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# Quality evaluation of 'JabelMarrah' papaya fruit harvested at different maturity stages

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## ABSTRACT

The objective of this study was to determine how ripening physiology and quality of 'JabelMarrah' papaya are affected by maturity stages at harvest. Papayas were harvested at four maturity stages (Stage 0: totally green; Stage 1: up to 25% of yellow skin; Stage 2: 26-50% of yellow skin; Stage 3:50-70% of yellow skin) and evaluated during ripening at 20ºC. Physical (skin color, pulp firmness), physiological (respiratory activity and ethylene production), and sensorial (flavor, odor, fruit firmness, and appearance) characteristics were evaluated. Regardless of maturity stages, fruit showed similar variation in respiration rate, exhibiting constant values after the 2$^{nd}$ day of storage at 20ºC (~31 mL $CO_2$ $kg^{-1}$ $h^{-1}$ for stages 0, 1, and 2, and ~37 mL $CO_2$ $kg^{-1}$ $h^{-1}$ for stage 3). Typical climacteric behavior was not observed for any maturity stage. Only fruit harvested at stage 0 and 1 showed a well-defined ethylene production peak of 2.1 µL $C_2H_4$ $kg^{-1}$ $h^{-1}$ after 7 days of storage and 1.3 µL $C_2H_4$ $kg^{-1}$ $h^{-1}$ after 6 days, respectively. Fruit harvested at the above mentioned maturity stages reached the edible condition (pulp firmness $\leq$ 20 N) after 7, 6, 4, and 3 days at 20ºC, respectively.

Regardless of the maturity stages of harvest, soluble solids did not alter during ripening. Fruit harvested at stages 2 and 3 were superior for sensorial evaluation, mainly for flavor and appearance. Harvest at different maturity stages affects fruit postharvest physiology and when harvested at early stages, it reduced fruit quality but did not affect the acceptability of consumption.

***Key words:****Carica papaya, ethylene, harvest stage, postharvest, respiration, sensorial evaluation.*

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## INTRODUCTION

Many studies have been conducted in order to understand the postharvest factors that influence papaya quality. However, information is scarce on the preharvest aspects that influence fruit postharvest physiology. Postharvest physiology can be affected by cultivar, environmental condition and also by harvest stage. Harvest stage is fundamental to obtain a high quality fruit with storage potential. Pratt and Goeschl (2007) reported that in cucurbits especially (melons) both maximum respiratory activity and ethylene production were dependent on fruit maturity at harvest. According to Lalel et al. (2011) only melons harvested at early maturity stages exhibit the climacteric pattern.

Harvest stage also has influence on fruit sensorial quality. Bananas harvested at more advanced maturity stages had better consumer acceptance (Ahmad et al., 2001). Knee and Smith (1989) verified that apples harvested at precocious maturity stages showed good conservation 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., 2011). According to Johnston et al. (2002) firmness loss in apples and kiwi is also affected by harvest stage.

In a country wise JabelMarrah and Damazein represents a major papayas for local markets; nevertheless, there are few studies considering its postharvest physiology. The poor quality of fruit is one of the limiting factors for expanding the papaya market. Therefore, knowledge of factors that influence ripening physiology is essential to elaborate adequate techniques to preserve fruit quality.

The aim of this investigation was to study how ripening physiology and quality of 'Jabel Marrah' papayas are affected by maturity stages at harvest.

## MATERIAL AND METHODS

Papaya fruit (*Carica papaya* L. 'Jabel Marrah') (a genotype resulting from mass selection of 'different cultivated plants; Costa and Pacova, 2003) were harvested in February 2013 from thedemonstration orchard of the college of Agricultural studies -Shambat, at maturity stages 0, 1, 2 and 3. Fruits were then transported in

trays each containing ten fruits of the same stage of maturity at 20ºC to the Food Research Centre- Shambat)where the postharvest trials were held.

The maturity stages were visually defined according to the skin color as: Stage 0 - totally green; Stage 1 - yellow color that does not cover more than 25% of skinsurface; Stage 2 - fruit with 26-50% of yellow skin; Stage 3 - fruit with more than 50% of yellow skin. Fruits were stored in chambers with controlled temperature (20ºC) and 80-90% relative humidity until fully ripe. Measurements of skin color, pulp firmness, soluble solids, respiration rate, and ethylene production were made after harvest and daily during the storage period, whereas those of sensorial characteristics were performed when fruits reached full ripening.

