Postharvest respiratory activity and changes in some chemical constituents during maturation of yellow mombin (*Spondias mombin*) fruit

Atividade respiratória pós-colheita e alterações de alguns constituintes químicos durante o amadurecimento do fruto da cajazeira (Spondias mombin)

Sílvio Almeida SAMPAIO[1], Pushkar Singh BORA[1]*, Heinz Johann HOLSCHUH[1], Silvanda de Melo SILVA[2]

Abstract

Mature fruit from the yellow mombin (*Spondias mombin*) was monitored for its respiration activity. Mature green fruit from the yellow mombin was stored in closed glass chambers and the concentration of oxygen and carbon dioxide at the end of a six hour respiration period was determined. At the same interval of time, the lid of the chamber was opened for air renewal. The increase in carbon dioxide and decrease in oxygen concentration demonstrated that the fruit was climacteric. The maximum liberation of CO_2 54.2 mL Kg^{-1} h^{-1} and maximum absorption of O_2 49.0 mL Kg^{-1} h^{-1} occurred 186 hours after the harvest which, obviously, represented the optimum fruit quality after the senescence process started. The respiratory quotient of fruit at a climacteric maximum was 1.11 representing the oxidation of carbohydrates. Total soluble solids increased from 9.1 °Brix (initial) to 13.7 °Brix (climacteric maximum) during maturation, while the total number of acids in the fruit decreased during maturation i.e. from 1.55% initially to 1.40% at pre-climacteric, 1.0% at climacteric maximum and 0.8% in the post-climacteric stage. A similar behaviour was observed in the case of ascorbic acid. There was a continuous decrease in chlorophyll and a continuous increase in the carotenoid content of fruit during maturation.

Keywords: yellow mombin; post-harvest respiration; maturation; chemical constituents.

Resumo

Cajás verde-maduros foram armazenados em recipientes de vidro fechados e a concentração de oxigênio (O_2) e de dióxido de carbono (CO_2) foi determinada em intervalos de 6 horas. Após a coleta das amostras da atmosfera, as tampas dos recipientes foram abertas para renovação do ar. O aumento da concentração do CO_2 e o decréscimo de O_2 durante o armazenamento demonstraram o comportamento climatérico da respiração do cajá. A liberação máxima de CO_2 54,2 mL kg^{-1} h^{-1} e a absorção máxima de O_2 49,0 mL kg^{-1} h^{-1} ocorreram após 186 horas da colheita, quando o fruto alcançou qualidade máxima, iniciando em seguida a senescência. O quociente de respiração no climatérico máximo foi 1,11, indicando a oxidação de carboidratos. Os Sólidos solúveis aumentaram de 9,1 °Brix iniciais para 13,7 °Brix no climatérico máximo, enquanto a acidez titulável total diminuiu de 1,55% iniciais para 1,40% no climatérico mínimo, 1,00% no climatérico máximo e 0,80% no pós-climatérico. Comportamento similar foi observado em relação aos teores de ácido ascórbico. A Clorofila diminuiu e os carotenóides aumentaram continuamente durante o amadurecimento do Cajá.

Palavras-chave: cajá; respiração pós-colheita; amadurecimento; constituintes químicos.

1 Introduction

The ripening process in fruit is accompanied by the synthesis of novel proteins and mRNA together with flavor and pigments. The synthesis requires energy and carbon skeleton blocks which are supplied to the fruit tissue by a process of respiration, the pattern and rate of which varies markedly between climacteric and non-climacteric fruit. In general, fruit with the highest respiratory rates such as bananas and avocados also tend to ripen most rapidly and hence possess a very limited shelf life[26]. This has led to the idea of regulating the respiration process as a possible target for biochemical handling of shelf life.

