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Effects of application of ultrasound waves in the shelf life of an amazon fruit: araçá-boi

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ABSTRACT

The aim of this work was to evaluate the effects of ultrasonic treatments in quality of araçá-boi fruits (*Eugenia stipitata* McVaugh) during storage. Araçá-boi fruits were processed at a constant ultrasonic frequency of 40 kHz at 5 and 15 min. In the sequence, they were divided in three groups: control (CG), 5 min (G5M) and 15 min (G15M) of ultrasonic treatment and stored at room temperature for six days. The quality of the untreated and treated fruits was evaluated at 0, 3 and 6 days of storage and the following quality parameters were analyzed: weight loss, vitamin C, pH, titratable acidity, soluble solid content, total and reducing sugars. The maximum shelf life of fruits was between 3 and 6 days after harvest, for the three groups. The exposure time to the ultrasonic treatment influenced the quality of the fruits. The fruits of the group G5M presented less degradation, for some parameters (weight loss, pH, titratable acidity and concentration of sugars). In contrast, the fruit of the group G15M showed accelerated degradation. The effect of the cavitation phenomenon provoked by ultrasound treatment cause the irreversible destruction and inactivation of enzymes. Thus, it is assumed that 5 min of the treatment may have been more effective in reducing the action of some enzymes, and with15 min, the cavitation phenomenon may have been excessive for cell tissue and caused degradation and anticipated senescence. The results of this study suggest that ultrasonic treatment can be effective in preserving the quality of fruits, but, the treatment time needs to be better investigated.

KEYWORDS: *Eugenia stipitata* McVaugh; quality parameter; ultrasonic treatment.

INTRODUCTION

The fruit ripening is a complex process, genetically programmed that involving changes in color, texture and flavor (ADAMS-PHILLIPS et al., 2004). These biochemical reactions can occur in two ways: rapidly in climacteric fruits or slower in non-climacteric fruits. Such reactions lead to fruits maturation and consequently to the fruits senescence which are related to the presence of enzymes and/or microorganisms. The search for technologies to inhibit or delay these reactions in the intact fruit and prolong its shelf life is persistent among researchers (CHITARRA; CHITARRA, 2005).

Some examples of conservation techniques currently employed are application of ethylene inhibitors (CANUTO *et al*., 2010), storage under refrigeration (TERUEL, 2008; GALANI *et al*., 2017), coating application (JIANG; JIANG, 2005; ATIENO et al., 2019) and packaging in modified atmosphere (MANGARAJ; GOSWAMI; MAHAJAN, 2009; RODRIGUES *et al*., 2016). These techniques have some disadvantages, such as, not always are possible to be applied due the difficulty of accessing chemical products (ethylene inhibitors, inert gases, coatings) and present high cost (storage under refrigeration).

The search for a quick, non-thermal and easy application and mainly that can increase the time of use of the fruits, maintaining their nutritional value and sensory characteristics, is that led to the interest in ultrasound treatment. Ultrasound technology has been used in many recent food applications. Several times it was applied as complementary technology to the processes, such as sterilization, freezing, extraction and filtration (reduce processing times and increase efficiency) (RAWSON *et al*., 2011).

According Cárcel *et al*. (2012), the insertion of new technologies can reduce processing time and improve the conditions of industrial operation, preserving their initial characteristics and resulting in high quality products.

Ultrasound offers advantages in terms of cost, productivity and selectivity, with less processing time, and reduction of chemical and physical damages to the environment (CHEMAT; ZILL-E-HUMA; KHAN, 2011). The ultrasound techniques applied in foods, includes frequencies between 20 kHz and 100 kHz (CÁRCEL *et al*., 2012). The ultrasound producing repeated cycles of compression and decompression, denominated acoustic cavitation, which is the nucleation process, growth and collapse of bubbles in liquids exposed to ultrasonic waves (RASTOGI, 2011). In the ultrasound treatment various radicals can form, such as hydroxide radical OH·, which is highly reactive and readily attacks organic substrates present in the reaction environment or recombines with another OH· radical to form H_2O_2. In these areas the temperatures are very high (GALLO; FERRARA; NAVIGLIO, 2018).