Fruit firmness was manually measured using a digital penetrometer fitted with an 8 mm diameter probe tip. The skin was previously removed with a peeler. Fruit skin color was measured as hue angle (Hº) with a colorimeter. These measurements were taken from four opposite points within the largest diameter area. For soluble solids measurements, rectangular samples of fruit pulp were removed from two opposite sides within the largest diameter portion and pressed for the evaluation of the juice in a digital refractometer. The data were expressed as ºBrix. Eight single fruit replicates were used for pulp firmness, skin color, and soluble solids evaluations.

For respiratory activity and ethylene production, fruits of known mass were individually placed into 1700 mL hermetic flasks for 1 h. After this time, gas samples (1mL) were taken through a silicone septum with a syringe. After measurements, the flasks were opened and fruits removed. The respiration rate and ethylene production were determined by the difference between the initial (when flasks were closed) and final (after 1 h) gas concentration, and expressed as mL $CO_2$ $kg^{-1}$ $h^{-1}$ and µL $C_2H_4$ $kg^{-1}$ $h^{-1}$, respectively. Seven single fruit replicates were used. The same fruits were used during the whole experimental period.

For sensorial evaluation, portions containing two pieces of papaya were placed in a plastic recipient and offered to 40 untrained panelists. Fruits were evaluated for flavor, odor, firmness and appearance on a five points scale corresponding to excellent, good, regular, bad, and very bad.

The experimental design was completely randomized and data were analyzed using the ANOVA procedure through DMRT for mean separation.

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## RESULTS AND DISCUSSION

Papaya fruit harvested at all maturity stages presented normal ripening, evidenced by changes in quality attributes, mainly in skin color and pulp firmness. However, typical climacteric respiration was not observed (Figure1). Regardless of maturity stages, fruit showed a similar variation in respiration rate (Figure1). The respiratory activity decreased during the first two days of storage at 20ºC, but after the 3rd day a trend for an increase in respiration rate was observed, mainly for fruits harvested at stages 0 and 1. During ripening respiratory activity was ~31 mL $CO_2$ $kg^{-1}$ $h^{-1}$ for fruits harvested at stages 0, 1, and 2, and averaged 37mL $CO_2$ $kg^{-1}$ $h^{-1}$ for fruits harvested at stage 3 (Figure 1).

