

The post-harvest ripening of three plantain cultivars (*Musa* spp., AAB group).

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THE POST-HARVEST RIPENING OF THREE PLANTAIN CULTIVARS (*MUSA* SPP., AAB GROUP).

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Fruits, Mar.-Apr. 1991, vol. 46, n° 2, p. 137-143.

ABSTRACT - The post-harvest changes in the fruit from three plantain cultivars (*Musa* spp., AAB group) were examined with respect to the rate of ripening, weight loss, pulp texture and the distribution of starch. The cultivars examined included a French plantain (Obino L'Ewai), a False Horn plantain (Agbagba) and a Horn plantain (Ubok Iba). The rates at which the cultivars ripened differed, with Obino L'Ewai ripening quickest and Agbagba slowest. The weight loss after 11 days in Obino L'Ewai was significantly more than either Agbagba or Ubok Iba. Also, the stomatal density of Obino L'Ewai was significantly higher than either Agbagba or Ubok Iba. Differences were detected between the cultivars in both the timing and degree of pulp softening, which occurred earliest in Agbagba and progressed least in Ubok Iba. In all cultivars the failure to stain for starch was first noticeable in the locular tissues although the stage of ripeness when the locular starch disappeared varied from yellow in Obino L'Ewai to nearly black in Agbagba and Ubok Iba.

INTRODUCTION

Plantain (*Musa* spp., AAB group ; STOVER and SIMMONDS, 1987) is an important staple food in Central and West Africa which, along with other bananas, provides approximately 60 million people with one quarter of their calories (WILSON, 1987). The fruit are harvested at the green ripe stage of maturity and cooked prior to consumption, the method of cooking depending on the stage of ripeness (MARRIOTT and LANCASTER, 1983). Compared to the extensive work on dessert bananas (*Musa* spp., AAA group) there has been relatively little research done on the physiological changes occurring during plantain fruit development. The recent spread of Black Sigatoka disease

EVOLUTION APRES RECOLTE DE TROIS CULTIVARS DE PLANTAIN (*MUSA* SPP. GROUPE AAB).

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RESUME - Etude, chez trois cultivars de plantain, de l'évolution du fruit après la récolte sous les aspects suivants : degré de mûrissement, perte de poids, texture de la pulpe et répartition de l'amidon. Les cultivars comprenaient un French plantain (Obino l'Ewai), un False Horn (Agbagba) et un Horn (Ubok Iba) ; la maturation diffère selon les cas ; elle est plus rapide chez Obino l'Ewai et plus lente pour l'Agbagba. La perte de poids après 11 jours était plus significative chez le premier ; on enregistre des différences en ce qui concerne tant l'évolution que l'intensité de ramollissement de la pulpe ; celui-ci survient plus rapidement chez Ubok Iba. Dans tous les cas l'absence de réponse au test à l'iode (identification de l'amidon) est observée en premier lieu dans les tissus loculaires alors que la peau de Obino l'Ewai est jaune et celle des deux autres cultivars noire.

caused by *Mycosphaerella fijiensis* in Central and West Africa, to which plantain is susceptible, has increased interest in plantain. The disease attacks the leaves reducing the photosynthetic area and may reduce the yield of infected plants by 30-50% (STOVER, 1983). An initial survey suggests that, when presented cooked in a traditional manner, cooking bananas (*Musa* spp., ABB group) which may be less susceptible to Black Sigatoka, may provide an acceptable alternative to the more susceptible plantains (HAHN *et al.*, 1989). There is however a need for more basic information on the desirable ripening and post-harvest qualities which potential alternatives must possess.