The extensive Brazilian territory, characterized by a variety of climatic conditions and distinct soil present an extremely diversified agricultural production. Although the fruit culture occupies only 5% of the cultivated area, its significant production potential has the capacity to place Brazil among top fruit producers in the world. The north and northeast region of Brazil is home to numerous native and exotic fruits which are not well known in areas outside the region of their production. Some of the fruit such as ciriguela (*Spondias purpurea* L.), umbú (*Spondias tuburosa* L.), custard apple (*Annona squamosa*), carambola (*Averrhoa carambola* L.), mangaba (*Hancornia speciosa*), sapotí (*Achras sapotaceae)*, etc. present characteristics appropriate for their consumption as fresh fruit, as well as for the preparation of drinks and ice-cream etc, while others-pitanga (*Eugeniauniflora*), soursop (*Annona muricata*), jackfruit (*Artocarpus heterophyllus*), tamarind (*Tamarindus índica*) and cajá (*Spondias mombin* L.) for their industrialization. Recently, these fruits have attracted the attention of fruit processing industries due to the potential of industrializing and exporting them. However, the highly perishable nature of these fruits and inherent short shelf life present a serious problem in terms of transporting and marketing them. It is believed that the postharvest losses of these fruits are more than 50% of their production[9].

The cajazeira (*Spondias mombin L.*) tree belongs to the family of *Anacardiáceas* and it originally comes from Central America. The species grows spontaneously in the Northeast region of Brazil. The cajá fruit, also known as yellow mombin, has an orange–yellow pulp, pleasant aroma, sweet sour taste and vitamin A in quantities higher than cashew, guava, some

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[1] *Programa de Pós-graduação em Ciência e Tecnologia de Alimentos, Universidade Federal da Paraíba, CEP 58059-900, João Pessoa - PB, Brasil, E-mail: pradesh@uol.com.br*
[2] *Departamento de Ciências Fundamentais e Sociais, Centro de Ciências Agrárias, Universidade Federal da Paraíba, João Pessoa - PB, Brasil*
**A quem a correspondência deve ser enviada*

papaya and mango cultivars[17]. However, the short shelf-life limits its commercialization to either being sold as fresh fruit or as frozen pulp[4,22-24]. To extend its shelf-life, it is necessary to understand the biological and environmental processes involved in postharvest deterioration, which could serve as a basis to develop technology, to extend its shelf-life and maintain the quality of the fruit. However, so far no study has been reported on the postharvest respiration and maturation behavior of this fruit except for the changes in the chemical composition of the fruit during maturation from immature green to ripe stages[3]. Therefore, the present work was carried out to provide data on the respiration behavior and on the changes in some important chemical constituents of the fruit.

2 Materials and methods

2.1 The fruit

Fully developed mature green fruit from the yellow mombin were acquired from the CEASA in Recife city in the state of Pernambuco a day after the harvest. Undamaged pieces of fruit of similar sizes were selected and washed with chlorinated water. Finally, the pieces of fruit were dried with a towel.

The graded and washed pieces of fruit were divided into four batches of 1 kg each. The fruit from each batch was stored in a glass box fitted with a small fan at the bottom to homogenise the air inside it. The box was closed airtight using a lid with a hole in it, which was also closed airtight with a rubber stopper. The air from the box was removed with a syringe and analysed by the Facile method[5].

2.2 Determination of postharvest respiration rates

The respiration rates of the fruit in terms of consumption of oxygen and evolution of carbon dioxide was determined using a volumetric analysis. Figure 1 shows the schematic representation of the method. A gas sample of 100 µL from the box was collected at an interval of 6 hours and injected in the measuring graduated pipet of the facile assembly, containing 0.002 N sulphuric acid. At 6 hours intervals, the lid of the boxes was opened to circulate fresh air. Intervals of 6 hours were established so that the concentration of CO_2 in the box did not exceed 5%. The acid solution was substituted with a fresh sulphuric acid solution (0.002 N) and the bubble was given a light but careful movement in the pipet to eliminate the presence of moisture in the gas sample. The volume of the gas without moisture (V_1) was read in the pipet. The sulphuric acid solution was substituted with 10% sodium hydroxide solution and then with 5% of pyrogallol solution. After substituting each solution, the gas bubble was moved several times along the graduated pipet so that the sodium hydroxide removed the carbon dioxide and pyrogallol oxygen. The volume of the gas was noted after each treatment. Let it be V_2 and V_3. The results were expressed in terms of percentages.

