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Artigo Científico

Postharvest conservation of mangaba fruit treated with 1-methylcyclopropene and modified atmosphere[1]

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Abstract: The 1-methylcyclopropene (1-MCP) has been used in maintaining the quality and increase shelf-life of many species of non-climacteric and climacteric fruits. The objective of this work was to evaluate the efficiency 1-MCP associated to modified atmosphere (MA) on postharvest quality maintenance of mangaba fruit. Fruits were harvested in maturation characterized by the presence of reddish spots, all over the yellow greenish pigmentation of the skin. The mangaba fruits were submitted to application of 1-MCP in the doses of 0, 100, 200 e 300 μL L^{-1} for 12 hours under room conditions (24 + 2 ° C and 83 + 2% RH) and evaluated for soluble solids (SS), titratable acidity (TA), SS/TA ratio, ascorbic acid, mass loss, and general appearance. The association of MA with 1-MCP did not provide additional benefits on quality. However, 1-MCP at 200 μL L^{-1} extended the postharvest life of mangaba, stored under and room conditions, from 5 to 7 days.

Keys words: *Hancornia speciosa*, 1-MCP, Quality, General appearance.

Conservação pós-colheita de mangaba tratadas com 1-metilciclopropeno e atmosfera modificada

Resumo: O 1-metilciclopropeno (1-MCP) têm sido usado na manutenção da qualidade e no incremento da vida-útil de muitas espécies de frutos não climatéricos e climatéricos. O objetivo deste trabalho foi avaliar a eficiência de 1-MCP associado com atmosfera modifficada (MA) na manutenção da qualidade pós-colheita de mangaba. Os frutos foram colhidos em maturação caracterizada pela presença de manchas avermelhadas, em toda a pigmentação amarela esverdeada da casca. As mangabas foram submetidas a aplicação de 1-MCP nas concentrações de 0, 100, 200 e 300 μL L^{-1} por 12 horas em condição ambiente (24 ± 2 °C e 83 + 2% UR) e avaliadas quanto aos sólidos solúveis (SS), acidez títulavel (AT), relação SS/AT, ácido ascórbico, perda de massa e aparência geral. A associação de MA com 1-MCP não proporcionou benefícios adicionais na qualidade. Entretanto, a dose de 200 μL L^{-1} de 1-MCP prolongou a vida útil de mangaba armazenada em condição ambiente de 5 para 7 dias.

Palavras-Chave: *Hancornia speciosa*, 1-MCP, Qualidade, Aparência geral.

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1 Introduction

The mangaba tree (*Hancornia speciosa* Gomes) is spontaneously found in tropical regions. In Brazil, it is distributed in the Central West, Southeast , and Northeast, with greater abundance in areas of coastal plains and tablelands of the Northeast, where is found almost the total national production (Lima et a., 2015a; Silva et al., 2017). Its fruit, mangaba, has shown a growing socio economic and scientific interest due to its high nutritional and medicinal values (Lima et al., 2015b).

Mangaba is a climacteric fruit of high perishability rate, making it necessary the development of appropriate technologies for handling and storage in order to maintain the postharvest quality and prolong its useful life (Lima et al., 2015a).

Studies on storage of fruit under room conditions are necessary, since, in Brazil, almost all fruit is sold, at the retail level, without refrigeration (Carnelossi et al., 2009). Maintaining postharvest quality, in turn, is related to minimizing the rate of deterioration, in order to keep the product attractive to consumers for a longer period (Guimarães et al., 2017). Modified atmosphere (MA) has proven to be effective in reducing metabolic rates and extending the useful life of mangaba (Soares Júnior et al., 2008; Santos et al., 2009; Lima et al., 2015c). The use of MA, by wrapping products with flexible film such as polyvinyl chloride (PVC), passively establish a gas composition inside the package different from the air, by reducing O_2 and elevating CO_2 levels, which can reduce the metabolic activity (Moura et al., 2013; Zhang et al., 2014).

