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Postharvest respiration and maturation of some lesser-known exotic fruits from Brazil – ciriguela (*Spondias purpurea* L.)

Silvio de Almeida Sampaio[1]
Pushkar Singh Bora[2 *]
Heinz Johann Holschuh[1]

ABSTRACT

Red mombin (*Spondias purpurea L*) fruits, locally known as ciriguela, were monitored for their respiration activity. Mature green fruits of red mombin were stored in closed glass containers and concentration of oxygen and carbon dioxide after five hours of respiration was determined. In the same time interval, the container lid was opened for air renewal. Increase in carbon dioxide and decrease in oxygen concentration demonstrated climacteric respiration behavior. Maximum CO_2 liberation, 111.8 $mL \cdot kg^{-1} \cdot h^{-1}$ and O_2 absorption 124.2 $mL \cdot kg^{-1} \cdot h^{-1}$ occurred at 140 and 130 h respectively, post-harvest, starting then the senescence process. Respiratory Quotients (R.Q.) during the period of post-harvest storage of red mombin: pre-climacteric, climacteric minimum, climacteric maximum and post-climacteric stages were 0.51, 0.61, 0.9 and 0.67, respectively. Total soluble solids increased from 7.7 ^{0}Brix (initial) to 15.7 ^{0}Brix (post climacteric stage) during ripening, but total acidity show no significant change. There was a continuous decrease in ascorbic acid and chlorophyll content of fruits. Total carotenoids increased continuously during ripening.

Key words: red mombin; ciriguela; post-harvest respiration; maturation; chemical constituents

RESUMO

Respiração e maturação pós-colheita de algumas frutas tropicais menos-conhecidas do Brasil - ciriguela (*Spondias purpurea* L.)

Ciriguelas (*Spondias purpurea* L.) foram monitoradas em relação a sua atividade respiratória. Frutos verde-maturos foram armazenados em recipientes de vidro fechados e as concentrações de oxigênio (O_2) e de dióxido de carbono (CO_2) determinadas em intervalos de cinco horas. Após a coleta de amostras da atmosfera, a tampa dos recipientes foi aberta para renovação do ar. O aumento na concentração de CO_2 e diminuição na de O_2 durante o armazenamento retratou comportamento climatérico. A liberação máxima de CO_2 111,8 $mL \cdot kg^{-1} \cdot h^{-1}$, e a absorção máxima de O_2 124,2 $mL \cdot kg^{-1} \cdot h^{-1}$ ocorreram 140 h e 130 h após a colheita, quando os processos de senescência se iniciaram. Os quocientes de respiração (Q.R.) durante o armazenamento das ciriguelas no pré-climatérico, climatérico mínimo, climatérico máximo e pós-climatérico foram 0,51, 0,61, 0,90 e 0,67, respectivamente. Os teores de sólidos solúveis aumentaram de 7,7 °Brix para 15,7 °Brix durante o amadurecimento, porém a acidez titulável não demonstrou alterações significativas. Houve decréscimo contínuo no teor de ácido ascórbico e clorofila e aumento contínuo no de carotenóides, durante o amadurecimento.

Palavras chave: Spondias purpúrea, ciriguela, respiração pós-colheita, amadurecimento, constituintes químicos.

[1] Programa de Pós –graduação em Ciência e Tecnologia de Alimentos, Universidade Federal da Paraíba
[2] Departamento de Tecnologia Química e Alimentos. Universidade Federal da Paraíba, Cidade Universitária, CEP 58059-900 João Pessoa. E-mail: pradesh@uol.com.br
[*] corresponding author

INTRODUCTION

The north and northeast regions of Brazil are home of numerous native and exotic fruits little known outside their production areas. Some fruits, such as red mombin (Spondias *purpurea* L.), Brazil plum (*Spondias tuberosa* L.), custard apple (*Annona squamosa*), star fruit (*Averrhoa carambola*), mangaba (*Hancornia speciosa*), sapodilla (*Amilcara achras)*, etc. have characteristics well suited for fresh fruit consumption as well as preparation of beverages and ice-creams, while others – Surinam cherry (*Eugenia uniflora*), soursop (*Annona muricata*), jackfruit (*Artocarpus heterophyllus*), tamarind (*Tamarindus índica*) and yellow mombin (*Spondias mombin* L.), for industrialization.