One of the major advantages of ultrasound compared to other techniques in the food industry is that waves are generally considered safe, non-toxic and non-polluting (CHEMAT; ZILL-E-HUMA; KHAN, 2011).

Some authors reported the use of ultrasound treatment in fruits, such as strawberry (CAO *et al*., 2010), citrus juices (BHAT *et al*., 2011), tomato (ADEKUNTE *et al*., 2010), carrot-grape juice (NADEEM *et al*., 2018), and verified good results.

In the Amazon region there are several fruits that are still little known and used in the food industry, such as araçá-boi. The araçazeiro-boi (*Eugenia stipitata*

McVaugh) is a fruit tree native to the Amazon region, belongs to the family Myrtaceae, it is similar to guava and Brazilian grape tree (ANDRADE *et al*., 1997). The fruit is a globose berry, thin and velvety skin, yellow color when ripe, weighing of the 30 - 800 g, and rounded or flattened shape with longitudinal diameter of 5 - 10 cm. The pulp is succulent, acid, yellow, little fibrous, having the 4 - 10 oblong seeds with 0,5 a 1,0 cm of length (SACRAMENTO; BARRETTO; FARIA, *et al*., 2008).

Thus, the aim of this work was to apply different times of ultrasound treatments in araçá-boi fruits and evaluate its effect on quality parameters during storage.

MATERIALS AND METHODS

ACQUISITION AND PREPARATION OF THE RAW MATERIAL

The araçá-boi fruits *in natura* were harvested in the region of Ariquemes, Rondônia state, Brazil. The fruits were harvested at the end of their growth, in intermediary maturity stage and transported immediately to the laboratory of Food Science and Technology of the Federal University of Rondônia – UNIR, campus Ariquemes.

The fruits were inspected, observing mechanical damages and selected considering the uniformity of size and color. The fruits that presented the best external visual appearance were chose. After selection, the fruits were washed with detergent, coconut babaçu fatty acid soap (1 mL/ 1L the water) and sanitized with chlorine dioxide 8% (1 mL/ 1L the water for 2 min). The sanitized fruits were packed in polymeric pot and separated in three groups: 1) without ultrasonic treatment - control group (CG), 2) application of 5 min of ultrasonic treatment (G5M), and 3) application of 15 min of ultrasonic treatment (G15M). Each group contained three samples of fruit. The three group were stored at room temperature (average 35 °C).

APPLICATION OF ULTRASOUND WAVES

An ultrasonic power bath with capacity of 2,6 L, was used (SANDERS, model Soniclean 2PS, Brazil). The fruits were individually packed in polyethylene bags and immersed totally in the bath to receive the sonication. The samples were processed at a constant ultrasonic frequency of 40 kHz in different times described in the section 2.1.

EVALUATION OF PHYSICOCHEMICAL FRUITS QUALITY

The fruits quality parameters of the three groups were evaluated on 0, 3 and 6 days of storage or until signs of senescence were observed. All analyzes were performed in triplicate. Soluble solids content (SSC), pH and titratable acidity (TA) were determined by IAL (2005), and the results expressed as °Brix and %, respectively. The content of sugars (total and reducing) was determined by spectrophotometry (IAL, 2005) and the results expressed as $g.100g^{-1}$. The ascorbic acid content (vitamin C) was determined by the Tillmans method (titrimetric) and the results expressed in mg of ascorbic acid per 100 mL of pulp (CARVALHO *et al.*, 1990). The determination of weight loss was performed by the mass difference and the results expressed as %. The results were subjected to analysis of variance (ANOVA) and Tukey's test ($p < 0.05$) for comparison of mean values using the ASSISTAT software, version 7.7 beta.

