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Climatization for scheduled ripening of caja-manga

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Being a climacteric fruit, the caja harvested still green has uneven ripening. Thus, the aim of this study was to evaluate the effect of ripening techniques aiming to promote a uniform ripening and reduction of quality loss in caja-manga fruits. The treatments resulted from the application of four ripening techniques (control, muffled, ethrel, and calcium carbide) and they were evaluated in 5 times, with 3 days intervals, for 12 days (0, 3, 6, 9, and 12 days). The fruits were evaluated physico-chemically with respect to soluble solids, titratable acidity, ratio, firmness, and color. Although, all treatments promoted the fruit ripening, ethrel showed homogenous and consistent fruit characteristics with ripening reactions in 6 days, being considered the best treatment. It showed intense yellow color (85 Hue), weight loss of about 5% compared to other treatments and tissue softening (29 N firmness) and increase in soluble solids (Brix 11°).

Key words: *Spondias mombin* L., exotic fruits, Ethrel, carbide.

INTRODUCTION

The caja-manga (*Spondias dulcis*) originating in French Polynesia and inserted in Brazil by the northeast region has attracted researchers and food processing industries, mainly because of its taste and innovative aspect, besides bioactive compounds as antioxidant capacity, presence of vitamins and carotenoids (Vanzela et al., 2011; Barreto et al., 2009).

This fruit is considered exotic, tropical, climacteric and it is mainly grown in the Brazilian North and Northeast. It has ellipsoid shape of drupe type with seeds provided with rigid and spinescent fibers that partially plunge in the pulp. The pulp is juicy, bittersweet and strongly aromatic, being highly appreciated in natura. It contains about 72.6 to 78% of moisture, 0.35 to 0.53% of fat, 0.25 to 1.2% of protein, 0.7% of ashes, 17.8% of carbohydrates, 1.5% of fiber, 1.2% of pectin, 9.3% of reducing sugar, and 5.0 to 13.1% of soluble solids (Vanzela et al., 2011; Donadio, 2000; Lorenzi et al., 2006). To supply the market demands, the climacteric fruits such as caja-manga should be harvested at physiological maturity, because

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when they are harvested at advanced maturity, it is hard to keep them conserved (Kader, 2002). However, when caja-manga is harvested before its point of consumption, it ripens unevenly and quickly and, in this case, there is also the possibility of significant losses. Aiming the lots homogenization and the scheduled ripening of the fruit, the climatization process has been adopted for post-harvest conservation of fruits and vegetables.

The fruit climatization can be performed with various active ingredients such as calcium carbide and exogenous ethylene. The moistened calcium carbide releases acethylene in the environment which is analogous to ethylene and can cause similar physiological effect on the plant tissues leading to a more uniform ripening (Bisognin et al., 2007). Another alternative is the use of ethephon (2-chloroethylphosphonic acid), which releases exogenous ethylene and increases the intensity and/or anticipate the fruit respiratory peak during the ripening (Nogueira et al., 2007). An effect that is biologically similar to the application of exogenous ethylene is the smothering technique of climacteric fruits. As it is a volatile gas, the ethylene released by the fruit is accumulated in the atmosphere. This high ethylene concentration will then act in the ripening of fruits which are muffled (Chitarra and Chitarra, 2005).

In view of what has been exposed, the aim of this study was to evaluate the effect of exogenous application of calcium carbide, ethrel and smothed technique on ripening of caja-manga and their effects in physical and chemical traits typical of fruit ripening.

MATERIALS AND METHODS

At Jabuticabal Farm and Winery, in Nova Fatima, Hidrolandia-GO, located at 16° 55'32.35 "south latitude and 49° 21'39.76 "west longitude, 180 unripe caja-manga fruits were harvested with about 56 cm and no imperfections. The fruits were washed and sanitized with sodium hypochlorite (200 ppm) for removing surface dirt and microbial contamination, and they were dried at room temperature.

The experiment was conducted in a completely randomized design (CRD) in split plot, with four ripening climatization techniques (control, muffled, fruit spraying with ethrel and ripening chamber with exposure to carbide), evaluated in 5 times, at 3 days intervals (0, 3, 6, 9, 12 days) for 12 days, at 20°C in a climatized room with four replications of three fruits.

For the treatment with Ethrel® (with Ethephon as the active ingrediente), fruits were sprayed with a mixture of 750 mg of the product and 100 L of water, 25 ml syrup were sprinkled to cover all parts of fruit. These fruits were dried at room temperature and armezandos in box. For the muffled treatment, the cardboard boxes containing fruits were wrapped in plastic bags (Polysack black polyethylene of 100 µ thick). The treatment with carbide was performed in a ripening chamber, solubilizing a portion of 160 $g.m^{-3}$ in water. The product was vaporized and a proper atmosphere within the chamber was created.