Red mombin (*Spondias purpurea* L.) is native of Central America dispersed in Mexico, Guatemala, Caribbean, and in some countries of South America, mainly in northeastern states of Brazil. The species belongs to the family A*nacardiaceae,* the same as mango (*Mangifera índica*) and cashew-nut (*Anacardium occidentale*). Inflorescence in panicles with numerous flowers that bear three or more fruits. The fruit is an oval drupe with about 50% pulp (Pinto, 1997) In spite of having a very pleasant aroma, color and taste, very little information is available on germplasm evaluation and characterization as well as description of cultivars adapted to different climatic conditions of Northeastern Brazil. Moreover, there is no cultivation system for the production of red mombin. According to Popenoe (1979) and Kersul *et al* (1998), size, shape and color of fruits vary depending on the botanical variety and maturity stage. Fruit is consumed fresh, and information on physical characteristics (Leung and Flores, 1901; Bezerra *et al*, 1990) and chemical composition (Kosiol & Mácia, 1998) is available.

Red mombin is rarely transported to distant markets, as they are highly perishable (Diaz Peres *et al*., 1998), posing a serious problem to commercialization. It is believed that post-harvest losses reach up to 50% of the total production (FAO, 1993). Understanding the biological and environmental processes involved in post-harvest deterioration is crucial to develop technology for fruit shelf-life extension and maintenance of quality. So far no study has been reported on post-harvest respiration / maturation behavior of this fruit except for the study by Pareira *et al*., 2000 on Mexican ciruela. The present work was, therefore, carried out to provide data on the respiration behavior and changes in some important chemical constituents of red mombin grown in Northeastern Brazil.

MATERIALS AND METHODS

Fruits:

Fully developed green red mombin fruits were purchased from the Research and Training Center of the Rural University of Pernambuco, Serra Talhada, Pernambuco, Brazil. Undamaged fruits of similar sizes were selected, washed with chlorinated water, and dried with a towel.

The graded and washed fruits were divided into four lots of 1 kg each. Fruits from each lot were stored in glass boxes provided with a small fan at the bottom to homogenize the air within. The boxes were closed airtight with a lid provided with a hole, which was also closed airtight with a rubber stopper. Air samples were removed from the box with a syringe and analyzed by the Facile method (Calbo, 2001).

Determination of Post-Harvest Respiration Rates

Fruit respiration rates in terms of oxygen consumption and carbon dioxide evolution were determined through volumetric analysis. Gas sample of 100 µl was collected from the box at an interval of 5 h and injected in the measuring graduated pipette of the facile assembly, containing 0.002N sulphuric acid. At 5 h interval the box lids were opened for fresh air circulation. The interval of 5 h was established in order the CO_2 concentration in the boxes not to exceed 5%. The acid solution was replaced by a fresh sulphuric acid solution (0.002N) and the bubble was given a light but careful movement in the pipette to eliminate the presence of moisture in the gas sample. The volume of gas without moisture (V_1) was read in the pipette. The sulphuric acid solution was replaced by 10% sodium hydroxide solution and then by 5% pyrogallol solution. After replacement of each solution, the gas bubble was moved several times along the graduated pipette so the sodium hydroxide could remove the carbon dioxide and pyrogallol oxygen. The gas volume was recorded after each treatment, letting it be V_2 and V_3. Results were expressed in terms of percentage.

$$(\%)\ CO_2 = \frac{V1 - V2}{V1} \times 100 \quad \text{and} \quad (\%)\ O_2 = \frac{V2 - V3}{V1} \times 100$$

The percent of oxygen consumed was determined by subtracting the percentage of measured oxygen from the percentage of oxygen in the air (Calbo, 2001).

Determination of Physicochemical and Chemical Constituents

Determination of titritable acidity, total soluble solids, ascorbic acid, total chlorophyll and total carotenoids were carried out by the methods described by Ranganna (1979). Concentration of chlorophyll and carotenoids is presented in terms of extract absorbance.

Determination of Temperature and Relative Humidity

Temperature and relative humidity inside the boxes containing the fruits were measured with an electronic detector GV/508 at a 5 h interval.

Statistical Analysis

The Statistical Analysis System (SAS) version 6.12 (SAS Institute, 1996) was used for the analysis.

RESULTS AND DISCUSSION

The post harvest respiration behavior of red mombin fruits (Fig. 1) was typical of climacteric fruits (as reported by Biale, 1960): a minimum pre-climacteric followed by a rapid increase in the rate of respiration reaching to a maximum (climacteric maximum) then a sudden drop in respiration activity (post climacteric) characterized as senescence.