RESULTS AND DISCUSSION

The three groups evaluated were stored for six days. However, on the sixth day, the fruits were in progress degenerative and it was not possible to perform the analysis of the quality parameters. From this result, it was defined that, the araça-boi fruits showed a short shelf life, between 3 and 6 days after harvest, for the three groups. These findings are in agreement with Freitas (2016), which affirmed that araçá-boi fruit is highly perishable (one or two days). This fact may be due the high concentration of water (85 %) and also for presenting a thin skin.

Even not observing difference between the three groups about the shelf life, some important aspects were observed.

The fruits G5M presented lower degree of senescence on the sixth day, when compared to the others treatments, even so, were inappropriate for consumption. Such fact can be attributed to the effect of the cavitation phenomenon provoked by ultrasound treatment. The effect of cavitation is generated by collapse of bubbles during the treatment, causing the irreversible destruction and inactivation of enzymes (MAWSON *et al*., 2011). In fruits, the deterioration of color, flavor, and nutritional value are catalyzed for oxidative enzymes like polyphenoloxidase, peroxidase, β-glucosidase and lipoxygenase (LIAVOGA; MATELLA 2012). The pectinmethylesterase and polygalacturonase are involved in the pectin modification and subsequent changes in texture (DUVETTER *et al.*, 2009). Thus, it is assumed that five min of the treatment may have been more effective in reducing the action of some enzymes, such as those mentioned above.

On the other hand, the highest time of treatment applied to fruits (15 min), may have caused disruption of the chemical structures of the plant cell wall, accelerating the degradation. Tian *et al*. (2004) reported that the extreme agitation, during the ultrasonic treatment, favors the creation of microcurrent that may result the rupture of the chemical bonds, such as Van der Waals and hydrogen bonds, and consequently, cause accelerated degradation of the material.

The physical and chemical characterization of stored (0 and 3 days) araçá-boi fruits submitted to ultrasonic treatments is presented in Table 1.

In general, the araçá-boi fruits presented relatively low values of SSC, pH and sugar concentration. However, values of vitamin C and titratable acidity were high.

In relation to weight loss, after 3 days of storage was observed a reduction of 10.8%, 10.2% and 11.2% for GC, G5M and G15M groups, respectively. These values are similar to those found for Freitas (2016) found a weight reduction of 11% for araçá-boi fruits (*Eugenia stipitata* McVaugh) stored at ambient temperature for three days.

Table 1 - Mean and standard deviation of quality parameters evaluated in araçá-boi fruit submitted to ultrasonic treatments, on the first and third day of storage.

Parameter	Storage time (days)	Treatments		
		CG	G5M	G15M
Weight loss (%)	0	-	-	-
	3	10.83	10.22	11.15
pH	0	2.57±0.01bB	2.65±0.02bA	2.35±0.01bC
	3	3.45±0.02aA	3.11±0.05aC	3.2±0.01aB
TA (%)	0	44.46±0.12aB	43.73±0.2aB	48.86±0.2aA
	3	13.6±0.4bC	20.06±1.3bA	17.26±0.2bB
Vitamin C ($mg.100g^{-1}$)	0	15.75±0.43aC	19.39±0.43aB	37.27±1.29aA
	3	11.97±0.21bB	3.67±0.04bC	15.48±0.08bA
SSC (°Brix)	0	5.0±0aA	5.0±0aA	5.0±0aA
	3	4.5±0bA	4.5±0bA	4.5±0bA
Ratio SSC/TA)	0	0.11	0.11	0.10
	3	0.33	0.22	0.26
Reducing sugar ($g.100g^{-1}$)	0	0.67±0.01aA	0.50±0.03bB	0.42±0.03bC
	3	0.51±0.03bC	0.81±0.02aA	0.73±0.03aB
Total sugar ($g.100g^{-1}$)	0	0.75±0.02bA	0.56±0.01bB	0.43±0.02bC
	3	0.85±0.01aC	1.06±0.01aA	0.99±0.01aB

NOTE: (-) not applicable. Lowercase letters classify the different storage days in the same column and uppercase letters classify the different treatments in the same row. The means followed by the same letter do not differ statistically from each other. The Tukey test was applied at a 5% probability level.

