CARIBBEAN FOOD CROPS SOCIETY

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FRUIT DEVELOPMENT & MODIFIED ATMOSPHERE STORAGE OF BREADFRUIT, *ARTOCARPUS ALTILIS* (PARK.) FOSB.

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ABSTRACT

Developing breadfruit reach maturity some 15-20 weeks after the female inflorescence is first detectable on the tree. The first half of this developmental period is characterised by size increase while the latter phase involves the laying down of starch reserves and increases in dry weight. The respiratory climacteric of harvested breadfruit parallels the softening of the fruit and peaks at 200 ml CO_2 kg^{-1} h^{-1}. Peak ethylene production is lower (1.5 μl C_2H_4 kg^{-1} h^{-1}) than would be anticipated from such high respiratory rates, nonetheless, fruit are highly sensitive to ethylene. Attempts at Modified Atmosphere Storage using a wide range of coatings and plastic films have shown that breadfruit can be successfully stored at ambient for up to 3 weeks in polyethylene bags without ill effects. Such successful treatments were characterised by CO_2 levels of about 10% (v/v) and O_2 levels of 5-8 % (v/v) in the bags.

INTRODUCTION

Breadfruit, *Artocarpus altilis* (Park.) Fosb., is a common backyard tree in the Caribbean, noteworthy because this year we celebrate the 200th anniversary of the introduction of this crop to the Caribbean from Tahiti (Howard, 1953). Several cultivars are recognised throughout the Caribbean (Andrews, 1991) and over a hundred are known in the Pacific (Ragone, 1989). In Barbados, a single "white flesh" cultivar predominates which, following exchange of herbarium material with the National Tropical Botanical Garden, Hawaii, has been recognised as synonymous with the Tahiti cv. "rare" (Ragone, 1993).

The importance of breadfruit as an export crop for the ethnic market in North America and Europe is growing steadily (Andrews, 1991) but this commercialisation is hampered by our limited knowledge of the fruit's development and its extreme perishability. In this study we characterise fruit development and ripening and investigate the potential of Modified Atmosphere Storage (MAS) to extend shelf life.

MATERIALS & METHODS

Developing fruit were identified on mature breadfruit trees by fingering the terminal leaf sheath, confirming the presence of female inflorescences/fruit at a size of 1-2 cm in diameter and tagging these branches. Diameters of developing fruit were measured and batches of 6 fruit harvested fortnightly for dry and fresh weight determination. Chlorophyll levels were measured in triplicate fruit of known age using batches 10 peel discs from each (Porra *et al.*, 1989). Starch levels were obtained by isolating alcohol insoluble solids (AIS) from fresh fruit pulp and measuring the generation of reducing groups following amyloglucosidase treatment (Denison *et al.*, 1990).

Carefully harvested mature fruit (with surface latex and fully expanded surface polygons) were placed in 25-L plastic bell-jars at room temperature (25-30°C) and ventilated with humidified air (_1.5 $L.min^{-1}$), the exit flow entering a 225-MK3 infra-red gas analyser (ADC Ltd, Hoddesdon, U.K.) via a WA-161 multi-channel switching unit (ADC Ltd., Hoddesdon, U.K.). Linkage to a microcomputer allowed automatic half-hourly data logging. Ethylene production was monitored twice daily in the same fruit by temporarily reducing the flow-rate to 0.18 $L.min^{-1}$ and injecting a 1 ml air sample from the exit air stream into a Photovac gas chromatograph (Photovac Inc., Ontario, Canada). Both instruments were calibrated with appropriate certified standards (Matheson Gas Products, NJ, U.S.A). Fruit were assessed visually for the % area showing skin discolouration. Fruit softening was assessed by finger pressure (1 = fully firm, 2 = spongey, 3 = soft).

Replicates of 8 fruits were brush-coated with several commercial coatings, viz. Semperfresh (Semperfresh Biotechnology Ltd., Reading, U.K.), Nutri-Save (NovaChem, Halifax, Canada), Sta-Fresh MP (FMC Corp., Lakeland, FL, U.S.A) and a "homemade" chitosan coating (Ghaouth *et al.*, 1990). Fruit were also heat-sealed in a range of films ; - high density polyethylene (HDPE) and low density polyethylene (LDPE) (Superior Plastic, Barbados), Clysar LLP & EHC (DuPont, Willmington, DE, U.S.A) and Sealed Fresh 1.5 MIL (Sealed Fresh Inc., Englewood, CO, U.S.A). Fruit were either stored at ambient or in large incubators at 13°C and monitored for firmness and discoloration. In further experiments, a $1^{1/2}$" 22g hypodermic needle was stuck into each control, coated or bagged fruit and a 5 ml syringe without plunger but capped by a sub-seal attached to this. The gas building up in this syringe chamber was sampled daily, CO_2 and C_2H_4 being measured as described above and O_2 measured using a GowMac oxygen meter (GowMac Instruments, Gillingham, Kent, U.K.).

