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Effect of the Maturity Stage and Storage Temperature on the Postharvest Quality of *Carica papaya* L. Variety Solo 8

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ABSTRACT

The level of maturity of *Carica papaya* L. cv. 'Solo 8' at harvest influences considerably most of its flavoring characteristics during ripening. The objective of this study was to determine the level of maturity at harvesting that provides the optimum organoleptic characteristics of *C. papaya* and to find the best temperature for its storage. Three maturity stages were selected (green immature: fruit had green skin without yellow spots, green mature: fruit presented 1/32nd of the yellow skin and advanced maturity: fruit presented 1/8th of the yellow skin). Thirty six fruit at each maturity stage were stored at 15, 22, and 28°C for 12 days and infection rate, weight lost, acidity, pH, firmness, vitamin C content, reducing and total sugars contents, and index of refraction were measured every four days. In addition, trained panelists performed a sensory evaluation of the fruit. At the mature and advanced stages, the fruits had a sweet taste with total sugar content varying from 3.42 to 6.43 g/100 g at day 0 to 7.2 to 8.39 g/100 g at day 12, respectively. Furthermore, the infection rate and the loss of weight of the fruit were higher at the advanced and green immature stages. The content of vitamin C was higher in fruit stored at 15°C compared to those stored at 22 and 28°C. This study indicates that *C. papaya* stored at 15°C for 12 days at the green mature stage presented the best organoleptic characteristics.

Keywords: harvest time, organoleptic characteristics, papaya, postharvest shelf life, storage temperature

INTRODUCTION

In Côte d'Ivoire, horticulture holds a very important place in agriculture and economy.

In fact the field of horticulture offers a large range of fruit and vegetables products including the papaya, which contribute largely to the country's economy (Dembélé *et al.* 2004). The country, which is the second exporter of papaya after Ghana, sends about 1163 tons of papaya every year toward the European Union market (N'da *et al.* 2008). However, concerns of the European Union about the quality of imported agricultural products have led the Côte d'Ivoire to increase its quality procedures when trading with the union countries. Complying with international legal and commercial quality requirements represents a major challenge for fruit exporters (PIP 2006).

Generally, fruit are harvested after they have reached a physiological maturity stage, when development is completed and growing has stopped (Manrique and Lajolo 2004). From this point, postharvest ripening begins, and fruit acquire the organoleptic characteristics to be consumed (Watada *et al.* 1984). Bron and Jacomino (2006) reported that harvest time is fundamental to obtain a high quality fruit with storage potential. According to Lalel *et al.* (2003), only melons harvested at early maturity stages exhibit the climacteric pattern. Harvest time also has an influence on fruit sensorial quality. Bananas harvested at more advanced maturity stages had better consumer acceptance but had a short shelf life (Ahmad *et al.* 2001). Knee and Smith (1989) verified that apples harvested at precocious maturity stages showed long shelf life but presented an unsatisfactory flavor and color when ripe. Maturity stages at harvest also affect the biosynthesis of volatile compounds in mangoes, responsible for fruit flavor (Lalel *et al.* 2003). According to Johnston *et al.* (2002) and MacRae *et al.* (1989), firmness loss in apples and kiwi is also affected by harvest time. Papaya (*Carica papaya* L.) acquires its significant organoleptic properties when it is harvested at optimal maturity (Guichard 1990). Consequently, harvesting the fruit before the optimal maturity does not allow the optimal development of the organoleptic characteristics and leads to a non-homogeneous ripening (Jaimes-Miranda 2006). Moreover, when the fruit is picked at advanced maturity, the storage period remains short regardless of the method used and its commercialization is limited locally and internationally (N'da *et al.* 1996).

Refrigeration is the most commonly used technique to control fruit ripening. Cold storage slows down enzymatic reactions such as those related to respiration and senescence, minimizing losses of fruit quality attributes (Bron and Jacomino 2009). According to Kader (2002), papaya respiration rate, which is approximately 15-35 mL CO_2 kg^{-1} h^{-1} at 20°C, decreases to 4-6 mL CO_2 kg^{-1} h^{-1} when fruit are stored at 10°C. Chaplin *et al.* (1991) was successful in the application of cold storage at 15°C to mango cv. 'Kensington' for 4 weeks, with acceptable ripening and quality index upon ripening. While, Chen and Paull (1986) observed that papayas harvested at physiological maturity showed chilling injury symptoms after 2 weeks at 7°C and were characterized by irregular and slow ripening and by an increase in susceptibility to fungus. Proulx *et al.* (2005) reported that storage of color break papayas cv. 'Exp. 15' from 0.5 to 10°C resulted in the development of chilling injury. Papaya fruit, like other tropical fruit, are sensitive to chilling temperatures (usually lower than 10°C) and may develop chilling injury symptoms such as pitting of the skin, scald, hard lumps in the pulp around the vascular bundles, water soaking of the flesh, abnormal ripening with blotchy discoloration, and increased susceptibility to decay (Thompson and Lee 1971; El-Tomi *et al.* 1974; Chan *et al.* 1985; Chen and

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Paull 1986; Ali et *al*. 1993). Moreover, high storage temperatures lead to accelerated water loss and subsequently to shriveling and softening of the fruit (Proulx *et al*. 2005). Nunes *et al*. (1998) reported that the rate of loss of total ascorbic acid in strawberry fruit is very rapid after harvest, and increases as the storage time and temperature increase.