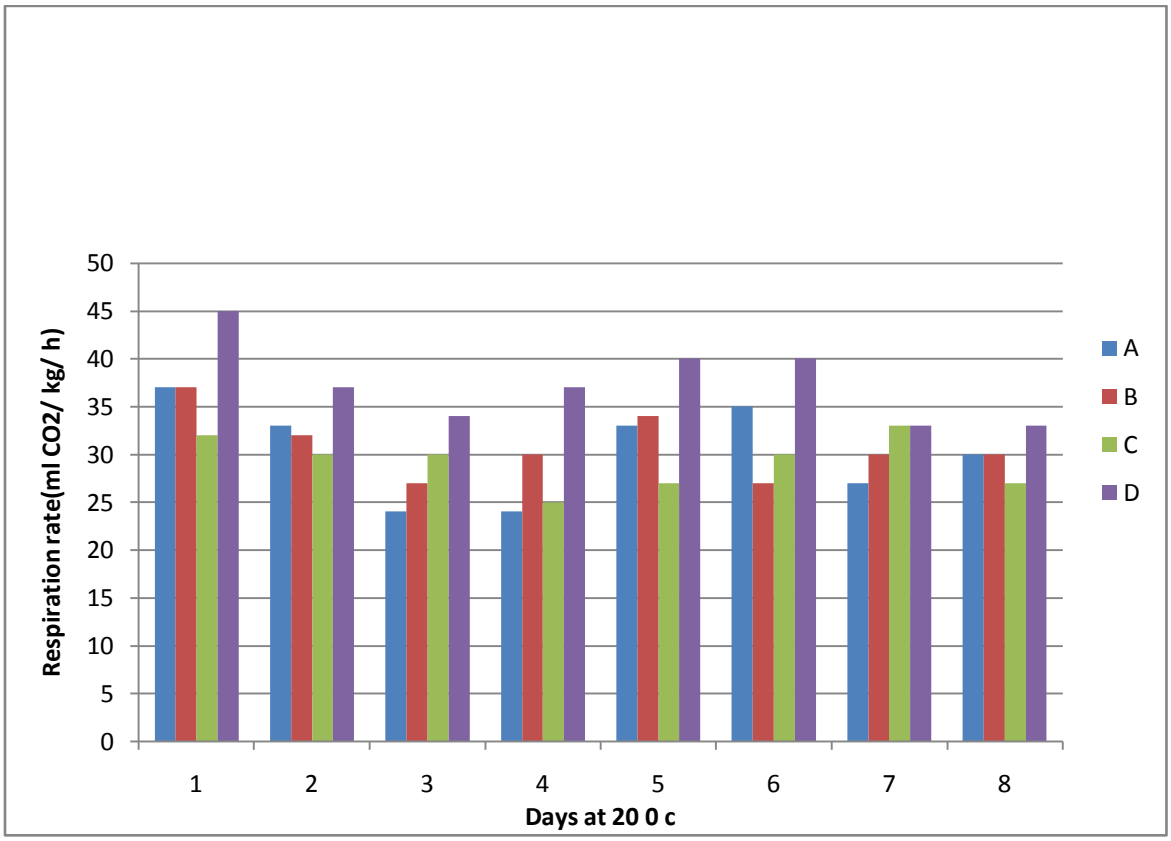


*Figure 1;respiration rate of Jabel Marrah papaya fruits harvested at four maturity stages and stored at 20 °c. Symbols stand for: A= stage o, B= stage 1,C = stage 2 and D= stage 3*

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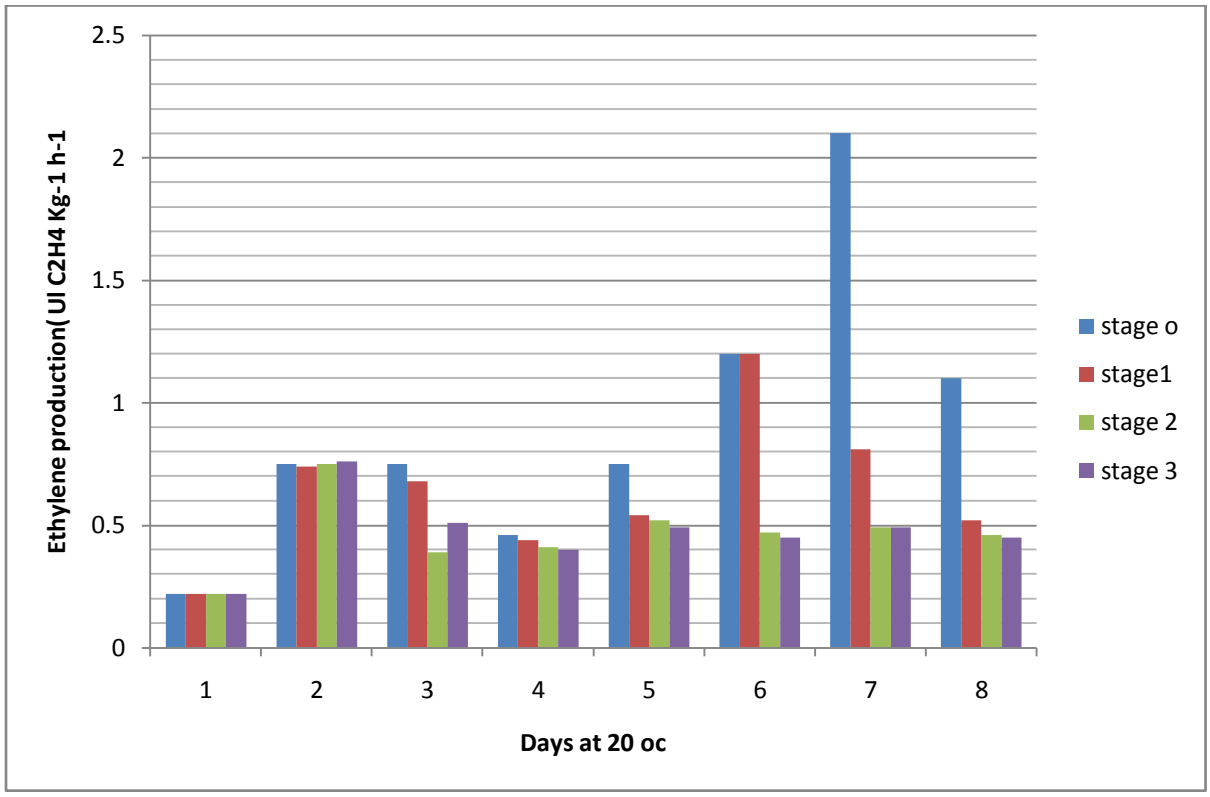


*Figure 2: ethylene production of Jabel Marrah papaya fruits harvested at four maturity stages and stored at 20 $^{o}$c.*

Fruit harvested at stage 0 showed two increases in ethylene production. The first increase occurred after 1 day of storage, reaching constant values up to the 5$^{th}$ day, and the second increase was characterized by a well defined peak of 2 µL $C_2H_4$ kg$^{-1}$ h$^{-1}$, after 7 day of storage at 20ºC (Figure 2). Fruit harvested at stages 1 and 0 showed a similar variation in ethylene production. However, the second increase in ethylene production for fruit harvested at stage 1 occurred at 6$^{th}$ day and, although significant ($P$< 0.05), it was less intense, reaching 1.3 µL $C_2H_4$ kg$^{-1}$ h$^{-1}$ (Figure 2). Fruit harvested at stages 2 and 3 showed the lowest ethylene production, with a mean value of 0.57 µL $C_2H_4$ kg$^{-1}$ h$^{-1}$, without any significant increase during the storage period (Figure 2).