$$(\%)CO_2 = \frac{V_1 - V_2}{V_1} \times 100 \text{ and } (\%)O_2 = \frac{V_2 - V_3}{V_1} \times 100 \qquad (1)$$

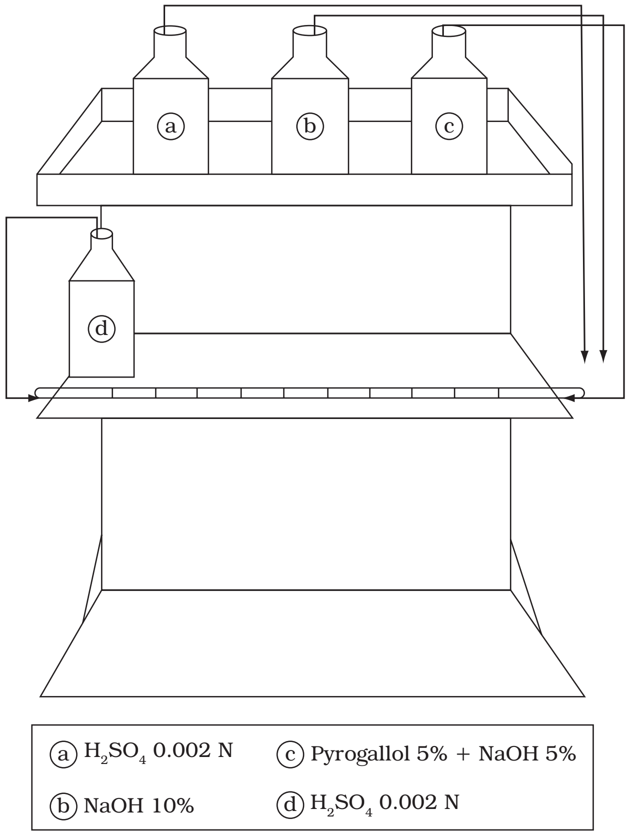

Figure 1. Schematic diagram of the Facile Method.

The percentage of oxygen consumed, was determined by subtracting the percentage of measured oxygen from the percentage of oxygen in the air[5]

2.3 Determination of physicochemical and chemical constituents

Determining the titratable acidity, total soluble solids, ascorbic acid, total chlorophyll and total carotenoids was carried out by the methods described by RANGANNA[16]. The concentration of chlorophyll and carotenoids is presented in terms of the absorbance of the extract.

2.4 Determination of temperature and relative humidity

The temperature and relative humidity inside the boxes that contained yellow mombin fruit were measured with an electronic detector GV/508 at an interval of 6 hours.

2.5 Statistical analysis

For the statistical analysis, the Statistical Analysis system (SAS) version 6.12[19] was used.

3 Results and discussion

The postharvest respiration behaviour of the yellow mombin fruit is shown in Figure 2. It was typical of climacteric fruits and similar to that of the avocado[1]. A minimum pre-climacteric followed by a rapid increase in the rate of respiration reaching a maximum (climacteric maximum) then a sudden drop in respiration activity (post climacteric) was characterised as senescence.

The pre-climacteric was marked by the initial production of 24.4 mL $Kg^{-1}.h^{-1}$ CO_2 and an initial oxygen absorption of 25.5 mL Kg^{-1} hr^{-1}.The minimum evolution of CO_2 11.0 mL Kg^{-1} hr^{-1} and the minimum absorption of O_2 15.5 mL Kg^{-1} hr^{-1}occurred at 102 and 108 hours, respectively after the harvest, thus indicating a climacteric minimum. The maximum liberation of CO_2, 54.2 mL Kg^{-1} h^{-1} and absorption of O_2 49.0 mL $Kg^{-1}.h^{-1}$ occurred at 186 hours after the harvest, defining the climacteric maximum. PEREIRA, FILGUEIRAS and ALVES[15] also reported a climacteric CO_2 maximum of 60.0 mL Kg^{-1} h^{-1} for the Mexican Ciruela.