The objective of this study was to determine the level of maturity at harvesting that provides the optimum organoleptic characteristics of *C. papaya* L. cv. 'Solo 8', the most cultivated variety in Côte d'Ivoire and to find the best temperature for its storage. Thus, parameters such as the loss of weight, infection rate, titratable acidity, pH, firmness, vitamin C content, reducing and total sugars, soluble dry solids have been evaluated every four days during storage at 15, 22, and 28°C. In addition, organoleptic evaluations have been performed to complete the physico-chemical tests.

MATERIALS AND METHODS

Sampling

This study was performed on *Carica papaya* L. cv. 'Solo 8'. The fruit were harvested in a farm at Tomassé (Azaguié), about 50 Km from the International Airport of Abidjan, Côte d'Ivoire, and were transported in a truck (28°C) immediately to the laboratory [Laboratory of Food Biochemistry and Tropical Products Technology, Abobo-Adjamé University]. The papayas were harvested at three stages of maturity namely, the green immature stage (the fruit had green skin without yellow spots), the mature stage (the fruit had green skin with the beginning of yellow spots) and the advanced maturity stage (1/8 of the fruit skin is yellow). The fruit were washed with water, sorted according to uniformity in shape, size and weight, placed in boxes, and then stored immediately at 15, 22, and 28°C for 12 days. Twelve fruit from each of the 3 maturity stages were placed in a box and 12 boxes of each maturity stage were stored at these three different temperatures. During the 12 days storage, 3 boxes (36 fruit) of each maturity stage were pulled out every four days from each storage temperature and the evaluation parameters were measured. All the tests were repeated three times.

Physical parameters

1. Infection

For each analysis day, the degree of infection was expressed as the percentage of infected fruit for each treatment (Tano *et al.* 2007).

2. Firmness

Using a penetrometer (Fruit Pressure Testing, model FT 327, EFFEGI, Milan, Italy) equipped with an indicator of force, the tip of the device is pressed to the middle of the papaya at a deph of 8 mm until it penetrates the pulp of the fruit. The value indicated by the device represents the maximum force expressed in Newton (N) required for the pulp to cede to the tip of the penetrometer, expressing the firmness (Tano *et al.* 2007; Yué Bi 2010).

3. Loss of weight

The loss of weight was measured using the method of Proulx et *al*. (2005). Weight loss was determined during the storage period by monitoring the weight of the 12 fruit of each box. Weight loss was expressed as the percentage of the loss of weight with respect to the initial weight and was determined in triplicate.

Chemical parameters

1. Ascorbic acid

The ascorbic acid (vitamin C) content was determined according to the method described by Poncracz (1971) using 2,6-dichlorophenol indolphenol. Ten grams of papaya pulp were ground in 20 mL of metaphosphoric acid/acetic acid (3% metaphosphoric acid – 8% acetic acid). The ground matter was centrifuged (Centrifuge Jouan Multifunction B4i-BR4i, Germany) at 4000 rpm for 20 min. One milliliter of the supernatant was titrated with 2,6-dichlorophenol indolphenol. The ascorbic acid content was calculated by the following equation:

Ascorbic acid content (mg/100 g) $= \frac{(Ve-V0)*20}{(Vc-V0)*10} * 100$

where Ve is the volume of 2,6-dichloropenol indolphenol used to titrate 1 mL of supernatant, V_0 is the volume of 2,6-dichlorophenol indolphenol used to titrate 1 mL of metaphosphoric acid/acetic acid, and Vc is the volume of 2,6-dichlorophenol indolphenol used to titrate 1 mL of standard solution of ascorbic acid (1 mg/mL).

2. pH and titratable acidity

The pH of the samples was measured with a numerical pH meter (Consort P107, Belgium). Titratable acidity was measured according to the AOAC method (2000). This measurement was done by titrating against 0.1 N NaOH using 1% phenolphthalein as indicator.