Previous studies with other papaya cultivars have demonstrated a respiration peak. Wills and Widjanarko (1995) found a respiration rate of 36 mL $CO_2$ $kg^{-1}$ $h^{-1}$ in papayas (harvested at mature green stage), 5 days after harvest, while maximum ethylene production (5 µL $C_2H_4$ $kg^{-1}$ $h^{-1}$) was achieved on the $6^{th}$ day. Selvaraj et al. (1982) found that the climacteric peak in papayas occurred 140 day after anthesis, when fruits were already ripe, with yellow skin and soft pulp.

Various interrelated processes are involved in the physiology of ripening in a complex way, and for that reason fruit behavior during this period might not correspond to previous established patterns. Azzolini et al. (2005) demonstrated that 'Pedro Sato' guavas exhibited a gradual increase in respiration rate and ethylene production. Abdi et al. (1998) showed that plums also produced ethylene up to the end of ripening.

The interference of harvest stage on climacteric manifestation was studied by Lalel et al. (2003) who noticed that only mangoes harvested at early stages showed an ethylene peak with a significant increase of respiration. This led them to affirm that only fruit harvested at early stages were in a pre-climacteric phase. Possibly, this also occurred in our study, with fruits harvested at stages 2 and 3 showing maximum ethylene production while attached to the plant. In a study conducted by Johnston et al. (2002), apples harvested at a less advanced maturity stage showed higher ethylene production than those harvested at more advanced stages. According to Trewavas (1982), in fruits at more advanced maturity stages the quantity of ethylene receptors is higher, leading to a lower need for ethylene production. Consequently, we may argue that the need of ethylene for ripening is greater in fruits harvested precociously.

There is evidence that the basal level of ethylene and respiration activity were sufficient to stimulate biochemical changes associated with fruit ripening.

Fruits harvested at more advanced maturity stages had lower pulp firmness when compared to those harvested at earlier stages (Figure 3). Because of high firmness variation (CV = 25%), statistical differences among maturity stages were not detectable (Figure 3).

The rate of firmness loss was also affected by maturity stage at harvest (Figure 3). At the $2^{nd}$ day of storage, fruits harvested at stage 0 lost approximately 39% of initial firmness, and more than 60% when harvested at stages 2 and 3 (Figure 3).

Johnston et al. (2002) and MacRae et al. (1989) also observed the slower initial softening in apples and kiwis harvested at early maturity stages. Possibly, in early maturity stages the enzymes related to softening were still not completely synthesized and activated. In addition, the quantity of ethylene receptors is reduced in fruits harvested when still green (Trewavas, 1982) and, for this reason, the ethylene-dependent processes can be delayed.

The ripening processes, including firmness loss, can be the result of an increase in ethylene sensitivity of the fruit tissue and not necessarily dependent on increases in ethylene production. Besides, a low quantity of this hormone can be sufficient for beginning the ripening processes. Flores et al. (2001) concluded that melon softening depends only partially on ethylene, since firmness loss of genotypes that express the antisense 1-aminocyclopropane-1-carboxylic acid oxidase was about 50% lower than in normal fruit. Therefore, it is reasonable to assume that other ethylene-independent processes are involved in fruit ripening. In fact, firmness loss has a close relationship with activity of pectic enzymes, which are related to ethylene but at different dependence levels (Jeong et al., 2002).

During ripening, fruits harvested at all maturity stages showed decreases in $H^o$, or yellow color development, mainly after the 2$^{nd}$ day of storage.

As observed for firmness, the increase in ethylene production found at stages 0 and 1 occurred when papayas had already achieved $H^o = 80^o$, i.e. a completely yellow skin. Also, in this case, it is reasonable to assume that skin color changes cannot be only dependent of high ethylene concentrations, but that ethylene simply coordinates the events that have already been initiated during ripening.

Independent of the maturity stages at which papayas were harvested, soluble solids did not differ during ripening ($P > 0.05$). Papaya has low starch content (around 6.5-8.1%; Selvaraj et al. 1982). Therefore, the fruit does not have significant amounts of starch to be hydrolyzed during ripening, which results in little, if any, change in soluble contents during the postharvest period.