The rate at which plantains ripen is accelerated by moisture loss and ripening may be retarded by maintaining fruit in an atmosphere of high humidity (THOMPSON *et al.*, 1972, 1974 ; GEORGE and MARRIOTT, 1982). The effect of water stress involves an ethylene mediated reduction in the preclimacteric period (GEORGE *and all.*, 1983). The rate of moisture loss from the fruit may be a reflection of the amount of wax on the fruit surface and the numbers and functionality of stomata. A study by FREEMAN and

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TURNER in 1985 showed that fruits of *Musa* spp. AA and AAA groups have less surface wax than fruit from either *Musa* spp. BB or ABB groups. Banana (*Musa* spp. AAA group) fruit stomata were demonstrated to be functional even after severance of the fruit from the plant, the speed of response being dependent mainly on humidity with light acting as a trigger for opening and darkness for closing (JOHNSON and BRUN, 1966).

The rate at which plantains ripen is significant in determining how long the fruit remains useable for specific methods of cooking. The selection of cultivars which remain green for a long time after harvest, or ripen only slowly, would facilitate marketing the fruit and reduce post-harvest losses. In this study the rate of ripening of three cultivars of plantain were examined by measuring changes in weight loss, peel coloration, pulp texture and the response to staining for starch. The stomatal density of each cultivar was also examined.

METHODS AND MATERIALS

Fruit were grown at the International Institute of Tropical Agriculture high rainfall station at Onne, Rivers State, Nigeria. The fruits were collected at normal harvest maturity as judged mainly by the fruit filling (SANCHEZ-NIEVA *et al.*, 1968). Three cultivars were examined : Obino L'Ewai (a French plantain), Agbagba (a False Horn plantain) and Ubok Iba (a Horn plantain). These are representatives of the three broad categories of plantain based on their bunch characteristics. The French type have numerous small fruit per bunch, the Horn have fewer large fruit with the False Horn being intermediate (SWEN-NEN and VUYLSTEKE, 1987).

Forty fruits of each cultivar were sent to the International Institute of Tropical Agriculture at Ibadan, Nigeria, where immediately on arrival (within 24 hours) they were split into fingers and the cut pedicels sealed with a low melting point wax. The fruit of each cultivar were divided randomly into two groups of 20 fruits and allowed to ripen in the laboratory at $27 \pm 1^\circ\text{C}$. In one group the changes in peel colour were scored visually and the fresh weight of individual fruit was measured daily. After 11 days the weight loss data of the three cultivars was analysed for differences by analysis of variance. The stages used in peel assessment were essentially those outlined by LANCASTER and MARRIOTT (1983), modified to accommodate the slightly different ripening of plantain compared to dessert bananas. The stages recognised were : 1, green ; 2, tinge of yellow ; 3, more green than yellow ; 4, more yellow than green ; 5, tinge of green ; 6, yellow ; 7, 20-50% surface brown and 8, 60-90% surface brown.

The second group of 20 fruits were used for destructive testing at each of the stages outlined above. At each stage of ripening two fruits were removed for each cultivar and the pulp and peel fresh weights determined to give the pulp : peel ratio. A 5mm disc was removed transversally from the centre of each fruit and one of the cut surfaces stained for starch with iodine/potassium iodide (0.2/2.0%). A 2cm long cylinder (2cm diameter) was then taken parallel to the long axis of the fruit from the cut ends of the two remaining pieces of each fruit for compression analysis (Model T-2100CI Texture Test System from Food Techno-

logy Corporation, Rockville, Maryland, USA) to give a measure of pulp hardness.

Stomatal density was determined by taking surface imprints from the mid region of the fruit at the green stage using nail varnish (HILU and RANDALL, 1984). These strips were then examined under the microscope to determine stomatal density. For each cultivar surface imprints from 10 areas (each of 1.5mm^2) from each of three fruits were counted and the scores averaged. Differences between cultivars were analysed by analysis of variance.