The pre-climacteric was marked by the initial production of 34.0 mL $kg^{-1}.h^{-1}$ CO_2 and initial oxygen absorption of 76.2mL. $kg^{-1}.h^{-1}$. The minimum evolution of CO_2 28.0 mL. $kg^{-1}.h^{-1}$and the minimum absorption of O_2 38.3 mL. $kg^{-1}.h^{-1}$ occurred at 40 and 55 h respectively, after the harvest. Thus indicating a climacteric minimum. The maximum liberation of CO_2, 111.8 mL. $kg^{-1}.h^{-1}$ and absorption of O_2 124.2 mL. $kg^{-1}.h^{-1}$ occurred at 140 and 130 h respectively, after the harvest, defining the climacteric maximum. However, Pareira *et al*. (2000) reported a higher value of CO_2 evolution, i.e., 190 mg. $kg^{-1}.h^{-1}$ at the climacteric minimum stage and 430 mg. $kg^{-1}.h^{-1}$ at climacteric maximum for Mexican ciruela fruits. As a result of intense respiratory activity the shelf life of Mexican ciruela was limited to 33 h after harvest against 140 h of red mombin from Northeastern Brazil. This difference in CO_2 liberation as well as shelf life between red mombin from Brazil and from Mexico may be attributed to the difference in variety and climate. The Respiratory Quotient (R.Q.) was calculated as a ratio of CO_2 liberated with O_2 consumed along the period of fruit post harvest storage and the result is shown in Fig. 2. The pre-climacteric, climacteric minimum, climacteric maximum and post-climacteric values of Respiratory Quotient were 0.51, 0.61, 0.9 and 0.67, respectively. Kader (1987) reported a range from 0.7 to 1.3 of R.Q for various fruits and vegetables. According to Blanke (1991), values of respiratory quotient close to 0.7 indicate lipid consumption, 0.8, oxidation of proteins and close to one, carbohydrate oxidation.

The behavior of chlorophyll and carotenoid pigments during maturation is presented in Fig. 3. A concomitant decrease in chlorophyll content was found during fruit ripening. The disappearance of chlorophyll is characterized by a change in the color of endocarp from dark green to light green between the pre-climacteric and the climacteric minimum stage, then to orange yellow during climacteric rise, and finally to purple red at climacteric peak, maintaining the color during post

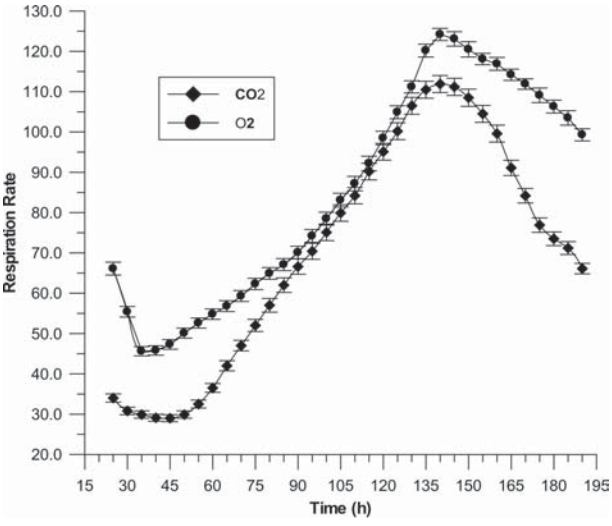

Figure 1: Post harvest respiration behavior of red mombin fruits stored at room temperature (28 ± 2 ^{0}C).

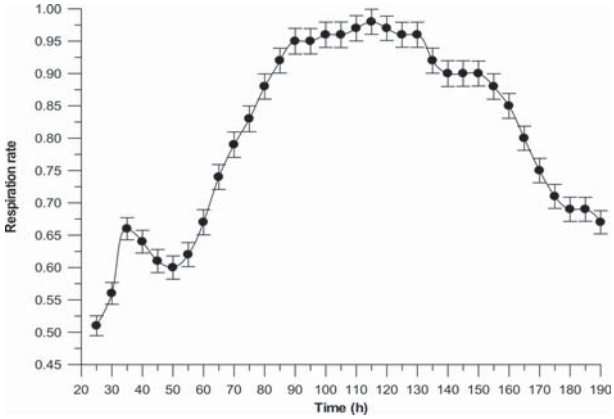

Figure 2: Respiration quotient of red mombin fruits during post-harvest storage at room temperature (28±2^0 C).