According to Selvaraj et al. (1982), sucrose content increases up to five times at 110-130 d after anthesis in papayas attached to the tree, when skin color begins to change. Therefore, it is important to consider that a higher sink demand occurs when fruit begins to turn yellow, and it is reasonable to assume that fruit harvested at maturity stages 0 and 1 did not have sufficient time to accumulate soluble sugar

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before harvest. According to Zhou and Paull (2001), the papaya sugar content remains constant during postharvest ripening, suggesting that sugar accumulation in pulp is related to continued sugar translocation from plant to fruit.

In sensorial analysis, the highest scores were attributed to fruit harvested at advanced maturity stages, when the edible condition was reached (Figure 3). In general, two groups were segregated ($P< 0.05$) according to sensorial analysis: fruits harvested at stages 2 and 3, and those harvested at stages 0 and 1. Since papaya has low acidity, flavor is attributed mainly to sugar content. Comparing the results obtained in sensorial analysis (Figure 3) with soluble solid values, it is noticeable that the panelists detected the differences found in soluble solids. Harvesting at early stages does decrease fruit quality but did not make the fruit unacceptable for consumption.

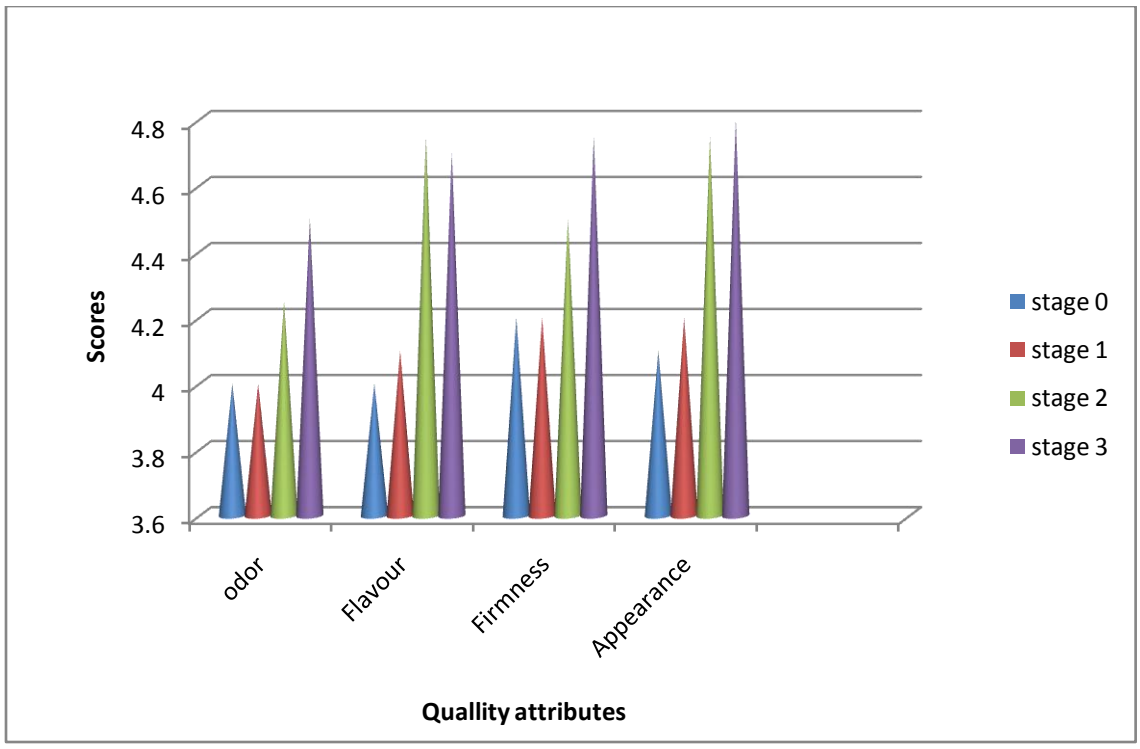


*Figure 3: Sensorial evaluation of ripe (Jabel Marrah) papaya fruits harvested at four maturity stages and stored at 20$^{o}$c .*

## CONCLUSIONS

Typical climacteric behavior was not verified for 'Jabel Marrah' papaya fruit harvested at different maturity stages. Fruit harvested at a more advanced maturity stage showed reduced ethylene production during postharvest. Fruits harvested at early stages are acceptable but lower sensory quality for consumption. The maturity stage at harvest affected the respiratory activity and ethylene production during postharvest of papayas.

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