RESULTS

All three cultivars lost weight continuously over the period examined (Fig. 1), although the rate of weight loss differed between the cultivars. The French plantain Obino L'Ewai (average fresh weight of 93.9 g per finger) had the highest rate of weight loss at 3.13% per day compared to the False Horn plantain Agbagba (average fresh weight of 180.5g per finger) at 2.36% per day and the Horn plantain Ubok Iba (average fresh weight of 256.8g per finger) at 2.42% per day. After 11 days the weight loss in Obino L'Ewai was significantly ($P < 0.001$) greater than that of Ubok Iba and Agbagba (by analysis of variance). The latter two cultivars were not significantly different. Within each cultivar no trend could be identified relating fruit size to weight loss although the Obino L'Ewai fruit ranged between 84g and 110g, Agbagba between 144g and 244g and Ubok Iba between 200g and 334g.

The stomatal densities of green fruit were found to differ between cultivars. There was a significantly higher ($P < 0.001$) density of stomata on Obino L'Ewai (405cm^{-2}) than either Agbagba (330cm^{-2}) or Ubok Iba (332cm^{-2}). The surface topography of the cultivars also differed as shown by the surface imprints (Plate 1). The imprints from Agbagba show numerous raised areas on the surface of the fruit which are not present in Ubok Iba and less prevalent in Obino L'Ewai.

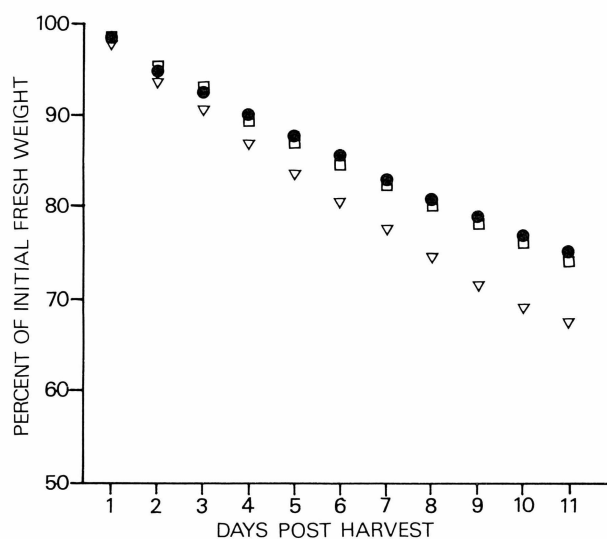


Fig. 1 • Loss of fresh weight during the ripening of fruit of the three plantain cultivars Obino l'Ewai (▽), Ubok Iba (□) and Agbagba (●). Each point is the average of 20 fruit weighed individually.