Combining with MA, the use of inhibitors of ethylene perception may allow producer and marketer to achieve greater competitiveness in the domestic market and, subsequently, exportation (Martins et al., 2013). The 1-methylcyclopropene (1-MCP) acts at cellular level by blocking the action of ethylene and has been successfully applied in flowers, fruits, and vegetables (Watkins, 2006). The use of 1-MCP has been found to be effective in controlling ripening and, consequently, in maintaining quality and increase the useful postharvest life of many species of non-climacteric and climacteric fruits (Villalobos-Acuña et al., 2010; Li et al., 2016). Based on that, the objective of this work was to evaluate the effect of 1-MCP on the quality of mangaba stored under modified atmosphere and room conditions.

2 Material and Methods

Fruits of mangaba tree were harvested from orchard of the Experimental Station of Mangabeira of the Empresa Estadual de Pesquisa Agropecuária da Paraíba S.A. (EMEPA), located at the Mesorregion of the Mata Paraibana, in the municipality of João Pessoa, Paraíba State, Brazil. Fruits from the clone TOU48, with aptitude for fresh consumption (SOUZA et al., 2007) were harvested at maturity stage in which the skin color was characterized by the presence reddish spots, all over the yellow greenish pigmentation (SANTOS et al., 2009), free from mechanical damages and diseases. In the laboratory, fruits were sorted by uniformity and washed in tap water and then immersed for two minutes in a 0.4 g L^{-1} fungicide solution.

For the application of 1 - methylcyclopropene (1-MCP), mangabas were placed inside 0.186 m^3 plastic chambers. In these chambers were placed vials of 100 mL containing septum adapted in the caps and inside those was added the commercial product in powder, at the equivalent concentrations of 100, 200, 300 µL L^{-1} of 1-MCP gaseous. Following, it was injected through the septum, 50 mL of water at 50 °C, stirring until complete dissolution of the product. The vials were placed inside the chambers containing fruits, through the side opening, and then opened to release the gas. The chambers then were quickly sealed and kept at room temperature for 12 hours. As a control, mangabas without application of 1 - MCP were kept in similar conditions. Following treatment, fruits were placed in polystyrene trays regular atmosphere (RA, without film) and modified atmospheres (MA) by wrapping with a 12µm thick PVC film and stored under room conditions (25±2 ºC e 83±2% RH). The evaluations were performed for the initial fruit characterization (day 0) and during storage at 2, 4, 6, 8, and 10 days, except for weight loss and general appearance, which were performed daily.

It was evaluated: Soluble solids (SS - %); titratable acidity (TA - % of citric acid); SS/ TA ratio (IAL, 2010). Ascorbic acid (mg $100g^{-1}$); weight loss, calculated taking as reference the initial mass of fruits using a semi-analytical scale; general appearance, carried out at daily basis by 12 non-trained judges, following a scale scored from 1 (inacceptable) to 9 (excellent) were performed according to SANTOS et al. (2009). Also based on those authors, the score 5 corresponded to the limit of acceptability, in which fruit acquisition was limited by undesirable appearance.

It was utilized a completely randomized design in a factorial scheme 2x4x5, being two storage atmospheres (regular atmosphere – RA and modified atmosphere – AM), four 1-MCP doses (0, 100, 200, 300 $\mu L\ L^{-1}$), and five storage periods, in three replications of 300g $fruit.rep^{-1}$. For the initial characterization, it was used three replications of approximately 3000 g of fruits.

Data were submitted to variance analysis (ANOVA), taking into account the significant interaction among factors and results submitted to polynomial regression analysis. Models for polynomial regression were selected based on the Test F significance and also by coefficients of determination higher than 0.70. In case of no significant adjustment to the tested models, means of treatment were line-linked.

3 Results

For initial fruit characterization, mangaba fruit of the clone TOU48 showed uniformity of ripeness, general appearance of fresh and turgid fruit, with bright yellow greenish color, presenting reddish spot all over the skin, no blemishes and/or physiological disorders, superior quality; soluble solids (SS) on average of 19%, titratable acidity of 1.7%, SS / TA ratio of 11.18, and a high content of ascorbic acid, 223 mg $100g^{-1}$.

For mangabas of control (0 $\mu L\ L^{-1}$ 1-MCP) and treated with of 100 e 200 $\mu L\ L^{-1}$ of 1-MCP, SS did not differ between fruits maintained regular atmosphere (RA) and modified (MA) atmospheres during storage (Figure 1). Fruits treated with 300 $\mu L\ L^{-1}$ of 1-MCP showed a more marked decline in SS, suggesting that this dose may have caused a physiological disorder in mangaba.