At the harvest day, experiment assembly and during 12 days with 3-day intervals, the fruits were analyzed for firmness, expressed in Newton (N) with the aid of texturometer using a probe which measured the penetration force in the fruit at a speed of 7 mm s^{-1} and 8 mm of penetration distance (those values were previously set and obtained by pre-testing). Regarding the soluble solids, readings of degrees Brix of the sample were made at 20°C in a digital refractometer (Atago N-1E). The total acidity was determined by titration with sodium hydroxide (NaOH) solution 0.1 N (AOAC, 2010). The soluble solids (SS) and titratable acidity (TA) were used to determine the maturation ratio-index (SS/TA). The color determination was performed at two equidistant points of the fruit, by reading three parameters defined by the CIELAB system, L*, a* and b* supplied by the colorimeter (Hunterlab, ColorQuest II). These parameters were used to calculate the Hue angle.

After being subjected to the test Cochran (homoscedasticity) and Lilliefors (data normality), the data were analyzed by variance analysis, Tukey test (qualitative factor) and regression (quantitative factor) at a significance level of 5% of probability.

RESULTS AND DISCUSSION

The ethrel treatment stood out regarding most parameters, which is an indicative of an uniform ripening, promoting lower firmness, higher TSS, higher brightness of the peel and consistente peel and pulp° h. The remaining climatization treatments had results that indicate uneven ripening treatment. Although, the carbide treatment resulted in a similar acidity to the ethrel treatment, and smaller weight loss, also resulted in lower soluble solids, and higher° h pulp. The smothering and control treatments resulted in very similar parameters and that also expresses an uneven ripening. The fruits remained firm, despite the weight loss was very representative (Table 1).

The time of storage (days) was significant for all parameters, which is very important since it is known that climacteric fruits such as caja suffer changes from the moment that they are detached from the mother plant. At twelve days, most parameters stood out and showed the best fruit ripening stage.

The interaction between time of storage and climatization ocurred for most parameters, with the exception of titratable acidity, ratio, and for pulp color. Evaluating the significant factors, it was observed that the firmness was influenced by the storage time and for climatization treatments. On average, at day 0, the fruits were with 87 N of firmness, which is typical for completely unripe fruits however, that during the experiment, fruits under ethrel effect lost firmness on the second day of evaluation before the other treatments (Table 2). After 12 days of evaluation, in all treatments, the fruits had the firmness reduced, fruits under the influence of carbide and muffled took longer to lose firmness, its happened from the 9th day on.

The firmness that is measured by a texturometer is based on the tissue collapse that is measured by the resistance to a force or stress. It is one of the most common physicochemical parameters to evaluate the progress of tissue softening that is peculiar of the fruit ripening process. In general, loss of firmness of the fruit during storage occurs primarily due to changes protopectins water-insoluble in water-soluble (Harker et al., 1997).

Table 1. Total titratable acidity (TTA), fruit firmness, weight loss (WL), totaloluble solids (TSS), Ratio, peel and pulp Angle Hue of caja manga fruits, due to climatization treatment and storage time.

Factor	TA (g/100 g citric acid)	Firmness (N)	WL (g)	SS (°Brix)	Ratio	Peel Hue (ºhue)	Pulp Hue (°hue)
Climatization(C)							
Control	0.72^{a}	77.62^{a}	5.37^{a}	9.50^{ab}	13.71^{b}	88.16^{b}	86.32^{bc}
Muffling	0.64^{b}	70.58^{a}	5.77^{a}	9.08^{bc}	14.37^{ab}	91.04^{ab}	88.11^{ab}
Calcium Carbide	0.64^{ab}	77.93^{a}	4.27^{b}	8.50^{c}	13.73^{b}	92.80^{a}	88.32^{a}
Ethrel	0.64^{ab}	47.27^{b}	5.31^{a}	10.24^{a}	16.68^{a}	87.74^{b}	85.43^{c}
F Climatization	3.45*	28.18**	7.92**	13.41**	4.22*	5.31**	5.05**
Periods							
0	0.65	87.74	0.00	8.27	12.74	98.16	85.29
3	0.47	91.43	1.84	8.22	17.75	98.13	88.27
6	0.60	71.08	4.04	8.97	15.17	92.53	87.33
9	0.72	53.37	7.90	9.86	14.07	83.43	86.44
12	0.85	40.15	12.08	11.32	13.39	77.40	87.91
F Periods (P)	37.45**	53.91**	36.71**	33.39**	6.60**	62.88**	5.05**
C×D	0.77^{ns}	4.26**	3.53**	6.33**	1.71^{ns}	5.72**	1.62^{ns}
CV (%)	12.01	15.43	17.03	8.33	12.13	4.49	2.13

Regression: Titrable acidity $y = 0.0048x^2 - 0.0364x + 0.6151$; $R^2 = 0.866^{**}$; ratio $y = -0.0786x^2 + 0.8635x + 13.686$; $R^2 = 0.4898$; pulp Hue $y = -0.0057x^2 + 0.2572x + 85.363$; $R^2 = 0.7489$. C×D interaction among factors.