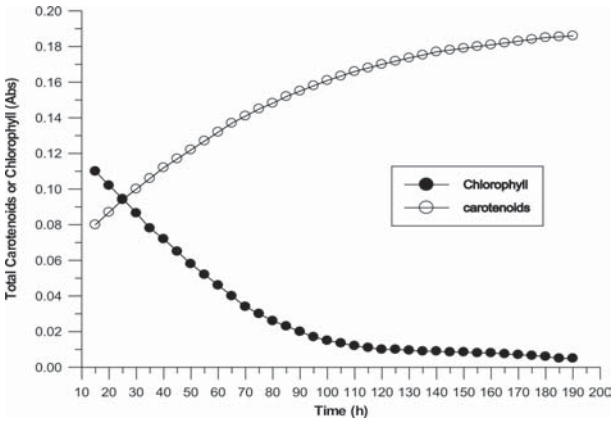

Figure 3: Change in total chlorophyll and carotenoid concentration during post harvest storage of red mombin fruits at room temperature (28±2 ^{0}C)

climacteric stage. During these stages of maturation there was a continuous increase in carotenoid content. The loss of the chlorophyll green color in the fruits is a result of its structure degradation associated with the synthesis and appearance of carotenoid pigments, which varies from yellow to orange. Gross and Flugel (1982) earlier reported an initial decrease in the carotenoid content during the early stage of ripening of bananas followed by carotenoid biosynthesis at the yellow-green to yellow ripe stage.

The temperature, relative humidity of the air inside the storage box and the transformation in physical and chemical parameters during post-harvest respiration of red mombin is shown in Table 1. The temperature inside the boxes varied from 28.6^0 C to 30.2^0 C. Total soluble solids increased from 7.7^0 Brix (initial) to 15.7^0 Brix (post climacteric stage) during maturation. There was significant difference between the Brix of fruits of pre-climacteric and climacteric minimum stage and the Brix of fruits of climacteric and post-climacteric stage. Bezerra *et al*. (1990) reported a Brix range from 15.7 to 19.3 for ripe fruits. Similarly, Kosiol and Mácia (1998) reported a Brix value of 18^0. Total acidity showed no significant change. During ripening, there is a progressive increase in total solids content as a result of the transformation of polysaccharides into sugars (Chan et al. 1979; Selvaraj *et al* 1982), decrease in acidity (Teisson & Pineau, 1982; Samson, 1986; Selvaraj *et al*. 1989) and increase in Brix-acid ratio. Contrary to the report that vitamin C content increases during ripening of guava fruit and decreases during senescence (Esteves *et al*. 1984), the ascorbic acid content of red mombin in our study decreased during ripening and the difference among the stages of ripening was significant.

Table 1. Changes in physical and chemical parameters during post-harvest respiration of red mombin (*Spondias purpurea* L.) fruits

Stage of ripening	Time (hr)	Relative Humidity (%)	Temperature (^{0}C)	Total Sol. Solids ^{0}Brix	Titratable Acidity (%)	Brix-Acid Ratio	Ascorbic acid (mg/100 g)
Initial	0	83.0±3.9	29.4±1.3	7.7±1.3^a	1.15±0.1^a	6.7±0.37^a	39.5±0.8^a
Pre-climacteric	25	85.8±2.9	30±2.0	8.1±0.3^a	1.09±0.2^a	7.4±0.32^a	29.2±1.7^b
Climacteric min.	40	88.1±2.7	28.6±1.0	9.8±1.1^a	1.01±0.1^a	9.7±0.44^b	23.8±3.1^b
Climacteric max.	140	91.7±2.3	29.9±1.0	15.0±1.7^b	1.0±0.1^a	15.0±0.77^c	11.4±1.6^c
Post-climacteric	190	92.02.1	29.9±0.9	15.7±1.0^b	1.0±0.0^a	15.7±0.89^c	8.31.7^c

Different letters in the same column represent statistically different values at $p<0.05$

CONCLUSIONS

The respiratory behavior showed that red mombin is a climacteric fruit. The climacteric rise in the CO_2 evolution started after about 40 h of storage, reaching a maximum after 140 h, then the process of senescence started. This gives the fruit a shelf life of about 6 days which is sufficient for transportation of mature dark green fruits to trade markets. Besides, with the use of substances to reduce the respiration rate, fruit shelf life can be extended further. Maximum fruit quality in terms of acid-Brix ratio and color was achieved 6 days after harvest of mature dark green fruits.

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