The Respiratory Quotient (R. Q.) was calculated as a ratio of CO_2 liberated with O_2 consumed throughout the post harvest storage period of yellow mombin fruit and the result is shown in Figure 3. The pre-climacteric, climacteric minimum, climacteric maximum and post-climacteric values of the Respiratory Quotient for this fruit were 0.96, 0.63, 1.11 and 0.59, respectively. KADER[12] reported a RQ range of 0.7 to 1.3 for various fruit and vegetables. According to MEYER, ANDERSON and BOHNING[13] RQ values lower than 1 can be a result of the unavailability of organic acids, incomplete oxidation of sugars and consequent synthesis of these acids with increased absorption of oxygen. RQ values are characteristic of diverse classes of foods. Values close to 0.7 indicate a consumption of lipids, close to 0.8 oxidation of proteins and close to 1.0 oxidation of carbohydrates[2].

The transformation in physical and chemical parameters during postharvest respiration of the yellow mombin fruit is shown in Table 1. The Temperature inside the boxes varied from 27.8 to 29.2 °C. The total soluble solids increased from 9.1 °Brix (initial) to 13.7 °Brix (climacteric maximum) during maturation. BORA et al.[3] also reported a soluble solid content of 12.5 °Brix for partially ripe yellow mombin fruit. The acidity of the fruit decreased during maturation i.e. from 1.35% initially to 1.31% at pre-climacteric, 1.0% at climacteric maximum and 0.8% in the post-climacteric stage. The concentration of organic acids decreases the fruit is ripening due to the participation of the acids as a source of energy during respiration[7,11]. A total acid content of 1.3 and 1.49% in ripe fruit was reported earlier by OLIVEIRA et al.[14] and BORA et al.[3]. The brix-acid ratio also increased during ripening. A significant difference was observed in these parameters in each step of the ripening process. It is well known that during ripening there is a progressive increase

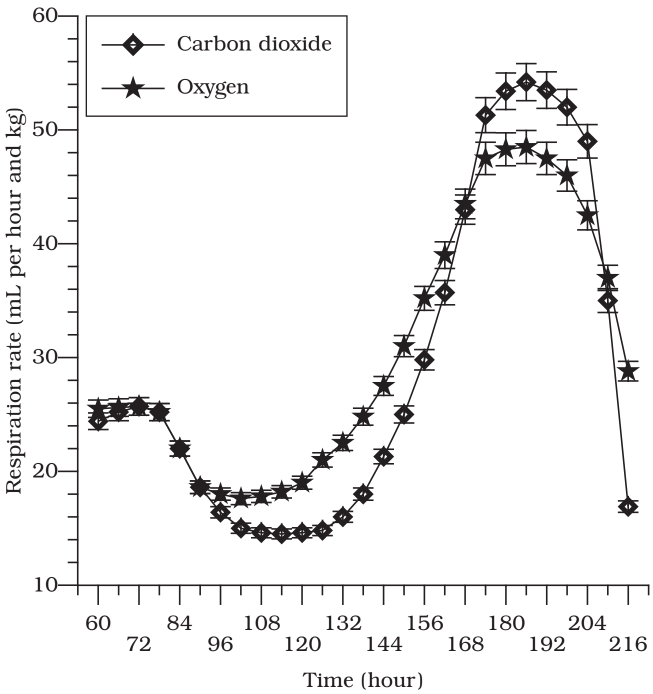

Figure 2. Liberation of carbon dioxide and consumption of oxygen (mL of gas per hour and kg) during postharvest respiration of yellow mombin fruit at room temperature.