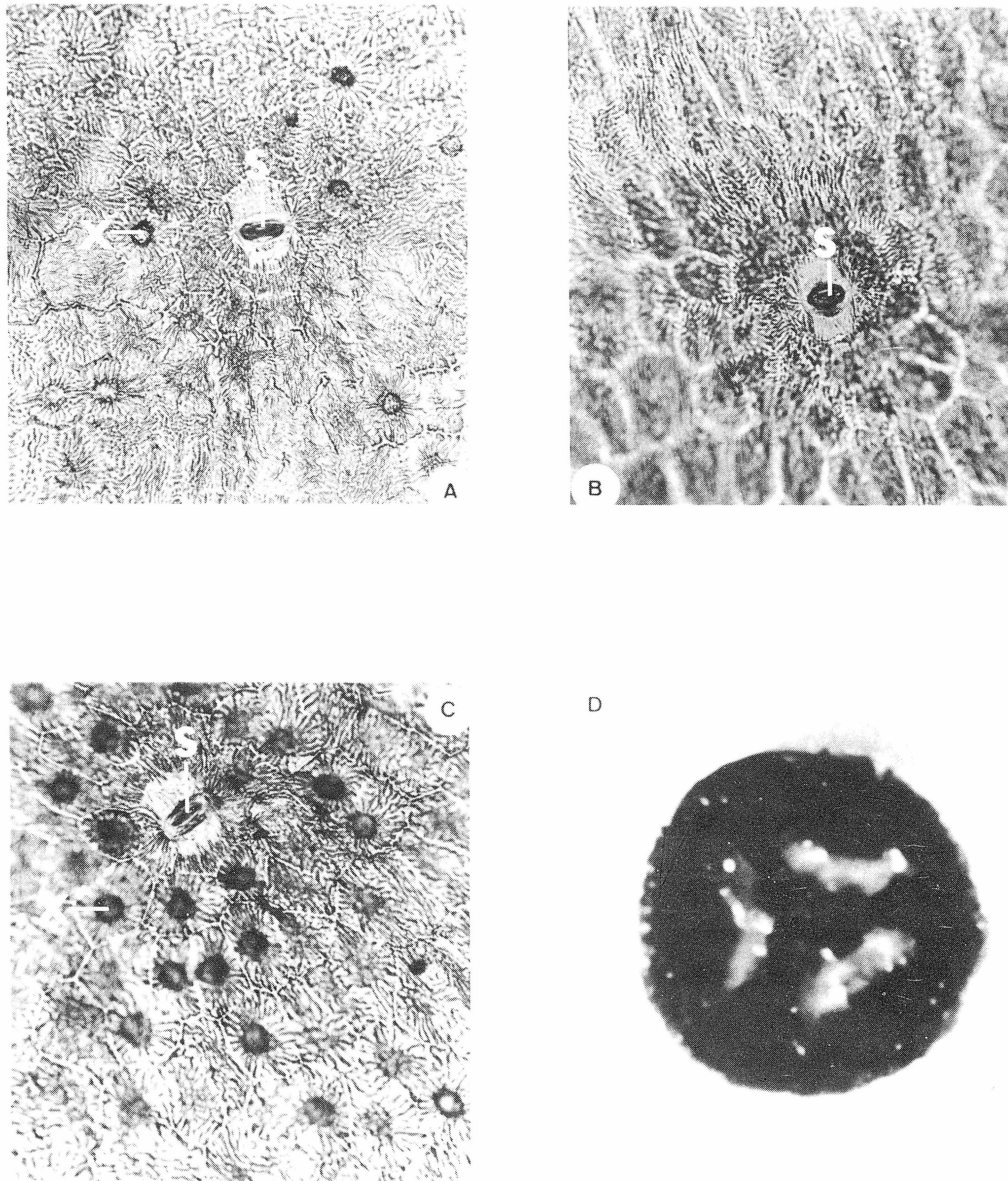


Plate 1 - Surface imprints of the peel around a stomate (S) showing raised areas (X). Taken from the mid-region of fruit of the cultivars A) Obino L'Ewai, B) Ubok Iba and C) Agbagba, D) Starch stained section of pulp from Obino L'Ewai at ripeness stage 8, (magnification approximately x 2).

The three cultivars moved through the ripening stages at different rates (Fig. 2). The Obino L'Ewai fruits ripened rapidly and in unison with all fruits reaching the full yellow stage after 8 days. The other two cultivars ripened over a longer period of time, and in neither had all the fruits reached the full yellow stage within the period of examination. The length of the green life also differed. The fruits of Obino L'Ewai had all progressed past the green stage by day 3 whereas Agbagba had green fruits up to day 8 and Ubok Iba up to day 11.

The resistance of the fruit pulp to compression decreased as ripening progressed in all cultivars (Fig. 3). In Obino L'Ewai and Ubok Iba the major decrease occurred between stages 5 and 6 whereas in Agbagba it took place between stages 4 and 5. There appears to be a slight firming of the

fruit pulp between stages 1 and 2 or 3 preceding the rapid decline in resistance. The degree of softening differed between the cultivars with Obino L'Ewai and Agbagba falling to a minimum resistance of approximately 30 N and Ubok Iba only decreasing to approximately 60 N. In immature fruit the maximum resistance to compression was measured as the point just before shearing of the tissue occurred producing a characteristic fracture plane (PELEG and GOMEZ-BRITO, 1977). In more mature fruits there was a greater degree of deformation and spreading of the base of the pulp cylinder during compression, with no shearing.