The pH values of the fruits presented a significant difference during storage, in which an increase of 34% for GC, 18% for G5M and 36% for G15M were observed. The increase was less pronounced for the G5M group. The increase in pH can accelerate the degradation of fruits, facilitating the development of pathogenic microorganisms. The content of organic acids in fruits, usually, decrease during the maturation process, due to oxidation of the acids in the metabolic cycle, a result of respiration (CHITARRA; CHITARRA, 2005), and consequently increase pH. The initials values found in this study were similar to reported by other authors (SACRAMENTO; BARRETTO; FARIA, 2008).

The initial values of the TA for the GC and G5M did not showed significant difference. On third day, all groups presented significant difference ($p < 0.05$) (Table 1). The TA values decreased during storage 69%, 54% and 65% for the GC, G5M and G15M, respectively.

In these two parameters related to the acidity of the araçá-boi fruits, was observed, the treatment with 5 min, subtly reduced the oxidation of acids during storage and consequently, showed a lower change in the pH value. These effects may be related to exposure time of action of ultrasound. São José *et al.* (2014) affirm that the overall inactivation depends on several factors, such as the type of antimicrobial agent, concentration and contact time.

In relation to vitamin C concentration, all three groups, in the two storage times, presented significant difference. The point interesting evaluated was, in the initial time (0 day), independent of the group (control or that received the ultrasonic treatment), presented a small differentiation in the concentration of the evaluate parameters, however, for vitamin C, was observed a high discrepancy between the initial values of the three groups (Table 1). It was perceived that the longer the exposure time of the fruits to the ultrasonic treatment, higher was the initial concentration of vitamin C. This feature can be a response of the fruit metabolism to the applied ultrasonic treatment. According to Gabriel (2012), the violent collapse of bubbles, that occur during of the ultrasonic treatment can generate high localized temperatures and pressures. São José and Vanetti (2012) accentuated that the occurrence of the "hot spots" (hot and high pressure zones) is limited in terms of duration and the treatment conditions. The treatment conditions should be appropriate for each type of material, otherwise, it may not be effective and damage to product. In fruit, can be occur rupture plant cell which culminates in the loss of original quality.

In specific cases, may occur increase the concentration of vitamin C, where this component is synthesized to act as a protector, an "antioxidant". Bendich and Langseth, (1995) describe that vitamin C is the first compound in the line of defense against radicals. On the other hand, some authors justified the increase of vitamin C can be due the application of ultrasonic treatment. Quang, Le and Le, (2014) applied ultrasonic treatments in apple juice at different times (2, 4, 6 and 8 minutes) with a fixed frequency of 20 kHz. They reported an increase of 41.5% in concentration of vitamin C (from the control group to the group treated for 6 minutes) and proposed that cavitation effect caused by ultrasonic treatment, may have reduced the particle size and improved the extraction and quantification of this component. Aadil *et al.* (2013) found an increase of 28% in vitamin C on grapefruit juice, after 90 minutes of treatment with a frequency of 28 kHz. Cheng *et al*. (2007) highlighted that the increase in vitamin C can be attributed to the effect of cavitation in removal of oxygen trapped in the plant matrix, avoiding the oxidation of the vitamin C.

Meantime, the reduction of vitamin C content was noted for all three groups during storage, especially for the G5M. Freitas (2016) also found a reduction in vitamin C content (8.3%) during storage at room temperature for araçá-boi. The decrease of vitamin C during the process of maturation may occur due to the action of the enzyme ascorbate oxidase (CHITARRA; CHITARRA, 2005). Costa *et al.* (2009) affirmed that ascorbic acid is a soluble and thermolabile vitamin, being rapidly oxidized when exposed to air. Considering that the G5M was inefficient to inactivate the enzyme ascorbate oxidase, when compared to the G15M. Once again, the time of exposure to ultrasonic treatment proved to be decisive for an effective result.

Araçá-boi fruits presented low SSC (approximately 5.0%), without significant difference between groups in both storage time. Was only observed reduction for the three groups during the three days of storage (Table 1). These values are similar to the values obtained by Sacramento, Barreto and Faria, (2008) in araçá-boi fruits (5.54 %). Cao *et al.* (2010) applied ultrasound waves in fruits of strawberries and also did not find significant difference between treated and control groups.