3. Reducing sugars and total sugars

One gram of papaya pulp was ground (Moulinex Masterchef 750, France) in 10 mL of ethanol to obtain the ethanol-soluble sugars. The mixture was centrifuged (Centrifuge Jouan Multifunction B4i-BR4i, Germany) at 3000 rpm for 30 min. The supernatant was used to determine the reducing sugars according to the method described by Bernfield (1955) using 3,5-dinitrosalicylic acid (DNS). 0.5 mL of DNS was added to 0.1 mL of the supernatant diluted in 0.9 mL of distilled water. The mixture was heated in a water bath at 100°C for 5 min and cooled for 5 min at room temperature (28 ± 2°C); then, 3.5 mL of distilled water were added. The absorbance was determined by a spectrophotometer (UV-102-02, Shimadzu, Kyoto, Japan) at 540 nm against a standard solution containing all of the reagents except the supernatant. The determination of the total sugars was performed by the method of Dubois *et al*. (1956). 1 mL of phenol 5% (w/v) was added to 0.1 mL of the supernatant diluted in 0.9 mL of distilled water. The mixture was homogenized, heated in a water bath at 100°C for 5 min, and let cool at room temperature for 5 min, then 2 mL of concentrated sulfuric acid was then added to the mixture. The optical density (O.D) was read at 490 nm against a standard solution on a spectrophotometer (Shimadzu, Japan).

Index of refraction

The index of refraction (expressed in °Brix) was measured with a refractometer (model N-20_E, ATAGO, Tokyo, Japan) equipped with a temperature corrector. A drop of papaya juice obtained after grinding was placed on the prism of the refractometer and the index of refraction was directly read under a sun light source.

Sensory analysis

The sensory evaluation was possible using the method described by Lateur *et al*. (2001). Three slices of every level of papaya maturity were served to ten well-trained panelists for evaluation. The evaluated criteria were firmness, crunchiness, sweetness, acidity, skin color, pulp color, and juiciness. A scale of 1 to 5 was used to indicate: 5 = excellent, 4 = good, 3 = average, 2 = bad and 1 = very bad.

Statistical analysis

The experiments were repeated twice. Since, there were no significant differences between the two experiments. The results were pooled and averaged. The experiments were laid out in a completely randomized block design with tree replicates. Data on infection, firmness, weight loss, pH, titratable acidity, reducing and total sugars contents, vitamin C contents, and refraction index were submitted to an analysis of variance (ANOVA). Statistical analysis was performed using SPSS 10.0. Significance between means was assessed using Duncan's test at $P < 0.05$.

Table 1 Titratable acidity and pH of *Carica papaya* L. picked at green immature, green mature and advanced maturity stages and stored at 15, 22, and 28°C for 12 days.

Developmental stage	Day	Titratable acidity (%)			pH		
		15°C	22°C	28°C	15°C	22°C	28°C
Green immature	0	0.028 ± 0.004 aK	0.028 ± 0.004 aK	0.028 ± 0.004 aK	5.63 ± 0.06 aI	5.63 ± 0.06 aI	5.63 ± 0.06 aI
	4	0.024 ± 0.004 aL	0.024 ± 0.004 abL	0.024 ± 0.004 abL	5.84 ± 0.06 bJ	5.67 ± 0.12 abK	5.68 ± 0.12 aK
	8	0.021 ± 0.004 aM	0.021 ± 0.004 bcM	0.018 ± 0.002 bcM	5.93 ± 0.04 cL	5.78 ± 0.02 bcM	5.72 ± 0.07 aM
	12	0.018 ± 0.006 bN	0.017 ± 0.002 cO	0.017 ± 0.002 cO	5.96 ± 0.00 cN	5.85 ± 0.05 cO	5.74 ± 0.00 aP
Green mature	0	0.018 ± 0.002 aE	0.018 ± 0.002 aE	0.018 ± 0.002 aE	5.60 ± 0.00 aE	5.60 ± 0.00 aE	5.60 ± 0.00 aE
	4	0.017 ± 0.002 aF	0.017 ± 0.004 aF	0.017 ± 0.004 aF	5.73 ± 0.05 bF	5.65 ± 0.05 aF	5.65 ± 0.05 abF
	8	0.016 ± 0.000 aI	0.015 ± 0.002 aI	0.016 ± 0.003 aI	5.81 ± 0.03 cG	5.77 ± 0.02 bG	5.71 ± 0.05 bG
	12	0.010 ± 0.000 bJ	0.014 ± 0.002 aJ	0.015 ± 0.002 aJ	5.82 ± 0.00 cH	5.80 ± 0.03 bH	5.81 ± 0.07 cH
Advanced maturity	0	0.017 ± 0.002 aA	0.017 ± 0.002 aA	0.017 ± 0.004 aA	5.67 ± 0.06 aA	5.67 ± 0.06 aA	5.67 ± 0.06 aA
	4	0.016 ± 0.000 aB	0.016 ± 0.003 abB	0.017 ± 0.002 aB	5.69 ± 0.05 aB	5.75 ± 0.04 abB	5.77 ± 0.05 bB
	8	0.015 ± 0.004 aC	0.014 ± 0.002 abC	0.016 ± 0.003 aC	5.70 ± 0.01 aC	5.77 ± 0.07 bC	5.87 ± 0.03 cC
	12	0.008 ± 0.002 bD	0.013 ± 0.000 bD	0.014 ± 0.002 aD	5.75 ± 0.07 aD	5.83 ± 0.01 bD	5.95 ± 0.00 dD