In all cultivars the pulp:peel ratio increased with ripening (Fig. 3). Slight differences existed between cultivars, the ratio increasing from 1.46 to 4.08 in Obino

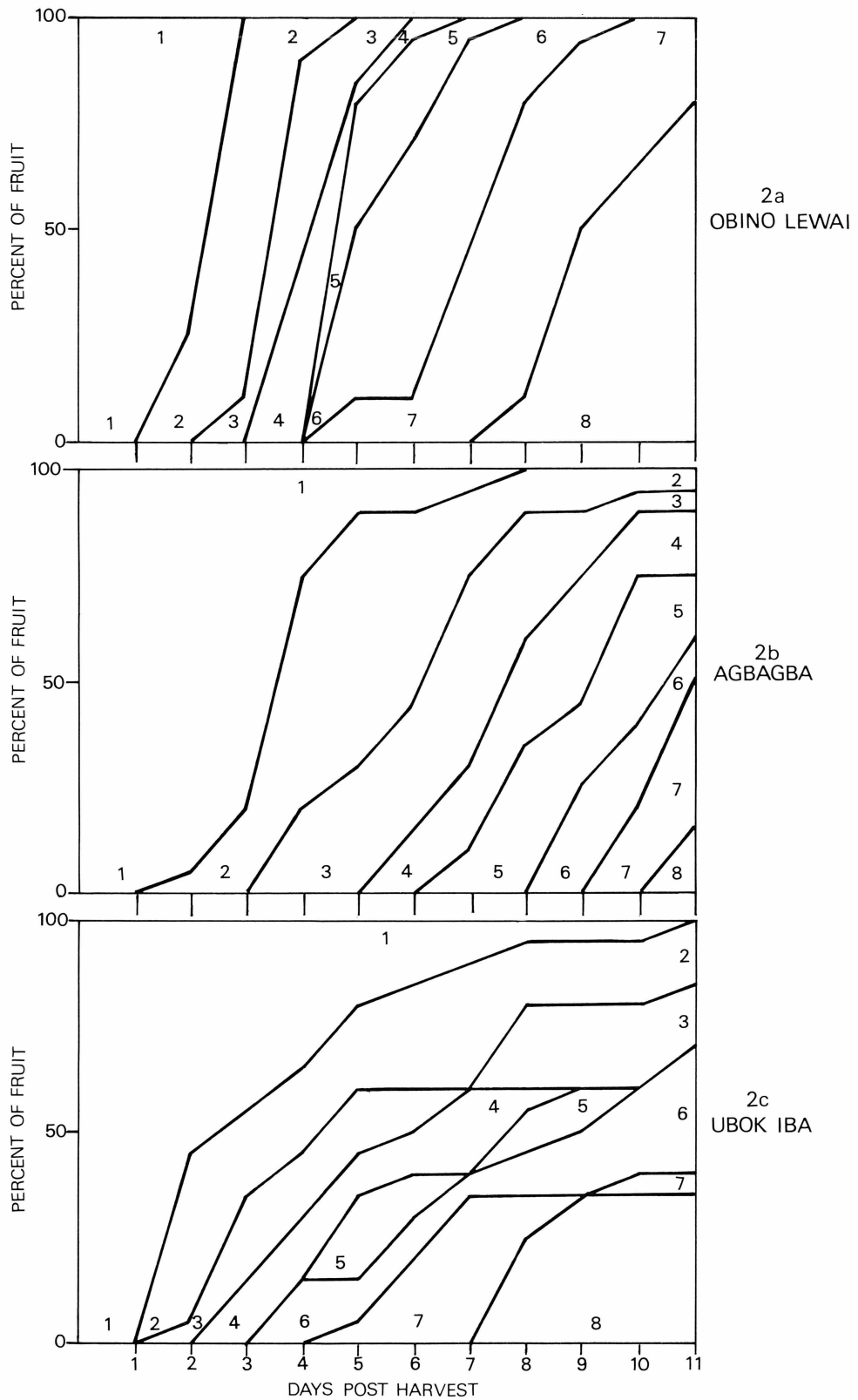


Fig. 2 a,b,c • Ripening of 20 individual fruit of Obino l'Ewai (a), Agbaga (b) and Ubok Iba (c). The stages of ripeness are : 1, green ; 2, tinge of yellow ; 3, more green than yellow ; 4, more yellow than green ; 5, tinge of green ; 6, yellow ; 7, 20-50% brown ; 8, 60-90% brown.

