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Respiration rate, ethylene production and biochemical variations of ackee fruit arils (*Blighia sapida* Köenig) stored under three temperature regimes

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ABSTRACT

The storage of fruit is characterized by many physiological and biochemical changes, and this study aimed to study respiration rate, ethylene production, and other biochemical variations of ackee fruit arils (*Blighia sapida*), cheese variety, stored at 5, 10 and 20 °C during eight days. During storage, respiration rate decreased but ethylene production increased. Glucose, fructose, sucrose, and short chain fructooligosaccharides – 1-kestose, nystose and DP-5 – and total phenolic compounds also decreased, however, the decrease was much higher at 20 °C. The L^*, a^*, b, C^* and H^* values showed that lower temperatures preserved much better colour and visual quality, and arils stored at 5 °C were rated excellent compared to those stored at 10 and 20 °C. The quality of arils stored at 10 °C also was more than satisfactory, while arils stored at 20 °C were completely spoiled after 8 days and showed high weight losses compared to arils stored at 5 and 10 °C, which did not show any spoilage and very low weight losses. In conclusion, the results demonstrated that ackee fruit arils can be stored in very good conditions for a minimum of eight days under low temperature regimes, although at 5 °C arils showed the best shelf-life.

1. Introduction

The ackee fruit, *Blighia sapida* Köenig, belongs to the Sapindaceae and is a native plant of West Africa that was introduced to Jamaica in 18th century. The ackee tree is a tropical evergreen, and the fruit is a capsule that is green when young. The fruit develops into a red coloured, fleshy capsule, three-celled with three valves with a septa in the middle, reaching 10 cm long and weighing 100 g at full maturity. The seeds are black, one in each cell with a fleshly aril around its base, and the aril is attached to the placenta by a red membrane.

As the ackee fruit ripens, the colour of the fruit changes from green to yellow, to yellow-red, and then to red when the fruit is fully open, showing the yellow arils and black seeds. When ripe, the fruit splits longitudinally into three sections to reveal glassy black seeds in each section surrounded by a thick yellow oily, fleshy portion which is the aril and is edible with a nutty flavour (Barceloux, 2008).

The ackee tree is found throughout Jamaica, however, the majority grows in Clarendon and St Elisabeth parishes. In Jamaica, two types of ackee are recognized – "cheese" or hard and "butter" or soft. The "cheese" ackee aril is hard, cream coloured and retains its shape when cooked, while the "butter" ackee aril is soft and yellow, losing its shape easily during cooking.

The aril is the edible part of the fruit consumed after the complete removal of the seed and the red membrane to which it is attached. The average ackee pod usually contains three pegs, less frequently two or four pegs, and rarely five pegs (Barnett, 1939). The ripe fleshy ackee arils are widely consumed by Jamaicans, and are one of the national dishes and considered as one of the national symbols in Jamaica.

The unripe fruit contain a water-soluble toxin, hypoglycin A (L-amino-methylene-cyclopropyl-propionic acid) and the less toxic hypoglycin B. The latter compound is the -glutamyl conjugate of hypoglycin A. Unripe ackee fruit also contains glutamate analogous that are carboxycyclopropylglycin compounds (Natalini et al., 2000). To prevent toxicity, the seeds and husk of the fully mature and ripe ackee fruit must be carefully removed and the aril thoroughly washed and cooked before consumption. However, cooking arils of unripe ackee fruits does not destroy the toxins, whereas

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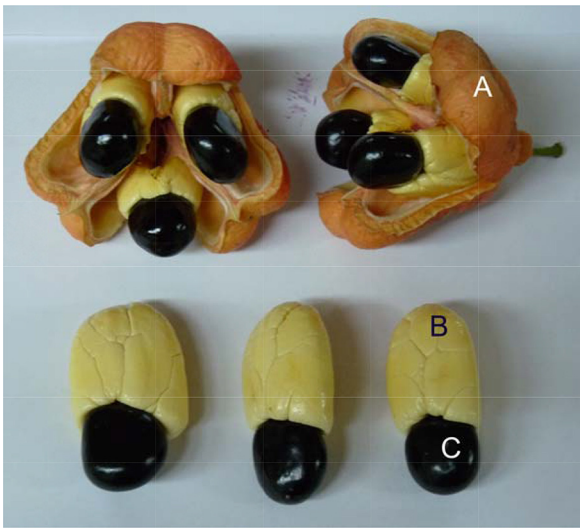

Fig. 1. Fully open and ripe ackee fruit. A: Husk, B: Edible aril, C: Seed.

cooking arils of mature and ripe fruit effectively eliminates the toxicity by leaching hypoglycin A (Golden et al., 1984; McTague and Forney, 1994).

Despite its importance and frequency of consumption in the local and regional diet, there is little data reporting the biochemical composition of ackee fruit during maturation. An extensive literature exists on the toxicity of hypoglycin A (Billington et al., 1978; Sherratt, 1986; Henry et al., 1998; Joskow et al., 2006), and more recently the variation of aril hypoglycin A during different ripening stages has been reported (Bowen-Forbes and Minott, 2011). However, there are no referenced data reporting the physiology and biochemistry of ackee fruit during storage. Moreover, the presence of fructooligosaccharides (FOS) or other secondary compounds such as phenolics have also not been reported.

