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Spontaneous postharvest fermentation of açai (*Euterpe oleracea*) fruit

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ABSTRACT

Açai (*Euterpe oleracea*) fruit (EOF) are widely commercialized in the Brazilian Amazon. These fruit contain a high bacterial load and are transported on boards stowed inside or outside the holds of small boats. In this context, postharvest parameters were assessed under conditions that simulated these two methods of EOF transport: stowage in closed polystyrene boxes, simulating the inside of cargo holds, i.e., transport in a closed system; and open baskets, simulating transport in an open environment, i.e., transport in the prow or bow of the boat. EOF suffered spontaneous fermentation of alcoholic, acetic, and lactic types in the closed system, which is the most common type of transportation of this fruit. In the closed system, there was a predominance of lactic acid bacteria over acetic acid bacteria, with 82% and 95% of the initial content of D-glucose and D-fructose being consumed, respectively, after 27 h of experiment. The weight loss reached 1.7% and there was a logarithmic decrease of the major phenolic compounds of the fruit in the closed system, with losses of 78% of cyanidin-3-rutinoside, 88% of cyanidin-3-glucoside, 78% of homorientin, and 72% of orientin after 27 h, which was higher than in the open system (58%, 66%, 73% and 62%, respectively). Analyses on EOF stowed in a closed system indicated that the respiratory rate was characteristic of a non-climacteric fruit, i.e., it showed a logarithmic decay in the production of CO_2 ($R^2 = 0.995$; $P < 0.05$). Thus, transport in a closed system results in more drastic nutritional and functional changes on EOF than when transport is carried out in an open system, suggesting that transportation in continuous aerobic conditions and a short period of time between picking and processing are preferable.

1. Introduction

Euterpe oleracea is a palm tree that is widespread in northern South America, with its greatest occurrence and economic importance in the floodplains of the Amazonian delta. *E. oleracea* fruit (EOF), known as açai, are produced by the palm tree in bunches beginning in the tree's third year. Each fruit is a sessile stone fruit with a woody endocarp, round in shape, with a diameter of 1–2 cm, and mass varying from 0.8 to 2.3 g. The *green* and *tinga* varieties are green before ripening and turn a pale green colour after ripening. In the case of the *black* variety, the most common one, the fruit turns a purple/violet colour (Bichara and Rogez, 2011). The production of EOF in Brazil in 2011 was 215,000 tons, with 109,000 tons originating in the state of Pará (IBGE, 2011), and this produce was transported to the main commercial centres of the Brazilian Amazon mainly in small boats.

In the past 15 years, a boom on marketing this fruit has occurred, not only on the Brazilian market, but also at the international level in the United States, Japan and Europe, for use in açai drinks, because of the fruit's nutritional value and antioxidant quality (Bichara and Rogez, 2011). The antioxidant quality of the açai drink is due to high concentrations of phenolic compounds, mainly cyanidin-3-rutinoside (C-3-R) and cyanidin-3-glucoside (C-3-G), which come to represent 30% of phenolic compounds and are responsible by the purple colour, and orientin and homorientin, secondarily (Rogez et al., 2011).

The local supply chain of EOF (Fig. 1) has potential for microbiological hazards, because the fruit undergo much handling throughout the supply chain (Rogez et al., 2012). The data report that the fruit of this palm have a basal level of microorganisms. The critical microbiological points are during threshing and transport (up to 30 h) in the holds of boats, and during sales in the markets of Amazonian cities (commercial centres), such as Belém, the capital of the state of Pará (Rogez, 2000). These conditions favour spontaneous fermentation processes in tropical fruits because the pH (between 3 and 5) and the sugar and water content are favourable to microbiological action. The respiratory activity of tropical fruits also favours fermentation, because they exhibit high oxygen consumption and carbonic gas dissipation, progressively making the environment anaerobic and prone to fermentation (Montet et al., 2004). Therefore, the aim of this paper was to

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evaluate the metabolic parameters and the type(s) of spontaneous fermentation(s) occurring in EOF during postharvest, particularly during transportation to commercial centres.

2. Materials and methods

2.1. Fruit

EOF (126 kg – with 1 kg corresponding to about 770 fruit) were collected in Abaetetuba, close to Belém (Eastern Brazilian Amazon) and immediately transported to the laboratory; the total time between picking and arrival was 10 h. The fruit were harvested at the fully mature stage, as recommended by Rogez et al. (2011).

2.2. Fermentation conditions of EOF

The two most common conditions of transport of the EOF on boats were simulated as follows: in closed polystyrene boxes (closed system, such as in boat cargo holds), and in open baskets (open system, such as on the open decks of boats). Ten kilogram portions of EOF were stacked in each of eight polystyrene boxes, and ten additional 1.8-kg portions of EOF were stacked in an open basket, for the simulation of the first and second conditions of transportation, respectively, for 27 h. In the open basket, the upper and lower portions were not analysed, as they were not representative of all fruit.