For the titratable acidity (TA), independently of 1-MCP doses, TA was lower in fruits kept in RA but increased during storage (Figure 1). Mangabas kept under RA showed an increase in the TA content from the fourth day of storage, which was kept higher for the dose of 200 $\mu L\ L^{-1}$ of 1-MCP.

Mangabas kept under RA showed a decline in the SS/TA ratio from the fourth to the eighth day of storage (Figure 2). Under MA, SS/TA ratio was kept stable during 6 days, increasing afterward until the eighth day of storage.

For ascorbic acid, there was interaction among atmosphere, doses of 1-MCP, and storage periods and its content in mangaba was reduced during storage in both MA and RA, showing, however, a tendency of increasing by the end of storage period. Followed ten days of storage, the ascorbic acid content decreased more than 50%, being, in an average, higher under MA. Fruits kept under RA, in turn, showed a smooth decline of ascorbic acid during storage and for those treated with 1-MCP the content was higher by the end of storage period. For fruit under MA, ascorbic acid has declined about 75% from initial content to the sixth day, followed by a sharp increase (0 $\mu L\ L^{-1}$ 1-MCP-1) until the tenth day of storage (Figure 2).

For the general appearance, the use of 1-MCP, mainly for the dose of 200 $\mu L\ L^{-1}$, positively influenced the quality of mangaba also kept under RA, since it increased fruit's postharvest life, keeping the appearance by seven days, i.e, two more days as compared with control. When under RA, mangabas without 1-MCP (control) showed acceptable general appearance during five days, when fruits still presented slightly freshness, moderate loss of turgidity, little wrinkling, slightly fading and attractive appearance, absence of disease, dark spots or external damage and/or rot (Figure 3).

Mangabas kept under MA and RA, and treated with 0, 100 and 200 $\mu L\ L^{-1}$ 1-MCP differed in general appearance, which under RA remained acceptable until the seventh days of storage (Figure 3), mainly for 200 $\mu L\ L^{-1}$ 1-MCP. After nine days, more than 50% fruits, for both RA and AM, were markedly wilted, wrinkled surface, without flavor or apparent brightness, with dark spots, external damage and/or rotten.