The ackee fruit arils occupy a large place in regional and even international diets and economies since the product is processed and exported, and the development of the export of this produce as fresh ready-to-use produce is becoming a priority for the fresh crop regional producers and exporters. The aim of this study is to report, and for the first time, the variation in some physiological and biochemical parameters by assessing the variation of the respiration rate, ethylene production, and the biochemical variations of fresh ackee fruit arils stored under three temperature regimes.

2. Materials and methods

2.1. Plant materials

The cheese (hard) variety ackee trees of a single genotype are growing in the Botanical Garden of the University of the West Indies. The experiment was conducted during two successive bearing seasons. The fruit were harvested when fully open from the same trees and during the same period of time (November) (Fig. 1).

2.2. Storage conditions

Immediately after harvest, the arils were carefully removed from the seeds and husk by pulling on the red soft membrane and this separation is easily done, as the fruit is ripe and the red membrane very soft. After their separation, arils were packed in polystyrene boxes. Boxes of 300 g were stored under each temperature regime: $5 \pm 1\,^{\circ}C$, $10 \pm 1\,^{\circ}C$ and $20 \pm 1\,^{\circ}C$, at 90%, 90% and 85% relative humidity, respectively. The respiration rate, ethylene production, colour, and other assessments were done on samples that did not show any defect, and the experiment was run during eight days due the spoilage of samples stored at 20 °C. For sugar analysis, samples were freeze-dried and stored until analysis, while for total phenolic compounds, analyses were run on fresh arils immediately after sampling.

2.3. Respiration rate ($RRCO_2$) assessment

The respiration ($RRCO_2$) was determined by the glass jar technique as described by Benkeblia et al. (2000). Arils (200 ± 10 g) were placed in 2 L glass jars previously equilibrated for 24 h at the required temperatures and stored in temperature-controlled rooms. Jars were initially left open in the cold rooms. At intervals, jars were closed and gas samples were taken at time 0 and after 1, 2, 3, 4, 5 and 6 h. Gas samples were analysed using ICA gas analyser (model ICA250, International Controlled Atmosphere Ltd Instrument Division, Kent, UK). Respiration rates ($RRCO_2$) were calculated by linear regression from CO_2 depletion curves and expressed in mmol kg^{-1} h^{-1}.

2.4. Ethylene production assessment

Ethylene production was determined by the same method described for the respiration rate. Gas samples are analysed using ICA ethylene analyser (model ICA56, International Controlled Atmosphere Ltd Instrument Division, Kent, UK). Ethylene production was calculated by linear regression from ethylene production curves and expressed in nmol kg^{-1} h^{-1}.

2.5. Saccharides and FOS extraction

Saccharides and FOS were extracted by the method described by Shiomi (1993). Briefly, samples (5 g) were homogenized in 50 mL of aqueous ethanol (70%) containing a small amount of calcium carbonate (0.5 g L^{-1}). The homogenate was boiled under reflux in a water bath for 15 min and filtered. The residue was extracted three times with aqueous ethanol and one time with water in the same conditions. The extracts were combined and made up to 300 mL with distilled water. An aliquot of the solution (50 mL) was concentrated to dryness under vacuum at 35 °C using a rotavapour. This dry concentrate was redissolved in 5 mL of water, and an aliquot of 1 mL was filtered through a 0.45 μm filter and analysed by high performance anion exchange chromatography (HPAEC Dionex, Sunnyvale, CA, USA). The remainder (4 mL) was used for total and reducing sugars analysis as described below.

2.6. HPAEC-PAD saccharides and FOS analysis

Saccharides and FOS analyses were carried out as described by Benkeblia and Shiomi (2006). Sugars were separated and analysed by HPAEC-PAD using an ion chromatographer Dionex ICS-3000 (Sunnyvale, CA, USA) with a guard-column CarboPac PA-1 (4 mm × 50 mm) and a column CarboPac-PA100 (4 mm × 250 mm) and pulsed amperometric detector (PAD). The gradient was established by mixing eluent A (150 mM NaOH) with eluent B (500 mM acetate–Na in 150 mM NaOH) in two ways. System I: 0–1 min, 25 mM; 1–2 min, 25–50 mM; 2–20 min, 50–200 mM, 20–22 min, 500 mM; 22–30, 25 mM. System II: 0–1 min, 25 mM; 1–2 min, 25–50 mM; 2–14 min, 50–500 mM, 14–22 min, 500 mM; and 22–30, 25 mM. The established gradient of mixing eluent A with eluent B was: 0–1 min, 95% A–5% B; 1–2 min, 80% A–20% B; 2–20 min, 60% A–40% B; 20–22 min, 100% B, 22–30 min, 95% A–5% B. The flow rate through the column was 1.0 mL min-1. The applied PAD potentials for E1 (500 ms), E2 (100 ms) and E3 (50 ms) were 0.01, 0.60 and −0.60 V, respectively, and the output range was