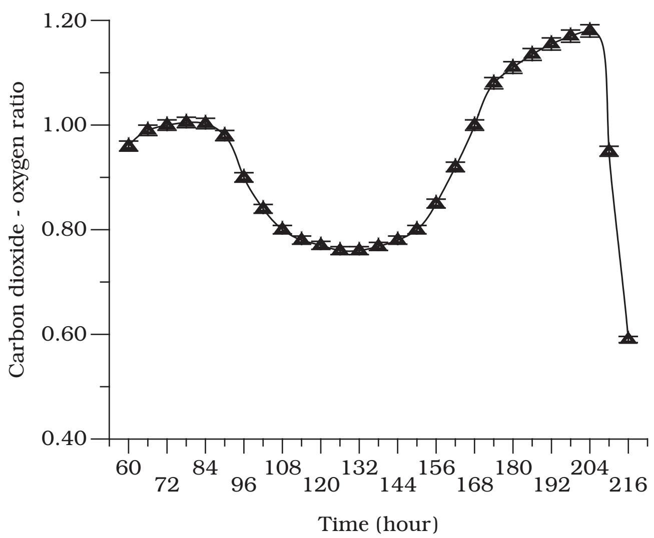

Figure 3. Respiration Quotient (CO_2/O_2 ratio) of the yellow mombin fruit during post-harvest storage at room temperature.

Table 1. Changes in the physical and chemical parameters during post-harvest respiration of cajá (*Spondias mombin* L.) fruit.

Stage of ripening	Time (hour)	Relative umidity (%)	Temperature (°C)	Total sol. solids °Brix	Titratable acidity (%)	Brix-acid ratio	Ascorbic acid (mg%)
Initial	48	86.0 ± 4.2	27.8 ± 1.9	9.1 ± 0.6[a]	1.35 ± 0.39[a]	6.74	13.1 ± 1.0[a]
Pre-climacteric	54	89.8 ± 1.9	28.5 ± 1.1	9.6 ± 1.2[a]	1.31 ± 0.56[a]	7.33	11.6 ± 1.3[a]
Climacteric min.	102	88.1 ± 3.7	28.5 ± 0.8	10.9 ± 0.9[a]	1.20 ± 0.07[a]	9.08	10.2 ± 1.0[b]
Climacteric max.	168	91.7 ± 2.3	29.2 ± 0.8	13.7 ± 1.0[b]	1.0 ± 0.04[a]	13.7	8.0 ± 0.8[c]
Post-climacteric	192	88.6 ± 2.1	28.9 ± 1.1	13.1 ± 1.2[b]	0.8 ± 0.1[b]	16.37	7.4 ± 1.1[c]

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

in the total solids content as a result of the transformation of polysaccharides to sugars[6,20], a decrease in acidity[18,21,25] and an increase in the brix-acid ratio. Contrary to the report that vitamin c content increases during ripening of guava fruit and decreases during senescence[8], the ascorbic acid content of cajá in this study decreased during ripening and the difference was significant among each stage of ripening.

The behaviour of chlorophyll and carotenoide pigments during maturation is presented in Figure 4. It was observed that there was a continuous decrease in chlorophyll and a continuous increase in the carotenoide content of the fruit. The loss of the green colour of chlorophyll in the fruit is a result of the degradation of its structure caused by the change in pH, presence of the oxidation system and the activity of chlorophyllase enzyme. The change in the colour of peel followed the next sequence: a) from initial dark green to light green at climacteric minimum; b) from light green to orange yellow during climacteric rise in respiration; and c) maintaining an orange yellow colour during the climacteric peak and senescence. This transformation in colour is attributed to the permanence and synthesis of carotenoides during the ripening process. GROSS and FLUGEL[10] earlier reported an initial decrease in the carotenoid content during an early stage of ripening in bananas followed by carotenoide biosynthesis at the yellow-green to yellow ripe stage.