RESULTS & DISCUSSION

Fruit growth in breadfruit represents a single sigmoidal curve with equatorial and polar diameters reaching a maximum some 14 weeks after the globular female inflorescence is first detectable (fig.1A). Contrasting with this early, rapid size generation dry weight and fresh weight increases lag somewhat and appear to be double sigmoidal curves (fig.1B). Only after the rapid size increase of the first 10 weeks is complete, does the fruit begin to dramatically increase its dry weight, starch representing some 60% of AIS, a figure comparable with published starch values for breadfruit flour (Graham & De Bravo, 1981). The transient cessation of growth half way through development (fig.1B) seems characteristic of the fruit and was evident in a second batch of fruit monitored under different environmental conditions.

Such characterisation of fruit development is a first step in establishing maturity indices. The skin peel is initially a light green colour, darkens and then finally pales, and this is confirmed by assay of chlorophyll levels (fig.1C) as well as by comparison with the Munsell Book of Colour 5GY colour chart. Folk tradition holds that breadfruit are mature when drops of latex are evident on the fruit surface and this can occur on fruit as young as 14 weeks old. Taste tests revealed that fruit acceptable as mature range in age from 15-19 weeks old. This correlates well with the starch accumulation profile of the fruit. Fully mature fruit not only bear surface latex but show a flattening of each initially domed, polygonal segment and the disappearance of the once prominent, tiny protuberance at the centre of each segment. All of these parameters need to be considered in assessing maturity.

Fruit ripening is evidenced by a dramatic, rapid softening of the fruit and once this has begun the fruit is no longer fit for consumption At ambient temperatures of 25-30°C, breadfruit, even at optimal maturity, begins to soften 2-4 days after harvest. As shown previously (Thompson *et al.*, 1974; Maharaj & Sankat, 1990), refrigeration retards the onset of ripening considerably, 12°C being the minimum acceptable temperature if chilling injury is to be avoided. Breadfruit is a climacteric fruit with one of the highest known respiratory rates (Biale & Barcus, 1970) and the peak of $C0_2$ production coincides with softening and peak C_2H_4 production (fig. 2). Despite these high respiratory rates its peak C_2H_4 production of 1.5μl1 kg^{-1} h^{-1} is relatively low and the fruit is quite sensitive to C_2H_4. We have found exposure of mature breadfruit to as little as 5 ppm C_2H_4 for 3h to be deleterious (data not shown).

While refrigeration at 13°C clearly delays the onset of ripening, the skin of fruit stored in this manner soon turns an unsightly brown colour. Attempts to control this with anti-oxidants and polyphenol oxidase inhibitors like diethyldithiocarbamate were unsuccessful. One traditional short term storage method for breadfruit in the Caribbean is to keep them submerged in water. In fact, when this is carried out at 13°C such fruit retain their fresh green skin without discoloration for 2-3 weeks. Skin browning therefore seems to be a water loss problem

A range of fruit coatings were assessed for their role in enhancing storage life at 13°C. Of these, Nutrisave, Semperfresh and chitosan delayed softening while StaFresh MP did not delay softening but reduced skin browning and water loss (data not shown). Internally, however, these coated fruit were often discoloured with soft areas and off odours.

In contrast, film wrapping of fruit delayed ripening and skin browning both at ambient and at 13°C. By 12 days at 13°C, unwrapped fruit had completely softened and were fully brown. In contrast, under the same conditions fruit wrapped in most of the films showed little skin discoloration and did not soften. Unfortunately, taste tests on fruit wrapped in plastic films and stored at 13°C reveal an undesirable sweetness and for some films off-flavours with increasing storage time.

Surprisingly, some films at ambient temperatures were particularly effective at preventing softening as well as skin discolouration, notably the thinnest (25μm & 30μm) low and high density polyethylene Films and Sealed Fresh 1.5 MIL (fig. 3). Preliminary taste tests rated such fruit highly and it therefore seemed important to try to investigate the gas atmospheres developing within these fruit. All film-sealed fruit showed reduced intemal O_2 levels cornpared to control unbagged fruit but the successful films maintained the highest O_2 levels of these (fig.4), of the order of 4-8%. Compared to control fruit, bagged fruit showed elevated CO_2 levels but internal CO_2 was lowest in the 3 films referred to above (fig.4), of the order of 5-15%. Ethylene levels level did not correlate with ripening behaviour (Fig 4) While preliminary, these results go some way in explaining the efficacy of the thin polyethylene films and the Sealed Fresh film, viz. that they maintain adequate oxygenation while preventing excessive CO_2 accumulation. Further work is in progress but the possibility of transporting this commodity by sea freight, as against the more costly air freight, begins to seem a real possibility .

ACKNOWLEDGEMENTS

This research was supported under Grant No. 534-0936-G-00-9117, Program in Science & Technology Cooperation, Office of the Science Advisor, U. S. Agency for Intemational Development. We are also grateful to Dr. S. New, TROPRO, Barbados, for his continued interest and guidance.

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