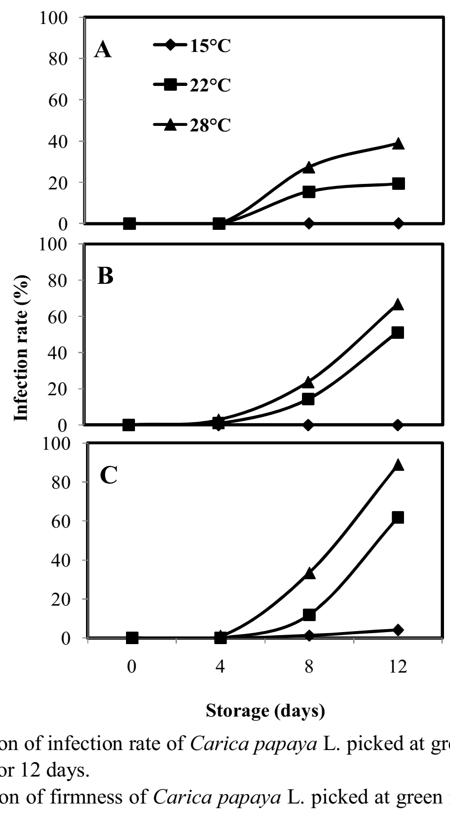
The values, followed by the same low case letter in a column and the same upper case in a row, are not significantly different at $p < 0.05$. The reading is done in the same column for lower case letters and in the same row for the upper cases.

RESULTS AND DISCUSSION

The infection rate of fruit (**Fig. 1**) was high at the advanced maturity stage and at 22 and 28°C. The fragility of the fruit at this maturity stage may be due to microbial infections. Moreover, 22 and 28°C are temperatures at which the growth of mold such as *Colletotrichum gloeosporioides* is favored (Coates *et al.* 1995). The results of this work confirmed those of Baiyewu *et al.* (2005) who showed that the optimal temperature for microbial growth on papayas was between 30 and 35°C. During storage, the pH of the fruit increased near 6 (**Table 1**) favorable to the growth of micro-organisms. Additionally, the changing in the sugar content of the fruit during the ripening process may be responsible for mold contamination. Indeed, according to Aharoni *et al.* (1985) and King *et al.* (1995), the fruit and vegetables lose their resistance to the molds infections with the advance of ripening and senescence.

The loss of firmness (**Fig. 2**) was significant ($P < 0.05$) for all the fruit regardless of the maturity stage and the storage temperature. However, the loss of firmness was more pronounced for higher storage temperatures (22 and 28°C) and with maturity stages (green mature and advanced maturity). The loss of firmness could be explained by the loss of water by transpiration of the fruit during storage. Accordingly, Chaib (2007) mentioned that during maturation, the loss of firmness of fruit was the consequence of changes in the hydrostatic pressure of parenchyma cells. Furthermore, fruit respiration and ethylene synthesis lead to reactions such as chlorophyll degradation and enzymatic hydrolysis of the cell wall of fruit, which are responsible of the softening of fruit. These results agreed with those of Fisher and Bennett (1991), Fils-Lycaon and Buret (1991) and Ketsa and Daengkanit (1999) who showed that the activity of parietal hydrolases (polygalacturonase, cellulases, β-galactosidase, pectinemethyl esterase) increased during the maturation of fruit such as melon and durian with a release of ethylene. Sancho *et al.* (2010) showed that the loss of firmness of papaya increased with the increase of the enzymatic ethylene-related degradation of the cell wall. According to Paul *et al.* (1999), the solubilization of pectin and hemicelluloses, and the loss of firmness in papaya hap-

