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# Post-harvest nutraceutical behaviour during ripening and senescence of 8 highly perishable fruit species from the Northern Brazilian Amazon region

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ABSTRACT

The post-harvest nutraceutical characteristics of highly perishable native fruits species from the Northern Brazilian Amazon region were studied during 12 day at 15 ± 1 °C and 95 ± 3% RH. Uxi and caja fruit showed climacteric behaviour while caju, açai de terra firme, camu-camu, inajá, murici and araçá-boi were non-climacteric. Soluble solids and sugars increased for climacteric fruit while total acidity remained constant for all fruits. In general, all fruit species had high levels of total phenolics (121–9889 mg GAE 100 $g^{-1}$ dry weight pulp), vitamin C (31–1532 mg AA 100 $mL^{-1}$ juice) and antioxidant activity (AOX) (75–2881 μmol Trolox Eq 100 $g^{-1}$ dry weight, ORAC value), however, camu-camu, acai and murici were among the highest. All fruits showed an increase in phenolic content (15–82%), a simultaneous decrease in ascorbic acid in both peel (88–98%) and pulp (89–97%), while AOX increased or decreased depending on the fruit species, very likely due to the specific phenolic profile being synthesized. We propose a hypothetical model where ripening/senescence induced a redox homeostasis imbalance which in turn triggered the responses.



## 1. Introduction

In recent years there has been an increased awareness about health and a demand for high-quality nutritive foods as a consequence of the search for a longer healthier life. Many studies have focused on the phenolic content and antioxidant capacity in plant species, aiming on understanding their role in the potential nutritional value of fresh produce, their commercial valorization and their association to the prevention of degenerative diseases caused, mainly, by oxidative stress.

Prior et al. (2003) defined antioxidants as substances that have properties capable of minimising the harmful effect of free radicals, inhibiting oxidative alterations in the molecules and are found most frequently in fruits, seeds and vegetable oils. The natural antioxidants include ascorbic acid, vitamin E, B-carotene and phenolics including flavonoids, tannins, phenolic acids among others frequently found in fruit and vegetables (Broinizi et al., 2007; Duarte-Almeida, Santos, Genovese, & Lajolo, 2006). The phenolic compounds have excellent antioxidant activity according to Sousa et al. (2007) mainly because of their reducing properties and chemical structure, which play an important role in neutralising or kidnapping free radicals and transition metal chelation, acting both at the initiation and propagation stages of the oxidative process.

It is estimated that the Northern Brazilian Amazon region has approximately 220 edible fruit producing plant species, representing 44% of native fruit diversity in Brazil. These fruits are considered a potential source of micronutrients, used in human nutrition to protect the populatiońs health against innumerable diseases. Traditional uses by locals support these claims. Furthermore, it is expected that these plant species may contain bioactive compounds with potential use as functional foods or nutraceuticals. These plant species have evolved under the Amazonian environment and adapted to the region, producing secondary metabolites that mitigate adverse conditions. Information on bioactive compounds of native fruits from that region is limited (Broinizi et al., 2007; Reynertson, Yang, Jiang, Basile, & Kennelly, 2008; Roesler, Catharino, Malta, Eberlin, & Pastore, 2007; Rufino, Alves, Brito, Silveira, & Moura, 2009; Rufino et al., 2010; Santos et al., 2008; Villanueva-Tiburcio, Condezo-Hoyos, & Asquieri, 2010), and more studies are needed to add value to these species.

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However, the valorization of native Amazon fruits is dependent of the development of the Amazon region itself. This ecosystem is very sensitive ecologically, has limited studies and supporting scientific knowledge generated, there is long distances among partners, suppliers, clients and especially markets that require specific strategies to overcome these limitations (Pallet, 2002). Furthermore, there is growing interest by companies in developed countries to access to new materials in centres of biodiversity like the Amazon, however, many of these tropical fruits are highly perishable which limits access to these species. Thus, knowledge on amazon fruit species postharvest behaviour and the initial characterisation of their chemical and functional properties will be an important step for their valorization because many of these species have not yet been studied.

In the present work we make available information regarding the nutraceutical behaviour of fruits native to the Amazon and consequently contribute to regional development. The main objective in the present study was the characterisation of the postharvest life, in relation to chemical composition and antioxidant capacity of eight highly perishable native fruit species from the Brazilian Amazon region for their potential use as source of nutraceuticals.

## 2. Materials and methods

### 2.1. Fruit material

The native fruits used to carry out the present study were (Fig. 1I): açai de terra firme (*Euterpe precatoria* Mart.), camu-camu (*Myrciaria dubia* HBK Mc Vaugh.), inajá [Maximiliana maripa (Correa) Drude], murici (*Byrsonima crassifolia* L. Kunt), araçá-boi (*Eugenia stipitata* Mc. Vaugh), cajá (*Spondias lutea* L.), caju (*Anacardium occidentale* L.) and uxi (*Endopleura uchi* Huber). The fruits, at complete physiological maturity stage (cajá and uxi – climacteric metabolism) and commercial maturity stage (caju, açai de terra firme, camu-camu, inajá, murici and araçá-boi – non-climacteric metabolism), based on harvest date, fruit size, brix and/or skin colour (see description below), were collected on rural properties located in Pará (PA), Amazonas (AM) and Roraima (RR) states in Brazil, 2010. Overall fruit quality changes based on flavour and texture observations during storage at 15 and 25 °C for 12 day, were run randomly with 35 students (Supplementary information). Respiration measurements were done placing fruit samples in 1 L jars for ~1 h. Headspace samples of 5 mL were taken and $CO_2$ concentration was measured on a Shimadzu CR 950 chromatograph equipped with a thermal conductivity detection system expressing results as mg $CO_2$ $kg^{-1}$ $h^{-1}$.