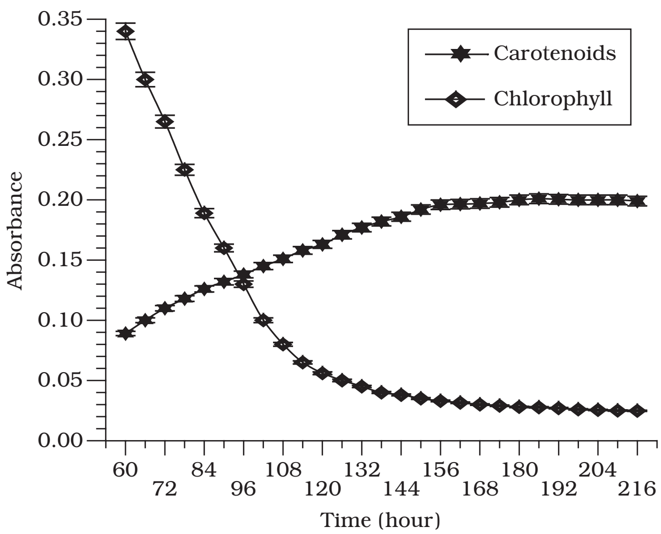

Figure 4. Total chlorophyll (λ = 660 nm) and carotenoid (λ = 452 nm) concentration of yellow mombin fruit during post-harvest storage.

4 Conclusions

The respiratory process monitored in terms of the evolution of CO_2 and consumption of O_2 of the fruit showed that yellow mombin is a climacteric fruit. The climacteric rise commenced after about 108 hours of storage reaching a maximum after 186 hours, and then the senescence process started. This gives the fruit a shelf life of about 8 days, which is appropriate to transport the mature green fruit to commercial centres. Moreover, with the use of substances that reduce the respiration rate, the shelf life of the fruit can be extended further. Maximum fruit quality in terms of acid-brix ratio and colour was achieved after 8 days of harvesting mature green fruit.

References

1. BIALE, J. B. The post-harvest biochemistry of tropical and subtropical fruits. **Advances in Food Research**. New York: Academic Press. v. 10, p. 293-354, 1960.
2. BLANKE, M. M. Respiration of apple and avocado fruits. **Postharvest News and Information.** Lipton: W.j. v. 2, p. 429-436, 1991.
3. BORA, P. S. et al. Changes in physical and chemical composition during maturation of yellow mombin (Spondias mombin) fruits. **Food Chemistry.** Oxford: Elsevier. v. 41, p. 341-348, 1991.
4. BOSCO, J. et al. **A cultura de cajazeira**. João Pessoa**:** EMEPA, Documento nº 28, 2000.
5. CALBO, A. G. **Facili**: Uma adaptação eudimétrica para medir CO_2 e O2 de micro amostras de atmosfera modificada e controlada. Brasilia: EMBRAPA/CNPH, p. 1-4, 2001.
6. CHAN, H. T. et al. Sugar composition of papaya during fruit development. **HortScience.** Alexandria: ASHS-Press. v. 14, p.140-141, 1979.
7. COOMBE, B. G. The development of fleshy fruits. **Annual Review in Plant Physiology**. Tulsa: Genamics. v. 27, p.207, 1976.
8. ESTEVES, M. T. C. et al. Characteristics of the fruits of six guava (*Psidium guajava* L.) cultivars during ripening II. Vitamin C and Tannin contents. **Anais...** In: VII Congresso Brasileiro de fruiticultura. Florianopolis, Brazil: Empresa Catarinense de Pesquisa Agropecuária S.A., v. 2, p. 490-500, 1984.
9. FAO. **Prevención de perdidas de alimentos poscosecha: Frutos, hortalizas, reíces y tuberculos**. Roma: FAO, 183 p. (Colección FAO capacitación, 17/2), 1993
10. GROSS, J.; FLUGEL, M. Pigment changes in peel of the ripening banana (Musa cavendishii). **Gartenbauwissenchaft.** Hannover: DGG. v. 47, p. 62-64, 1982.
11. KADER, A. A. Biochemical and physiological basis for effects of controlled and modified atmosphere on fruits and vegetables. **Food Technology.** Chicago: IFT, v.5, n.1, p.99-100, 102-104, 1986.
12. KADER, A. A. Respiration and gas exchange of vegetables. In: WEICHMANN, J. **Postharvest Physiology of Vegetables**. New York: Marcel Decker. v. 3, p. 25-43, 1987.
13. MEYER, B. S.; ANDERSON, D. B.; BOHNING. B. **Introducción a la fisiologia vegetal**, 2. ed., Buenos Aires: Editora Universitaria de Buenos Aires (EUDEPA), 579 p, 1970.
14. OLIVEIRA, M. E. B. et al. Avaliação de parâmetros de qualidade físico-químicos de polpa congelada de acerola, cajá e cajú. **Ciencia e Tecnologia de Alimentos**. Campinas: SBCTA. v. 19, n. 3, p. 326-332, 1999.
15. PAREIRA, E. C. P.; FILGUEIRAS, H. A. C.; ALVES, R. E. Actividad respiratoria y producción de etileno poscosecha de ciruela mexicana y jobo. **Revista Iberoamericana de Poscosecha.** Mexico City: s. Ed., v. 2, p. 155-160, 2000.
16. RANGANNA, S. **Manual of Analysis of fruit and Vegetable Products**. New Delhi: Tata McGraw Hill, 643 p., 1979.
17. RODRIGUES-AMAYA, D.; KIMURA, M. Carotenoides e valor de vitamina A em cajá (*Spondias lutea* L.). **Ciencia e Tecnologia de Alimentos**. Campinas: SBCTA, v. 9, n. 2, p. 148-162, 1989.
18. SAMSON, J. A. **Citrus.** In: Tropical Fruits, 2nd edition, UK ltd. Essex, UK: Longman Group. pp. 73-138, 1986.