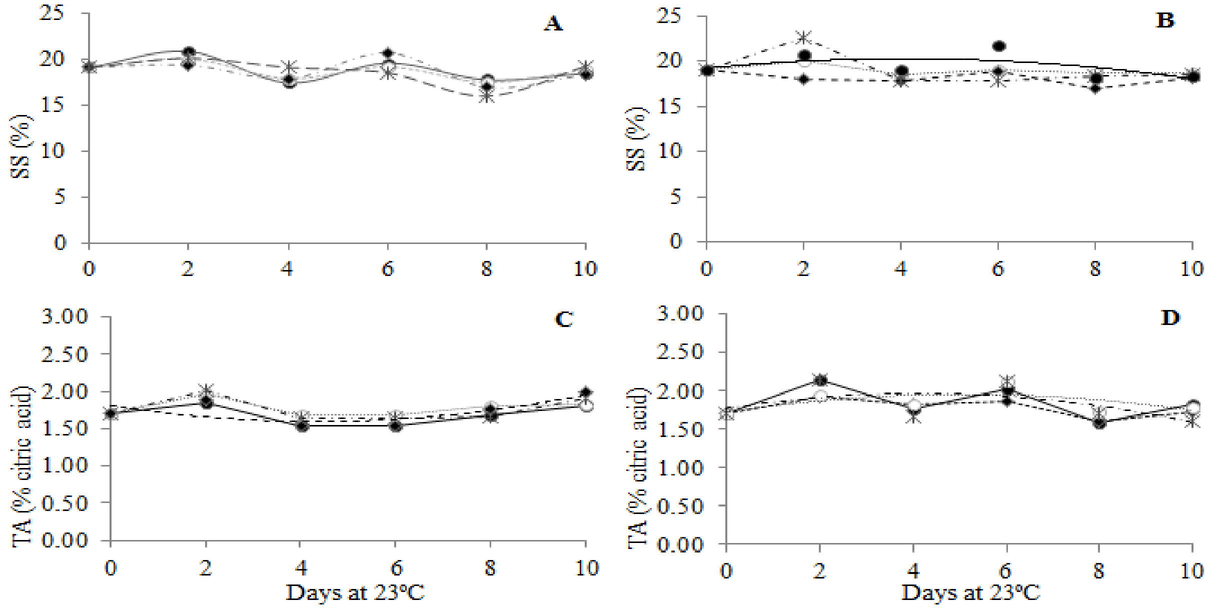

Figure 1 Soluble solids (SS - %) and Titratable acidity (TA-% citric acid) in mangabas, harvested in the maturity stage yellow greenish with reddish spots, treated with 1-methylcyclopropene during storage under room conditions (23 ± 2ºC e 83 ± 2 % RH) regular atmosphere (A and C) e modified atmospheres (B and D). Legend: 0μL L^{-1}; 100μL L^{-1}; 200μL L^{-1}; 300μL L^{-1}.

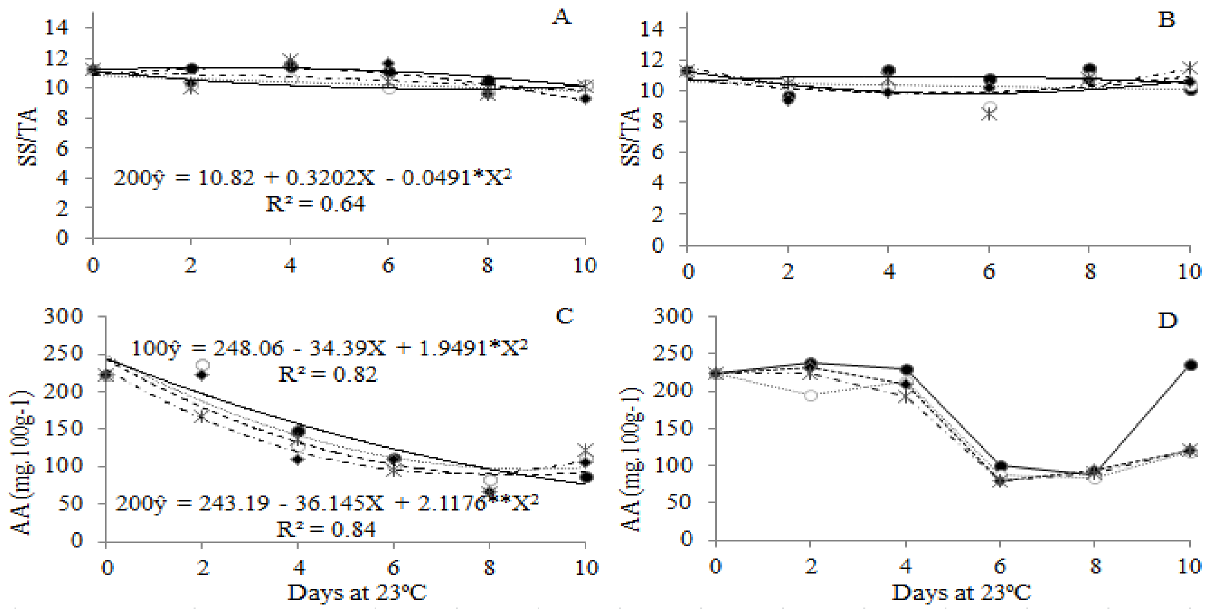

Figure 2 SS/AT ratio and ascorbic acid (AA) in mangabas harvested in the maturity stage yellow greenish with reddish spots, treated with 1-methylcyclopropene during storage under room conditions (23 ± 2ºC e 83 ± 2 % RH) and regular atmosphere (A and C) e modified atmospheres (B and D). Legend: 0μL L^{-1}; 100μL L^{-1}; 200μL L^{-1}; 300μL L^{-1}.