### 2.2. Morphological description

Açaí de terra firme (*Arecaceae*): round fruit, 1.22–1.53 cm in diameter, pulp with translucent appearance and a violet–purple dark colour, 1.75–1.92 g of fresh weight and 85.2–86.1% moisture content. Harvest performed in March in Manaus, AM (winter crop – rainy season).

Araçá-boi (*Myrtaceae*): Fruit with an elliptical shape, 5.44–6.73 cm in longitudinal diameter and 7.40–7.73 cm in transverse diameter, with a white–yellow peel and a creamy-white pulp shows mucilaginous texture, 95.82–99.88 g of fresh weight and 84.5–85.7% moisture content. Harvest performed in November in Boa Vista, RR.

Cajá (*Anacardiaceae*): Fruit with an elliptical shape, 3.01–3.13 cm in longitudinal diameter and 3.50–3.81 cm in transverse diameter, with a yellow pulp and peel, 76.03–79.78 g of fresh weight and 82.8–83.1% moisture content. Harvest performed in March in Belém, PA.

Cajú (*Anacardiaceae*): Fruit with a pyriform shape, 4.61–4.88 cm in basal diameter and 3.04–3.33 in apical diameter, pulp with fibrous texture and of yellow–orange colour and peel of reddish-orange colour, 95.23–98.10 g (pulp and nut) of fresh weight and 89.1–90.8% moisture content. Harvest performed in December in Boa Vista, RR.

Camu-camu (*Myrtaceae*): Round fruit, 2.35–2.86 cm in diameter, with a red–purple peel and a translucent white–pink pulp, 9.25–10.44 g of fresh weight and 91.5–92.3% moisture content. Harvest based on colour skin. Harvest performed in July in dry land (camu-camu de terra firme) in Boa Vista, RR.

Inajá (*Arecaceae*): Fruit with an ovoid shape, 4.13–4.22 cm in longitudinal diameter and 2.55–2.78 cm in transverse diameter, mucilaginous pulp, interspersed with fibres, resulting in a spongy texture with a light-yellow colour, 9.34–9.67 g of fresh weight and 81.9–83.4% moisture content. Harvest performed in July in São Luis da Anauá, RR.

Murici (*Malpighiaceae*): Round fruits, 1.7–2.2 cm in diameter, the pulp is fleshy and yellow translucent and the peel is yellow–orange, 2.22–2.37 g of fresh weight and 88.4–90.2% moisture content. Harvest performed in September in Boa Vista, RR.

Uxi (*Humiriaceae*): Fruit is a drupe oblong-ellipsoid, with 5.4–7.1 cm in longitudinal and 4.2–4.6 cm in diameter, the pulp is greenish-yellow colour, with an exocarp smooth, and peel of yellow–orange colour, 55.61–60.31 g of fresh weight and 91.2–92.2% moisture content. Harvest performed in October in Boa Vista, RR.

### 2.3. Preparation of extracts and samples

After harvesting, the fruits were transported to the Food Technology Laboratory at Roraima Federal University, Brazil, and selected for absence of visible damage and rot, standardised by size/calibre, epidermis colour and washed in an aqueous solution of sodium hypochlorite (NaOCl) at 2.5 g $L^{-1}$ for 30 min. The fruits were then washed in distilled water and dried on perforated trays and exposed for two hours to atmospheric air (25 ± 2 °C, 70 ± 3% RH).

The fruits were assessed at harvest (day 0) and at 3, 9 and 12 days of storage at 15 ± 1 °C and 95 ± 3% of RH. The seeds of the fruits were removed from the fruits using stainless steel knives. For the analysis of the functional compounds, the samples (peel and pulp) were processed separately in a blender, sieved, homogenised, and then they were lyophilized (freeze-dried samples). Antioxidant analyses were performed at the Plant Bioactives & Bioprocessing Research Laboratory of Texas A&M University, USA. For the quality chemistry analysis, fresh fruits were used and sampled as a whole extract. For total phenolics and vitamin C, fruit samples were separated by peel and pulp and extracts were obtained for both parts of the fruit.

### 2.4. Chemical analysis

*Soluble solids* were determined by refractometry, using a Shimadzu refractometer with temperature correction, using one drop of pure juice in each replication and the result was expressed in °Brix (IAL (Instituto Adolfo Lutz), 2008).

*Titratable acidity*, an AOAC (1998) method adapted by IAL (Instituto Adolfo Lutz) (2008), was determined by diluting 10 mL pure juice in 30 mL distilled water and tittering with NaOH to pH 8.1 and the result was expressed in equivalents of citric acid (Cmol $L^{-1}$ juice).

*Soluble sugars* were extracted successively with three portions of boiling 80% ethanol solution (v/v). The supernatants were combined, the ethanol was evaporated under vacuum in a "speedvac" system and the volume reconstituted with water. The soluble sugar content were analysed by HPLC-PAD (Dionex, Sunnyvale –