Table 2. Total Soluble Solids, fruit firmness, weight loss, peel and pulp Hue angle of cajá-manga fruits due to climatization treatments and storage time.

	Total soluble solids				Firmness			
	Control	Muffling	Carbide	Etrhel	Control	Muffling	Carbide	Etrhel
0	8.28^{a}	8.28^{a}	8.28^{a}	8.28^{a}	87.74^{a}	87.74^{a}	87.74^{a}	87.74^{a}
3	8.00^{b}	7.33^{b}	7.53^{b}	10.03^{a}	102.05^{a}	95.34^{a}	98.98^{a}	69.34^{b}
6	8.33^{b}	7.67^{b}	8.57^{b}	11.33^{a}	87.22^{a}	88.34^{a}	75.70^{a}	33.06^{b}
9	9.50^{ab}	11.07^{a}	8.53^{b}	10.37^{a}	63.35^{bc}	50.52^{b}	75.33^{a}	16.29^{c}
12	13.40^{a}	11.07^{b}	9.60^{b}	11.23^{b}	47.77^{a}	30.95^{a}	51.92^{a}	29.93^{a}

Total soluble solids — Regressions:
Control $y= 0.0729x^2 – 0.4833x + 8.4645$, $R^2 = 0.9758$;
Muffling $y= 0.0393x^2 – 0.1613x + 7.9264$, $R^2 = 0.7674$;
Carbide $y = 0.1216x + 7.772$, $R^2 = 0.6047$;
Ethrel $y= -0.0321x^2 + 0.5937x + 8.4207$, $R^2 = 0.832$.

Firmness — Regressions:
Control $y= 0.5463x^2 + 2.6006x + 91.522$, $R^2 = 0.9257$;
Muffling $y= -0.6758x^2 + 2.8293x + 90.093$, $R^2 = 0.9472$;
Carbide $y= -0.3682x^2 + 1.2418x + 90.365$, $R^2 = 0.8649$;
Ethrel $y= 0.6634x^2 - 13.583x + 92.948$, $R^2 = 0.9322$

No.	Weight loss				Peel hue			
	Control	Muffling	Carbide	Etrhel	Control	Muffling	Carbide	Etrhel
0	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	98.16^{a}	98.16^{a}	98.16^{a}	98.16^{a}
3	3.26^{a}	1.16^{b}	1.07^{b}	2.01^{ab}	99.99^{a}	100.68^{a}	99.39^{a}	92.48^{a}
6	4.02^{a}	3.97^{a}	3.18^{a}	5.02^{a}	78.14^{b}	93.36^{a}	99.64^{a}	98.98^{a}
9	7.98^{ab}	9.27^{a}	6.81^{b}	7.55^{ab}	86.42^{a}	84.99^{a}	87.47^{a}	74.84^{b}
12	11.59^{b}	14.48^{a}	10.29^{b}	11.99^{b}	78.08^{a}	78.02^{a}	79.24^{a}	74.24^{a}

Weight loss — Regressions:
Control $y= 0.9301x – 0.2106$, $R^2 = 0.9656$;
Muffling $y= 1.2355x – 1.6382$, $R^2 = 0.942$;
Carbide $y= 0.8776x – 0.9954$, $R^2 = 0.9573$;
Ethrel $y= 0.9841x – 0.5916$, $R^2 = 0.9812$

Peel hue — Regressions:
Control $y= -1.7911x + 98.904$, $R^2 = 0.6487$;
Muffling $y= -1.8651x + 102.23$, $R^2 = 0.882$;
Carbide $y= -1.6582x + 102.73$, $R^2 = 0.7475$;
Ethrel $y= -2.182x + 100.83$, $R^2 = 0.7075$

[a,b]Means followed by the same letter on the same line do not differ significantly.

The faster effect of ethylene compared to the other treatments, regarding firmness, can be attributed to the ethylene function in regulating the activity related to the tissue softening metabolism (Chitarra and Chitarra, 2005; Jeong et al., 2003). And this suggests an increase in the activity of softening enzymes, as celulase and polygalacturonase, also regulated by the action of ethylene (Chitarra and Chitarra, 2005; Lohani et al., 2004). However, all the treatments promoted fruit ripening.