1



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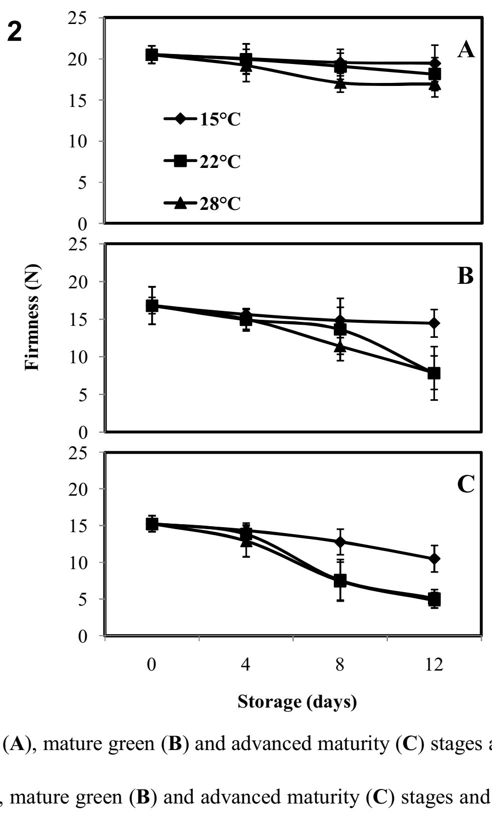
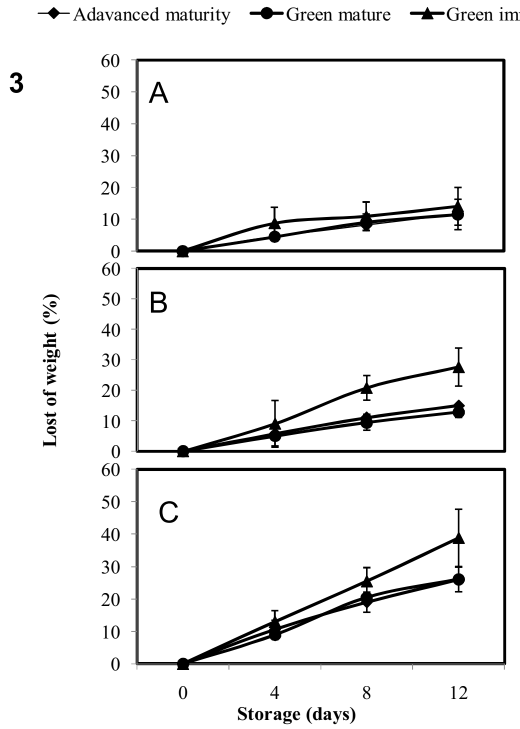


Fig. 1 Evolution of infection rate of *Carica papaya* L. picked at green immature (**A**), mature green (**B**) and advanced maturity (**C**) stages and stored at 15, 22 and 28°C for 12 days.

Fig. 2 Evolution of firmness of *Carica papaya* L. picked at green immature (**A**), mature green (**B**) and advanced maturity (**C**) stages and stored at 15, 22 and 28°C for 12 days.



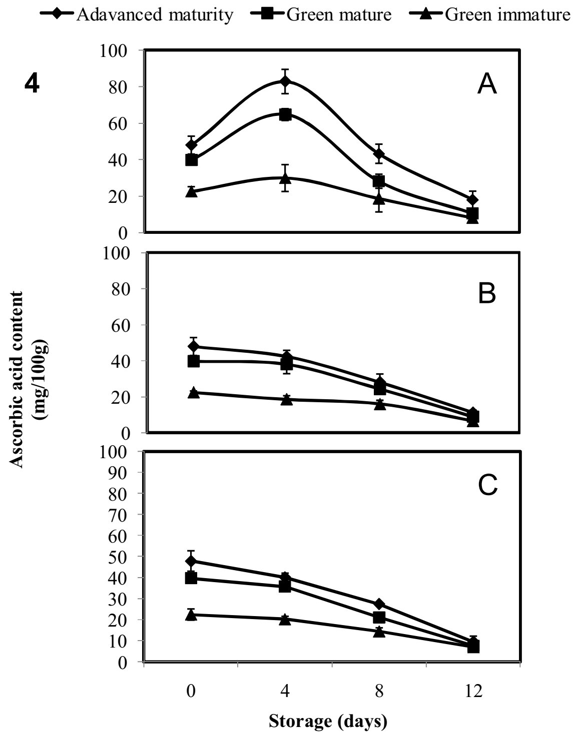


Fig. 3 Evolution of the loss of the weight of *Carica papaya* L. picked at green immature, green mature and advanced maturity stages and stored at 15°C (**A**), 22°C (**B**) and 28°C (**C**) for 12 days.

Fig. 4 Evolution of ascorbic acid content on *Carica papaya* L. picked at green immature, green mature and advanced maturity stages and stored at 15°C (**A**), 22°C (**B**) and 28°C (**C**) for 12 days.

pened all together and they increased with the storage time and temperature. However, these authors showed that some phenomena of fruit softening, such as the loss turgescence are not related to ethylene.