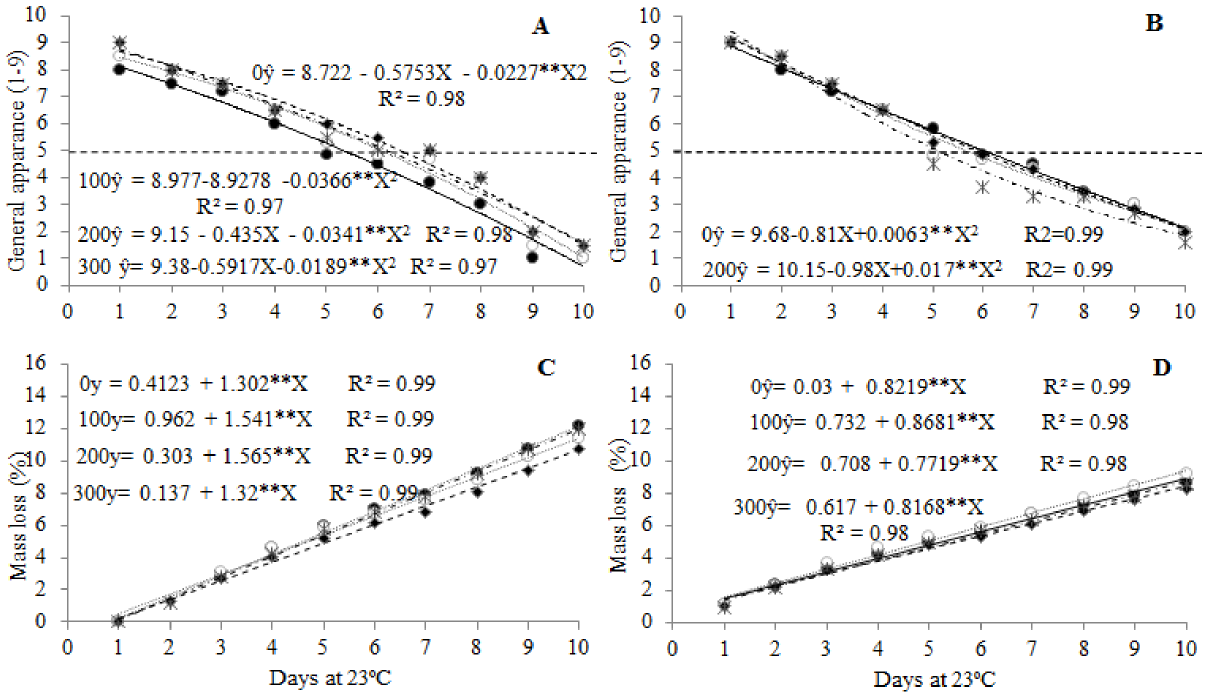

Figure 3 General appearance in mangabas, harvested in the maturity stage yellow greenish with reddish spots, treated with 1-methylcyclopropene during storage under room conditions (23 ± 2ºC e 83 ± 2 % RH) and regular atmosphere (A and C) e modified atmospheres (B and D). Legend: 0µL L^{-1}; 100µL L^{-1}; 200µL L^{-1}; 300µL L^{-1}.

4 Discussion

The results related soluble solids (SS) on average of 19%, SS / TA ratio of 11.18, and a high content of ascorbic acid, being these data higher than those reported by Plácido et al. (2016), mainly for ascorbic acid (AA), but in the range reported by Carnelossi et al. (2009) and Santos et al. (2009), for similar maturity stage.

These results are in agreement with Santos et al. (2009), which in mangaba harvested in different maturity stages (green, beginning of yellow pigmentation and yellow fruit with slight red spots) observed that the content of SS did not differ among fruits kept under RA and MA (trays were wrapped with polyvinyl chloride film of 13 µm thickness) through the end of storage, for the maturity stages green, red pigment initiation, and yellow with light reddish spots. In contrast, Carnelossi et al. (2009), reported an increase in the SS content until the fourth day of storage under RA (24±2°C), followed by a decrease in yellowish-green with red spots mangaba. Soares Júnior et al. (2008) also observed an increase in the SS content in “mature-green” mangaba during storage under MA (trays were wrapped with polyvinyl chloride films with a thickness of 15 µm, and low density polyethylene with a thickness of 30 µm) and refrigeration.

In contrast to mangaba in this experiment, in pears Villalobos-Acuña et al. (2010), reported that the application of 1-MCP did not influence SS or starch hydrolysis, which, in some fruits and vegetables, is responsible for the increase in soluble solids (Azerêdo et al., 2016; Guimarães et al.,2017).