2.3. Fermentation kinetics and sample preparation

From both open and closed conditions, 1.8-kg samples of EOF were collected after 0, 3, 7 (in triplicate), 13, 20, and 27 h. Each fruit sample was softened in water at 45 °C for 1 h, and then mechanically pulped in a 1:1 ratio of water: fruit according to the method of Pompeu et al. (2009b) (Fig. 1). The pulping machine was washed and sterilized routinely using 70% alcohol. Microbiological analyses were immediately performed on the fresh juice. Meanwhile

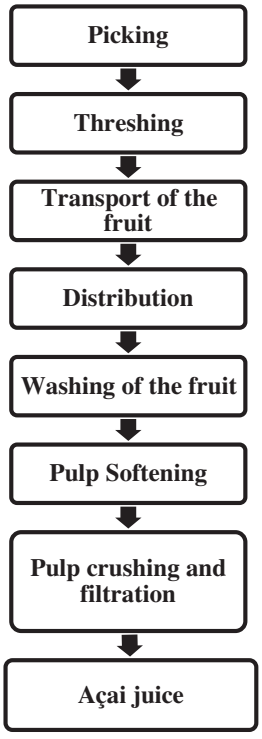

Fig. 1. Flow chart of the postharvest steps and of the processing of açai juice.

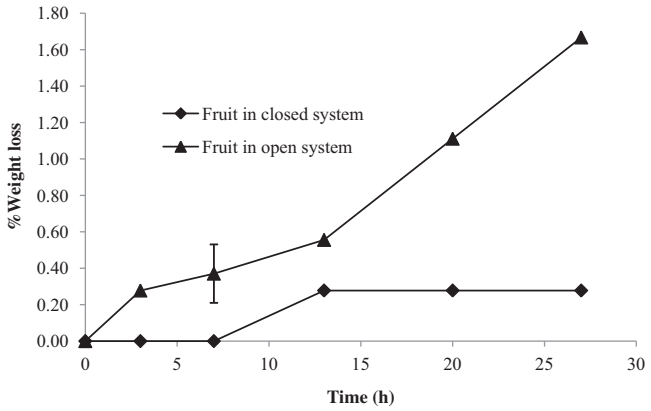

Fig. 2. Weight loss of *Euterpe oleracea* fruit over 27 h. The vertical bar is standard deviation ($n = 3$).

other samples were stored at −20 °C for the analysis of sugars, and for chromatographic analysis. Thermodynamic, weight loss, and respiration determinations were directly performed on EOF.

2.4. Weight loss

This parameter was monitored by the gravimetric method. Initially, the fruit were weighed into synthetic nets in 1.8-kg portions, which were then placed inside polystyrene boxes and open baskets among free EOF. Then, at each sampling time, the nets were retrieved and weighed on a balance with an accuracy of 0.01 g. The temperature of the EOF was monitored using thermometers (±0.2 °C; Model 2292; Incoterm, São Paulo, Brazil) located at the centre of the stack of fruit under both experimental conditions.

2.5. Estimation of the fruit's specific heat and enthalpy of fermentation

To estimate specific heat, the method of calorimetric mixtures of Shrivastava and Datta (1999) was used, as follows: 150 g EOF was mixed with 250 g water contained in an adiabatic calorimeter. At equilibrium, the temperature of the mixture was measured. The specific heat of the EOF was estimated using Eq. (1). This determination was carried out in triplicate.

$$c_p = \frac{(C_c + M_w * c_w) * (T_e - T_w)}{M_f * (T_f - T_e)} \quad (1)$$

where c_p is the specific heat of EOF; C_c is the heat capacity of calorimeter; M_w is the mass of water; c_w is the specific heat of water; M_f is the exact mass of EOF; T_e, T_w and T_f are the temperatures of equilibrium, water and fruit before of the mixture, respectively.

The enthalpy (ΔH) of spontaneous fermentation was calculated using Eq. (2), from the temperature variation of EOF ($\Delta T = T_{final} - T_{initial}$) during the fermentation at constant pressure.

$$\Delta H = c_p * \Delta T \quad (2)$$

2.6. Determination of respiration rate

The respiration rate of the EOF was only measured in the closed system (Bhande et al., 2008). The percentages of O_2 and CO_2 inside the boxes were obtained through a gas analyser (Eurotron/Green Line 8000; Milan, Italy). Eqs. (3) and (4) were used to obtain the respiration rate.

$$R_{O_2} = \left[\frac{(G_{O_2})_t - (G_{O_2})_{t+1}}{\Delta t}\right] * \frac{V}{M} \quad (3)$$