The SSC indicates the proportion (%) of dissolved solids in a solution. It is the sum of sugars (sucrose and hexoses), acids (citric, malic, ascorbic and others) and other minor components (phenols, amino acids, soluble pectins and minerals) (KADER, 2008). Thus, the reduction in SSC observed in the araçá-boi fruits may be associated with reduction of vitamin C (ascorbic acid) and TA during storage. In the same sense, the increase observed in the ratio SSC/AT was due the reduction of the parameters related to acidity.

The sugar content (reducing and total) of the fruits in the three groups in the two storage times showed a significant difference. An increase was observed between 0 and 3 days (Table 1). This increase in ripened fruit is the result of the hydrolysis of polysaccharides, particularly from starch-rich fruit (PRASANNA; PRABHA; THARANATHAN, 2007). Andrade *et al.* (1997) observed a concentration of 0.99 g.100 g^{-1} of reducing sugar in araçá-boi fruit, similar to the values found in this study.

CONCLUSIONS

The araçá-boi fruits stored at room temperature showed a short shelf-life (between 3 and 6 days), even after the application of ultrasound treatment. In this way, it was not possible to define the best treatment.

The group with 5 min of the ultrasound treatment showed better results for weight loss, pH and titratable acidity. A higher concentration of sugars (reducing and total) for this group was also observed. The opposite was found for the group with 15 min of ultrasound treatment. These fruits showed a more degradation of the quality parameters, possibly for stimulating the anticipation of senescence.

It was also observed that the ultrasonic treatment caused an increase in vitamin C concentration in both groups, immediately after the application.

Therefore, ultrasonic treatment may be effective in preserving fruits, but the potencies and times used in this study were not effective to extend the shelf-life of the araçá-boi fruits. Other potencies and times could be tested, and thus, to allow these fruits can be consumed in other regions of the country.

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Efeitos da aplicação de ondas ultra-som na vida útil de uma fruta amazônica: araçá-boi

RESUMO

O objetivo deste trabalho foi avaliar os efeitos dos tratamentos ultrassônicos na qualidade de frutos de araçá-boi (*Eugenia stipitata* McVaugh) durante o armazenamento. Os frutos de Araçá-boi foram processados a uma frequência ultra-sônica constante de 40 kHz aos 5 e 15 min. Na sequência, foram divididos em três grupos: controle (GC), 5 min (G5M) e 15 min (G15M) do tratamento ultrassônico e armazenados à temperatura ambiente por seis dias. A qualidade dos frutos não tratados e tratados foi avaliada aos 0, 3 e 6 dias de armazenamento e os seguintes parâmetros de qualidade foram analisados: perda de peso, vitamina C, pH, acidez titulável, teor de sólidos solúveis, açúcares totais e redutores. O prazo de validade máximo dos frutos foi de 3 a 6 dias após a colheita, para os três grupos. O tempo de exposição ao tratamento ultrassônico influenciou a qualidade dos frutos. Os frutos do grupo G5M apresentaram menor degradação, para alguns parâmetros (perda de peso, pH, acidez titulável e concentração de açúcares). Por outro lado, os frutos do grupo G15M apresentaram degradação acelerada. O efeito do fenômeno da cavitação provocado pelo tratamento com ultra-som causa a destruição irreversível e a inativação de enzimas. Assim, supõe-se que 5 minutos do tratamento possam ter sido mais eficazes na redução da ação de algumas enzimas e, com 15 minutos, o fenômeno da cavitação pode ter sido excessivo para o tecido celular, causando degradação e senescência antecipada. Os resultados deste estudo sugerem que o tratamento ultrassônico pode ser eficaz na preservação da qualidade das frutas, mas o tempo de tratamento precisa ser melhor investigado.

PALAVRAS-CHAVE: *Eugenia stipitata* McVaugh; parâmetros de qualidade; tratamento ultrasônico.

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