Santos et al. (2009) also observed a tendency of TA increase in mangaba of similar maturity during storage at RA. Carnelossi et al. (2009), also observed an increase in TA until the fourth day, with variations in TA content until the ninth day of storage in mature-green mangabas under RA. After harvest, the content of organic acids normally declines due to its utilization in the respiratory process or its conversion in sugars through gluconeogenesis (Azerêdo et al., 2016), although these changes may vary according to tissue, fruit, cultivar, maturity stage, and storage conditions (Melo et al., 2017). Santos et al. (2009) also observed a tendency of TA increase in mangaba of similar maturity during storage at RA and room conditions. Carnelossi et al. (2009)

also observed an increase in TA until the fourth day, with variations in TA content until the ninth day of storage in mature-green mangabas under RA.

The TA content for mangaba kept under MA varied during storage, increasing from the fourth day of storage, with subsequent decrease (Figure 1). In contrast, Santos et al. (2009), evaluating the effect of MA on postharvest conservation of mangaba at similar maturity stage, observed that fruit stored at MA, showed little changes in TA. In turn, Soares Junior et al. (2008) observed an increase in TA content in mature-green mangaba kept under MA and refrigeration.

The highest content of TA in fruits stored under MA observed in this study probably resulted in reduced metabolic activity due to a possible delay of the climacteric of mangaba (Azerêdo et al., 2016), as a result of atmosphere modification at storage (Martins et al., 2013) and/ or the use 1-MCP (Watkins, 2006).

For the SS/TA ratio (Table 1), there was interaction between atmosphere and periods of storage. High values for the SS/TA ratio indicate a smooth flavor due to an adequate sugar and acids balance, whereas low values are correlated to a predominant acid taste (Melo et al., 2017). Therefore, mangabas in this study showed taste predominantly acid. Higher values for SS/TA ratio were reported by Soares Júnior et al. (2008), evaluating the effect of atmosphere modification on quality of mangaba, with values varying from 19 to 40.

For fruits treated with 1-MCP the decline of ascorbic acid was lower (Table 1). The degradation of ascorbic acid is due to the action of the enzymes ascorbic acid oxidase and peroxidase during storage (Foyer, 2017). The use of 1-MCP and AM, in general, results in a decreased metabolic rate in climacteric fruits, consequently, reducing the consumption of O2 by reducing the rate of oxidative reactions, therefore, lower vitamin C loss (Tu et al., 2017).

Reductions in the ascorbic acid content are generally observed postharvest due to its involvement in the antioxidant reactions that take place during fruit senescence (Paliyath et al., 2008). A possible increase in ascorbic acid may also occur, since their biosynthesis is linked to pectin degradation, which releases precursors of ascorbic acid (Foyer, 2017). Thus, it is suggested that the increase in ascorbic acid found in fruits under MA starting on the sixth day of storage (Figure 2) may be related to its antioxidant effect in response to advances in oxidative reactions that occur by the end of ripening. Carnelossi et al. (2009) also reported that mangabas maintained at 24° C had a decline in vitamin C content that increased later.

These results are in accordance with Santos et al. (2009) that, in mangaba harvested in similar maturity, observed that fruits under MA presented lower mass loss. In this experiment, fruits kept in MA presented in average 8% of mass loss, while those kept in RA lost about 13% after ten days. Soares Júnior et al. (2008) also showed that modification of atmosphere with PVC film reduced the mass loss during mangaba's cold storage.

5 Conclusion

The use of modified atmosphere during mangaba storage under room conditions reduced mass loss and maintained quality acceptable for six days. The use of 1-MCP at the dose of 200 $\mu L\ L^{-1}$ for mangaba kept under ambient atmosphere (regular atmosphere) extended the shelf life from five to seven days. The combination of modified atmosphere with 1-MCP in mangaba stored under room conditions did not provide additional benefits in maintaining quality.