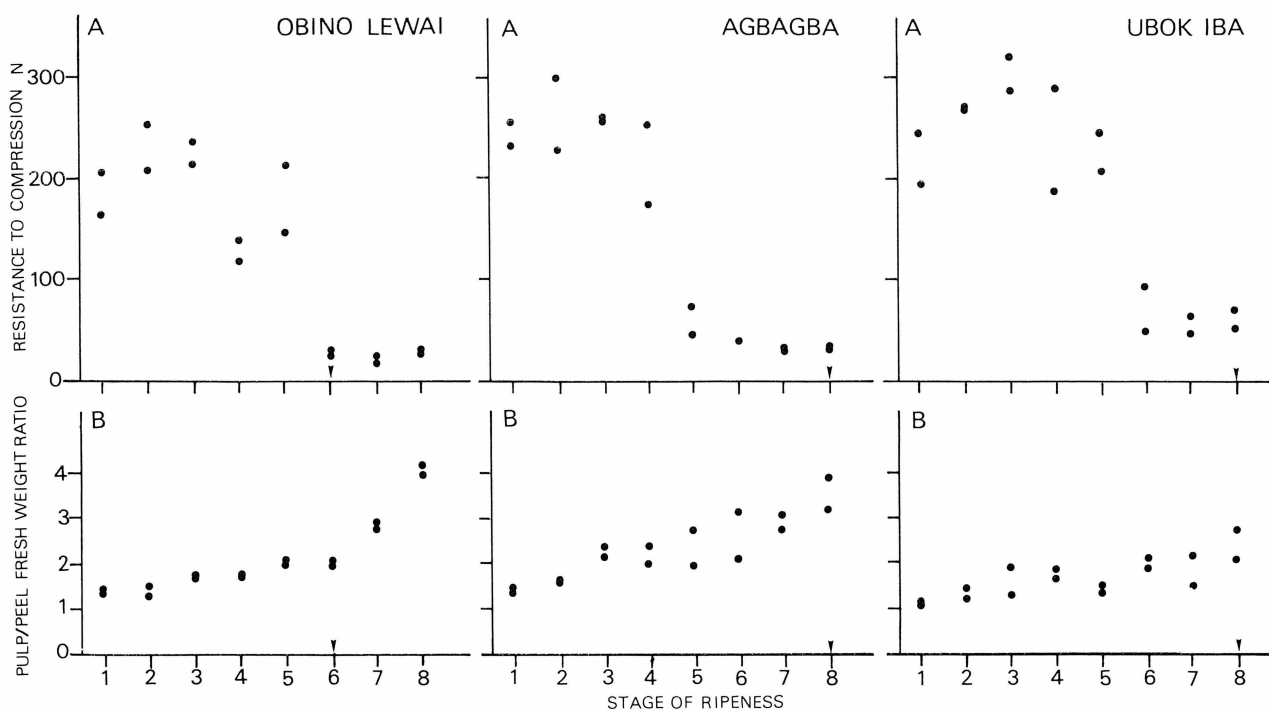


Fig. 3 • Resistance to compression (A) and pulp to peel ratio (B) of individual fruit at the eight stages of ripeness (see fig 2). Arrow indicates the stage of ripeness at which a lack of iodine staining was first noticeable in the locular tissue.

