, fresh mass and central cavity diameter differ according to PRD condition.

When mature, only firmness varies depending on PRD treatment. Firmer fruits were those produced with alternation frequency of 14 and 21 days and without water deficit.

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