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References

Almeida, M. M. B.; Sousa, P. H. M. Fonseca, M. L.; Magalhães, C. E. C.; Lopes, M. F. G.; Lemos, T. L. G. Avaliação de macro e microminerais em frutas tropicais cultivadas no nordeste brasileiro. **Ciência Tecnologia Alimentos**, v.29, n.3, p.581-586, 2009. http://dx.doi.org/10.1590/S0101-20612009000300020

Azerêdo, L. P. M.; Silva, S. D. M.; Dantas, R.; Pereira, W. Qualidade de manga Tommy Atkins da produção integrada recoberta com fécula de mandioca associada a óleos essenciais e quitosana. **Revista Brasileira de**

Fruticultura, v.38, n.1, p.141-150, 2016. http://dx.doi.org/10.1590/0100-2945-270/14

Carnelossi, M. A. G.; Sena, H. C.; Narain, N.; Yaguiu, P.; Silva, G. F. Physico-Chemical Quality Changes in Mangaba (*Hancornia speciosa* gomes) Fruit Stored at Different Temperatures. **Brazilian Archives of Biology and Technology**, v.52, n.4, p.985-990, 2009. http://dx.doi.org/10.1590/S1516-89132009000400023

Foyer, C. H. Ascorbic acid. In: Alscher, R. G.; Hess, J. L. **Antioxidants in higher plants**. CRC Press, p. 39-66, 2017. https://www.taylorfrancis.com/books/e/9781351369152

Guimarães, G. H. C.; Dantas, R. L.; Sousa, A. S. B.; Soares, L. G.; Melo, R.; Silva, R. S.; Lima, R. P.; Mendonça, R. M. N.; Beaudry, R. M.; Silva, S. M. Impact of cassava starch-alginate based coatings added with ascorbic acid and elicitor on quality and sensory attributes during pineapple storage. **African Journal of Agricultural Research**, v.12, n.9, p.664-673, 2017. https://doi.org/10.5897/AJAR2016.11652

IAL - Instituto Adolfo Lutz. Métodos físico-químicos para análise de alimentos (2010). 4. ed. São Paulo: IAL, Campinas. Disponível em: http://www.ial.sp.gov.br/index.php?option=com_remositoryandItemid=0andfunc=fileinfoandid=1 . Acesso em: 20 out. 2010.

Li, L.; Lichter, A.; Chalupowicz, D.; Gamrasni, D.; Goldberg, T.; Nerya, O.; Ben-Arie, R. Porat, R. Effects of the ethylene-action inhibitor 1-methylcyclopropene on postharvest quality of non-climacteric fruit crops. **Postharvest Biology and Technology**, v.111, p. 322-329, 2016. https://doi.org/10.1016/j.postharvbio.2015.09.031

Lima, J. P.; Azevedo, L.; De Souza, N. J.; Nunes, E. E.; Boas, E. V. D. B. V. First evaluation of the antimutagenic effect of mangaba fruit in vivo and its phenolic profile identification. **Food Research International**, v.75, p.216-224, 2015b. https://doi.org/10.1016/j.foodres.2015.05.045

Lima, J. P.; Fante, C. A.; Pires, C. R. F.; Nunes, E. E.; Alves, R. R.; Siqueira Elias, H. H.; Nunes, C. A.; Boas, E. V. D. B. V. The antioxidative potential and volatile constituents of mangaba fruit over the storage period. **Scientia Horticulturae**, v.194, p.1-6, 2015c. https://doi.org/10.1016/j.scienta.2015.05.035

Lima, J. P.; Rodrigues, L. F.; Monteiro, A. G. D. P.; Boas, E. V. D. B. V. Climacteric pattern of mangaba fruit (*Hancornia speciosa* Gomes) and its responses to temperature. **Scientia Horticulturae**, v.197, p.399-403, 2015a. https://doi.org/10.1016/j.scienta.2015.09.059

Martins, L. P.; Silva, S. M.; Mendonça, R. M. N.; Silva, A. P. Postharvest quality of ‘Smooth Cayenne’ pineapple treated with 1-methylcyclopropene and cold shock. **Acta Horticulturae**, v.1012, p.503–508, 2013 https://doi.org/10.17660/actahortic.2013.1012.66