The loss of weight (**Fig. 3**) of *C. papaya* was high at 22 and 28°C probably because of the high transpiration rate that happened at these temperatures, which is a non-renewable loss of water due to the fact that fruit were no more attached to the tree (Chen and Paull 1989). Most of the loss of vitamin C (**Fig. 4**) happened at high temperature (higher than 20°C) and at long storage period with the help of the sun light, which is known to break down the vitamin C. Our results were in agreement with those of Davidek et *al*. (1990) who indicated that vitamin C content decreased at long storage temperatures and times. Nevertheless, vitamin C content in fruit stored at 15°C increased from day 0 (47.87 mg/100 g) to day 4 (82.78 mg/100 g) before decreesing to 17.92 mg/100 g at the end of the storage period (day 12). These results could be explained by the rate of vitamin C who increases naturally during maturation and decreases during the ripening of the papaya (Lee and Kader 2000; Bron and Jacomino 2006). However, when the papaya is stored at high temperatures (22 and 28°C), the rate of vitamin C decreases because there is a strong degradation of this vitamin by heat and sun light. This argument is in agreement with Rai and Attar (2008) who reported that the losses of vitamin C during papaya postharvest ripening may be attributed to its sensitivity to heat and sun light. When the fruit are stored at low temperature (15°C), the loss of vitamin C is lower so that a peak was observable at day 4 (**Fig. 4A**).

The increase in reducing sugars (**Table 2**) and soluble dry solids (**Table 3**) during storage was probably due to enzymatic activities such as those of polygalacturonase, pectin Methyl esterase, which hydrolyzes pectin in simple sugars. As shown in **Table 2**, the content of total sugars initially increased, reaching for instance the maximum levels of 8.563, 10.200, 8.467 g/100g after day 8 at 15, 22 and 28°C, respectively for the advanced maturity stage. After this period the total sugars content decreased slightly to 6.570, 8.397 and 6.900 g/100 g until the end of the storage period. These results were in agreement with those of Gomez *et al*. (2002),

Table 2 Total and reducing sugars of *Carica papaya* L. picked at green immature, green mature and advanced maturity stages and stored at 15, 22, and 28°C for 12 days.

Developmental stage	Day	Total sugars (g/100 g)			Reducing sugars (g/100 g)		
		15°C	22°C	28°C	15°C	22°C	28°C
Green immature	J0	1.563 ± 0.202 aJ	1.607 ± 1.203 aJ	1.957 ± 1.301 aJ	0.403 ± 0.193 aJ	0.403 ± 0.193 aJ	0.403 ± 0.193 aJ
	J4	2.080 ± 0.492 aK	2.080 ± 0.492 abK	2.080 ± 0.495 aK	0.773 ± 0.235 aK	0.637 ± 0.393 abK	0.480 ± 0.030 abK
	J8	3.093 ± 0.748 aL	3.493 ± 1.094 abL	3.860 ± 1.370 aL	0.810 ± 0.065 aL	0.943 ± 0.240 bL	0.647 ± 0.074 bL
	J12	3.150 ± 1.738 aM	4.253 ± 1.790 bM	2.550 ± 0.552 aM	0.867 ± 0.372 aM	1.007 ± 0.216 bM	1.020 ± 0.128 cM
Green mature	J0	3.410 ± 0.830 aE	2.970 ± 0.885 aE	3.410 ± 0.930 aE	2.490 ± 1.249 aF	2.490 ± 1.249 aF	2.337 ± 0.142 aF
	J4	3.517 ± 0.405 aF	3.410 ±0.930 abF	7.207 ± 3.196 bG	2.530 ± 1.017 aG	2.530 ± 0.819 aG	2.367 ± 0.504 aG
	J8	4.453 ± 1.170 aH	4.877 ± 0.467 bH	5.677 ± 0.680 abH	2.593 ± 0.160 aH	2.680 ± 0.046 aH	2.490 ± 1.249 aH
	J12	4.307 ± 0.996 aI	4.527 ± 0.645 bI	4.777 ± 0.935 abI	2.740 ± 0.017 aI	2.743 ± 0.917 aI	2.670 ± 0.647 aI
Advance maturity	J0	6.430 ± 1.645 aA	6.430 ± 1.645 aA	6.430 ± 1.645 aA	2.633 ± 0.869 aA	2.633 ± 0.869 aA	2.633 ± 0.869 aA
	J4	6.800 ± 1.572 aB	5.390 ± 2.142 aB	9.327 ± 5.248 aB	4.230 ± 1.206 abB	3.797 ± 0.270 bB	3.190 ± 0.115 abB
	J8	8.563 ± 2.880 aC	10.200 ± 2.777 aC	8.467 ± 1.967 aC	4.303 ± 1.057 abC	4.027 ± 0.585 bC	4.123 ± 0.543 bcC
	J12	6.570 ± 0.262 aD	8.397± 3.435 aD	6.900 ± 0.619 aD	5.297 ± 0.270 bD	4.367 ± 0.086 bE	4.823 ± 0.611 cE

The values, followed by the same low case letter in a column and the same upper case in a row, are not significantly different at $p < 0.05$. The reading is done in the same column for lower case letters and in the same row for the upper cases.

Table 3 Soluble dry solids of *Carica papaya* L. picked at green immature, green mature and advanced maturity stages and stored at 15, 22, and 28°C for 12 days.