Calcium carbide and ethephon anticipated changes and also unified the physicochemical characteristics of mangos, including pulp firmness (Zeitschriften, 2009). Firmness loss in cajá-manga fruits during storage and noted that at room temperature the rate of firmness loss is higher because there is a higher proximity to the optimum action temperature of pectinolytic enzymes, similar to this study that was performed at 20°C (Kohatsu et al., 2011).

Similar to the loss of firmness, the fruits under ethre treatment lost mass faster than the others; this loss was more intense from day 6 on (Table 2), showing that the storage time was a significant factor for firmness as well as the climatization. For the other treatments, the losses were more significant only in the last days of evaluation, from the 9th day on for the smothering treatment and from the 12th for the control and carbide treatments.

The weight loss of the fruit during storage is due to water loss, especially because of the transpiration promoted by the pressure deficit between the fruit and the environment, and in this case, due to the low natural humidity. Fruits have independent lives when they are removed from the mother plant and use their own reserves of substrates that were accumulated during their growth and maturation, with consequent progressive depression in accumulated dry matter reserves, thus causing weight losses (Taiz and Zeiger, 2009).

It was noted that the weight loss increased linearly after mango treatment with ethrel and carbide (Silva et al., 2012). Moisture losses for vegetables in the order of 3 to 6%, as occurred in this study are enough to cause a marked decrease in quality. However, in resistant products, such as caja-manga, they are still traded with up to 10% of moisture losses (Chitarra and Chitarra, 2005).

The loss of water by transpiration, besides causing weight loss can greatly contribute to the increase of the concentration (or apparent concentration) of other water-soluble compounds, such as total soluble solids. Initially, the average for the total soluble solids content in fruits was 8.27° Brix. After being treated with ethrel they had a significant increase in this content in the first six days (11.33° Brix) which confirms the relation water loss × apparent increase of soluble compounds which occurred concomitantly on this treatment (Table 2). Storage time and each climatization treatment were significant for the soluble solids.

The control treatment had an TSS peak only at the end of the experiment (13.40° Brix) when there was also the largest weight loss (Table 2). Regarding the beginning of the experiment, all treatments had an increase in TSS, which is a typical characterisctic of fruit ripening.

The TSS in fruits, however, does not increase the apparently during ripening, because the starch content converted into simple sugars provide the increase in levels of total sugars, non-reducing sugars and total soluble solids. In this process, the amylase enzyme is the main one responsible for the result of starch hydrolysis in oligosaccharides (Watada, 1986).

The soluble solids content is a critical factor in determining the quality and consumer acceptability in vegetables and fruits, because it is related to sweetness as has been reported by Crisoto and Crisoto (2005) and Lopez et al. (2011). In caja-manga, this factor is essential to balance the acidity of the fruit.

The acidity of all the fruits in all treatments increased until the end of the twelve days of experiment (Table 2) and was significant regarding the storage time and the climatization factor. Although, it is not very common, the titratable acidity values may increase, probably due to the formation of galacturonic acid that is derived from pectins degradation, which usually occurs when the fruits are harvested unripe, or more commonly, decrease due to the respiratory process or the conversion into sugar (Silva, 2009; Samson, 1986). These changes have important role in the fruit flavor characteristics. The Identity and Quality Standards (IQS) to cajá pulps stipulates minimum values of total acidity of 0.9 g 100 g^{-1}, consistent with the acidity results in this study (Brasil, 1999). The fruits from the control treatment had the highest values of acidity at the end of the experiment.

The ratio is the relation between the soluble solids (°Brix) and titratable acid content and it was significant for days and climatization factors. It is the indicator used to determine the stage of maturation, determining the balance of sweet: acid flavor. The ethrel treatment was the one that changed the ratio range during the evaluation period with an average of 16 compared to 13 of the other treatments.

Regarding the color, there are some authors who relate °*h* with firmness loss and the autocatalytic production of ethylene. It was noted that, in general, the color changed from a light yellow (whitish) for a more intense yellow, nearing 90° h at the end of the evaluations for all treatments (Table 2). In this study, there is also a correlation between the loss of firmness with the Hue angle. It was noted that for the ethrhel treatment, there was a more intense and uniform modification in color from the 6th day of evaluation, which was earlier than for the more other treatments. The same was observed for firmness loss. This change in coloration, demonstrates that the ripening reactions are not only catabolic. Some plant organs use the energy released by respiration to continue the synthesis of pigments, enzymes and other elaborate molecular structure materials as soon as they are detached from the plant. These syntheses are an essential part of many fruits ripening process, as in this study.

Conclusion

Conclusively, the ethrel treatment is the best option to promote uniform ripening in cajá-manga fruits. It is possible for caja-manga to be harvested unripe avoiding further damage and then be treated with ethrel to foster the development in the desired time.

Conflit of interests

The authors have not declared any conflict of interests.

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