Melo, R. S.; Silva, S. M.; Sousa, A. S. B.; Lima, R. P.; Dantas, A. L.; Dantas, R. L.; Figueiredo, V. M. A. Maturação e qualidade de frutos de mandacaru (*Cereus jamacaru* P. DC.) de diferentes bioclimas do estado da Paraíba. **Agropecuária Técnica**, v.38, n.3, p.160-168, 2017. https://doi.org/10.25066/agrotec.v38i3.33818

Moura, F. T.; Melo Silva, S.; Schunemann, A. P.; Martins, L. P. Frutos do umbuzeiro armazenados sob atmosfera modificada e ambiente em diferentes estádios de maturacão. **Revista Ciência Agronômica**, v.44, n.4, p.764, 2013. http://ccarevista.ufc.br/seer/index.php/ccarevista/article/view/2376

Paliyath, G.; Murr, D.P.; Handa, A.K.; Lurie, S (2008). **Postharvest biology and technology of fruit, vegetables, and flowers**. Ames: WileyBlackwell, 497p. https://www.wiley.com/en-us/Postharvest+Biology+and+Technology+of+Fruits%2C+Vegetables%2C+and+Flowers-p-9780813804088

Plácido, G. R.; Silva, R. M.; Cagnin, C.; Silva, M. A. P.; Caliari, M. Physical and physicochemical composition of mangaba fruits (*Hancornia speciosa* Gomes) at three maturity stages. **African Journal of Agricultural Research**, v.11, n.19, p.1772-1776, 2016. https://doi.org/10.5897/AJAR2015.9712

Santos, A. F.; Silva, S. M.; Mendonça, R. M. N.; Alves, R. E. Conservação pós-colheita de mangaba em função da maturação, atmosfera e temperatura de armazenamento. **Ciência e Tecnologia de Alimentos**. v.29, n.1, p.85-91, 2009. https://ainfo.cnptia.embrapa.br/digital/bitstream/CNPAT-2010/11738/1/PA09029.pdf

Silva, A. V. C. D.; Amorim, J. A. E.; Vitória, M. F. D.; Ledo, A. D. S.; Rabbani, A. R. C. Characterization of trees, fruits and genetic diversity in natural populations of mangaba. **Ciência e Agrotecnologia**, v.41, n.3, p.255-262, 2017. http://dx.doi.org/10.1590/1413-70542017413048416

Soares Júnior, M.; Caliari, M.; Vera, R.; Souza, A. G. Conservação pós-colheita de mangaba sob refrigeração e modificação da atmosfera de armazenamento. **Pesquisa Agropecuária Tropical**, v.38, n.2, p.78-86, 2008. https://www.revistas.ufg.br/pat/article/view/4170

Souza, F. G.; Figueiredo, R. W.; Alves, R. E.; Maia, G. A.; Araújo, I. A. Qualidade pós-colheita de frutos de diferentes clones da mangabeira (*Harconia speciosa* Gomes). **Ciência e Agrotecnologia**, v.31, n.5, p.1449-1454, 2007. http://dx.doi.org/10.1590/S1413-70542007000500027

Tu, Yi-Jung; Njus, David; Schlegel, H. Bernhard. A theoretical study of ascorbic acid oxidation and HOO/O^{2-} radical scavenging. **Organic & biomolecular chemistry**, v.15, n.20, p.4417-4431, 2017. http://dx.doi.org/10.1039/c7ob00791

Villalobos-Acuña, M. G.; Biasi, W. V.; Flores, S.; Mitcham, E. J.; Elkins, R. B.; Willits, N. H. Preharvest Application of 1-Methylcyclopropene Influences Fruit Drop and Storage Potential of ‘Bartlett’ Pears. **HortScience**, v.45, n.4, p.610–616, 2010. http://hortsci.ashspublications.org/content/45/4/610.full

Watkins, C. B. The use of 1-methylcyclopropene (1-MCP) on fruits and vegetables. **Biotechnology Advances**, v.24, n.4, p.389-409, 2006. https://doi.org/10.1016/j.biotechadv.2006.01.005

Zhang, M.; Meng, X.; Bhandari, B.; Fang, Z.; Chen, H. Recent application of modified atmosphere packaging (MAP) in fresh and fresh-cut foods. **Food Reviews International**, v.31, n.2, p.172-193, 2015. https://doi.org/10.1080/87559129.2014.981826