Developmental stage	Day	Refraction index (°Brix)		
		15°C	22°C	28°C
Green immature	0	5.233 ± 0.058 aO	5.233 ± 0.058 aO	5.233 ± 0.058 aO
	4	5.900 ± 0.100 bP	5.567 ± 0.115 bQ	5.567 ± 0.115 bQ
	8	6.000 ± 0.000 bR	6.033 ± 0.058 cR	6.033 ± 0.058 cR
	12	6.567 ± 0.413 cS	6.267 ± 0.115 dS	6.267 ± 0.115 dS
Green mature	0	8.500 ± 0.500 aI	8.133 ± 0.208 aI	8.133 ± 0.208 aI
	4	8.133 ± 0.208 aJ	8.833 ± 0.208 bK	8.833 ± 0.208 bK
	8	9.167 ± 0.153 bL	9.067 ± 0.115 bM	9.000 ± 0.000 bM
	12	9.933 ± 0.115 cN	10.000 ± 0. 000 cN	9.933 ± 0.115 cN
Advanced maturity	0	10.000 ± 0.000 aA	10.000 ± 0.000 aA	10.000 ± 0.000 aA
	4	11.100 ± 0.173 bB	10.367 ± 0.153 abC	10.367 ± 0.153 bC
	8	11.366 ± 0.153 bD	10.600 ± 0.360 bE	11.000 ± 0.000 cE
	12	12.400 ± 0.173 cF	11.233 ± 0.252 cG	11.167 ± 0.289 cG

The values, followed by the same low case letter in a column and the same upper case in a row, are not significantly different at p < 0.05. The reading is done in the same column for lower case letters and in the same row for the upper cases.

who indicated in their experiments that the total sugars from green papaya fruit increased from 9.5 to 10% before dropping to 9% during maturation. Proulx *et al*. (2005) demonstrated that after 14 days of storage at 5, 10, 15, and 20°C, the total sugars in papayas picked at first sign of yellow color decreased from 30% of the initial value.

C. papaya picked at green immature stage (**Figs. 5A, 5D, 5G**) and stored at 15, 22, and 28°C did not show a significant ($P > 0.05$) difference between the studied organoleptic characteristics. Indeed, the fruit stayed firm during storage. The color of the skin, and the pulp, the acidity, the sweetness, the juiciness, and the crunchiness of the fruits remained invariable during storage. The abnormal organoleptic characteristics of the fruits at the green immature stage shown in this study could be explained by the fact that the fruit were not at the desirable maturity to allow a normal ripening. These results agreed with those of Jaimes-Miranda (2006) who indicated that the development stages of papayas were critical for the ripening capacity. In fact, immature fruit are unable to ripen even in presence of ethylene.

For *C. papaya* picked at green mature stage (**Figs. 5B, 5E, 5H**), the acidity and the sweetness of the fruit did not change significantly ($P < 0.05$) while the firmness, which was very pronounced at day 0, decreased progressively during storage. The panelists found a significant change in the evolution of the color of the skin and the pulp, the juiciness, and the crunchiness of the fruit. Indeed, the color of the skin of the papaya fruit changed from green mature at day 0 to completely yellow at day 12 when the fruit were stored at 28°C. However, at 15°C, the color of the skin increased progressively from green mature at day 0 to ¼ of yellow at day 12 while at 22°C for the same period, it changed from green mature to ¾ of yellow. At 15 and 22°C, the color of the pulp varied from red to dark red from day 0 to day 12 and the fruit became juicier and less crunchy. The sensory evaluation results were confirmed by those of the physico-chemical analysis, and those indicated by Obenland *et al*. (2011). The comparison of the first two maturity stages showed that the green mature fruit followed a natural ripening cycle during storage and presented better organoleptic characteristics which represent the optimal stage of maturity. At 15°C, the postharvest shelf life of the green mature papaya was longer than that of the green immature papaya because the low temperature delayed most of the biochemical reactions. This result was in accordance with that of Bron and Jacomino (2009) who drew similar conclusions when they indicated that the ripening and the softening of the papaya were delayed at 15°C because the enzymatic reactions also were reduced at that temperature.