19. SAS Institute. **Users Guide to Statistics**, Version 6.12. : Carry, USA: North Carolina State University, 956p, 1996.

20. SELVARAJ, Y. et al. Fruit set and the development pattern of fruits of five papaya varieties. **Indian Jornal of Hortscience**. New Delhi: Indian Soc. Hort. Science. v. 39, p.50-56, 1996.

21. SELVARAJ, Y.; KUMAR, R.; PAL, D. K. Changes in sugars, organic acids, amino acids, lipid constituents and aroma characteristics of ripening mango (Magnifera indica L.) fruit. **Jornal of Food Science and Technology**. Mysore, Índia: CFTRI, v. 26, p. 308-313, 1989.

22. SILVA, A. Q.; SILVA, H. Cajá uma fruteira tropical, **Informativo Sociedade Brasileira de Fruticultura**, Itajaí: SBF, v. 14, n. 4, 1995.

23. SOUZA, F. J. Enxertia de cajazeira (*Spondias mombin* L.) sobre porta–enxertos de umbuzeiro (*Spondias tuburosa* Arr. Câm). **Agrotópica**- Ilhéus, Bahia: Centro de Pesquisa de Cacau. v.11, p. 189-192, 1998.

24. SOUZA, F. J.; SOUZA, F. H. L.; FREITAS, J. B. S. Germinação de sementes e morfologia de endocarpo de cajazeira (Spondias mombin L.) **Agrotópica**- Ilhéus, Bahia: Centro de Pesquisa de Cacau, v. 11, p. 45-48, 1999.

25. TEISSON, C.; PINEAU, P. Quelqes donneés sur les derniéres phases du developpement de l´ananas. **Fruits**. Montpellier: CIRAD/EDP Science. v.37, s.n., p. 741-748, 1982.

26. TUCKER, G. A. Introduction-Respiration and Energy. In: **Biochemistry of Fruit Ripening**, ed. SEYMOUR, G. B., TAYLOR, J. E. AND TUCKER, G.A., London: Chapman Hill p. 3, 1996.