All the advanced maturity stage papaya fruit (**Figs. 5C, 5F, 5I**) showed a significant ($P < 0.05$) difference between all the organoleptic characteristics studied except the acidity. Thus at 22 and 28°C, the color of the fruit skin varied from 1/8 of yellow to totally yellow. These sensory results were confirmed by the physico-chemical analysis. However, at 15°C, the variation of the color of the skin from 1/8 of yellow to ¾ of yellow was probably due to the effect of the low temperature that delayed the development of the color and the loss of the firmness. In fact, the production of ethylene, which is responsible of the ripening in fruit, is highly reduced by low temperatures (Bron and Jacomino 2009). During storage, the color of the pulp varied from red to dark red. For the advanced mature stage at the three storage temperatures, most of the biochemical reactions were accelerated: chlorophyll was degraded, and pigments which give the red color of the pulp (carotenoids), were synthesized (Grimplet 2004). At 22 and 28°C, the fruit, which were very firm at day 0, became less and less firm from day 8 to day 12 where they reached a total softness when compared to the ones at 15°C. The sweetness and the juiciness increased progressively during storage probably because of the degradation activities of some enzymes (polygalacturonase, pectin methyl esterase) that hydrolyze pectin, contributing to the softening of the fruit and the release of the simple sugars responsible of the sweet taste of the fruit (Emega 2008).

CONCLUSION

The storage of *C. papaya* harvested at various stages of maturity (green immature, green mature and advanced maturity) at 15, 22, and 28°C has revealed several interesting phenomena. Indeed, the green immature papayas stored at these temperatures do not ripen whilst those harvested at the advanced maturity ripened too quickly regardless of the storage temperature. However, the papayas harvested at green mature stage and stored at 15°C ripened naturally and showed the best organoleptic characteristics. Consequently, in order to preserve the best quality of their fruit over a long period, papaya farmers should harvest their fruit at the green mature stage and store them at 15°C.

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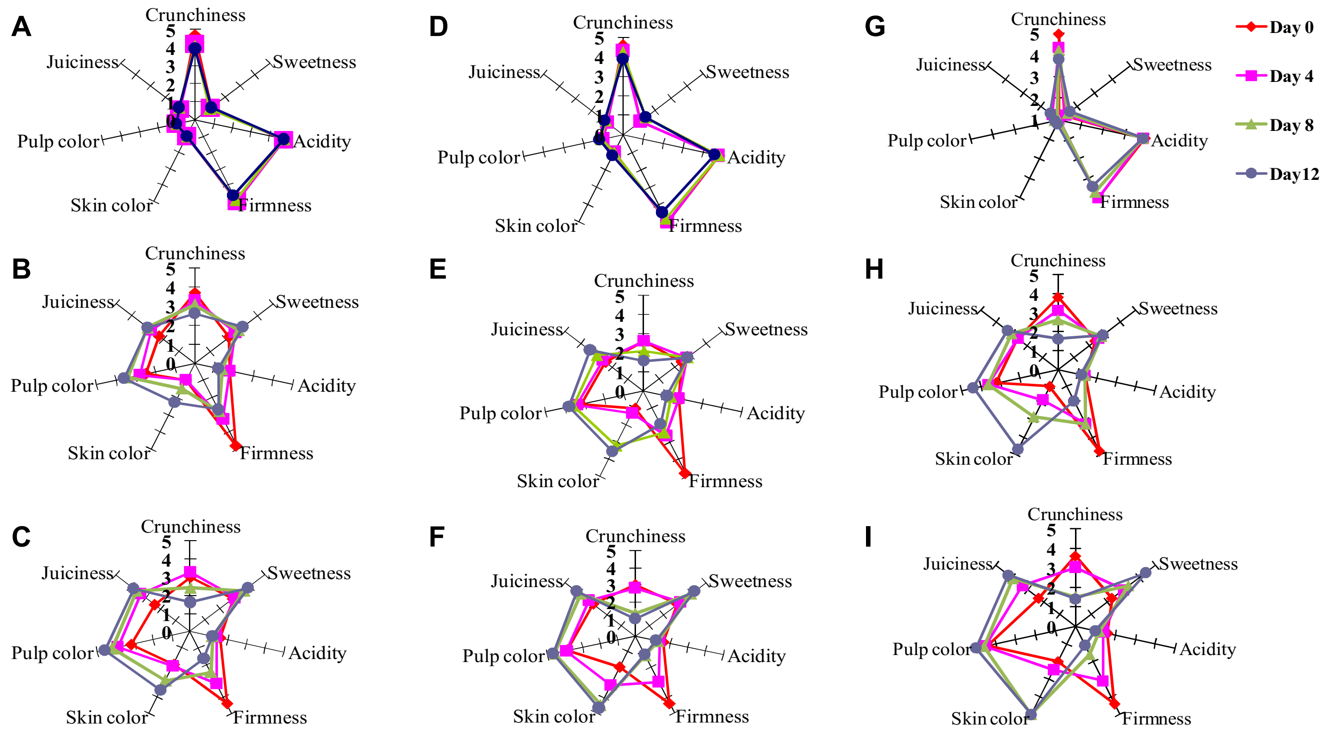

Fig. 5 Evolution of organoleptic parameters of *Carica papaya* L. picked at green immature (**A, D, G**), mature green (**B, E, H**) and advanced maturity (**C, F, I**) stages and stored at 15°C for 12 days (**A-C**), at 22°C for 12 days (**D-I**).

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