L'Ewai, from 1.41 to 3.49 in Agbagba and from 1.09 to 2.44 in Ubok Iba. There was a gradual increase in the ratio during ripening in all cultivars although in Obino L'Ewai there was also a rapid increase during the development of peel browning.

After staining with iodine/potassium iodide solution all cultivars showed an intense uniform staining of the whole cross section of the fruit while the peel remained green. The first visible signs of a failure to stain for starch occurred in the locules next to the degenerate seeds (Plate 1 D). In later stages of ripeness the area failing to stain increased in size but remained within the locules. In Obino L'Ewai the first signs of a lack of staining occurred when the fruit were yellow (stage 6). In Ubok Iba and Agbagba this change did not become noticeable until the fruit were almost totally brown (stage 8).

DISCUSSION

The three cultivars examined clearly show differences in their post-harvest ripening. Compared to Obino L'Ewai the Agbagba fruit showed up to four days longer green life. Once the first change from green had occurred, however, the progress of ripening appeared to be at the same rate as Obino L'Ewai. The rate of ripening of Agbagba was similar to that of an unnamed plantain cultivar described by ASIEDU (1987). The ripening of Ubok Iba was protracted with both green and half brown fruit present at day 9. This was probably the result of the sample being composed of more than one bunch. Ubok Iba is a Horn plantain producing relatively few large fruit per bunch and hence more than one bunch is required to provide the required sample

size. The degree of variation between fruit of Ubok Iba and between cultivars is to some extent a reflection of the lack of an accurate method of assessing harvest maturity of plantain. The time of harvesting is determined subjectively, mainly by the shape of the fruit (angularity or degree of filling, SANCHEZ-NIEVA *et al.*, 1968) and factors such as the drying of the floral remains. There is no guarantee that the pulp of different cultivars will be at the same stage of development using these criteria, and they may not be applied uniformly by different workers.

As might have been expected, Obino L'Ewai (large surface area to volume ratio) lost weight most rapidly as a percentage of the initial fresh weight. However, despite the size difference between Ubok Iba and Agbagba there was no difference between their rates of weight loss and similarly the differences in the weight loss of individual fruit could not be attributed to differences in their size. The average rates of weight loss measured in this study (2.36-3.13% per day) are higher than reported elsewhere (THOMPSON *et al.*, 1972). This is probably a result of the fruit being kept in a laboratory with some degree of air conditioning, and thus reduced humidity, whilst other workers have maintained fruit at high humidities.

The results of ASIEDU (1987) showed that the weight loss of plantain results mainly from the loss of water from the peel. The peel loses water both by transpiration to the atmosphere and also to the developing pulp by osmosis (STOVER and SIMMONDS, 1987), thereby contributing to an increase in the fresh weight of the pulp as the fruit ripens (ASIEDU, 1987). This results in an increase in the pulp:peel ratio during ripening. The pulp:peel ratios for the three cultivars examined in this paper of between

1.5 and 4.0, depending on cultivar and stage of ripeness, are in broad agreement with those published elsewhere (SANCHEZ-NIEVA *et al.*, 1970 ; ASIEDU, 1987).

Obino L'Ewai had significantly higher stomatal densities than either Agbagba or Ubok Iba. This may in part account for the result that Obino L'Ewai lost weight more rapidly than the other two cultivars. In dessert bananas the stomata are considered to be the major route for gaseous exchange (BANKS, 1984) and are still functional after the severance of the fruit from the parent plant (JOHNSON and BRUN, 1966). The stomatal densities recorded here for plantain are similar to those reported by COLLIN and FOLLIOT (1990) and for the dessert banana Valery (JOHNSON and BRUN, 1966). A report by WILLIAMS *et al.* (1989) showed that the stomata of different *Musa* cultivars differ markedly with some being located in pits and others surrounded by papillae. Some differences were noted between the plantain cultivars examined, the raised areas which were so prevalent on the surface of Agbagba being absent from Ubok Iba and less frequent in Obino L'Ewai.

In general the conversion of starch to sugars in plantains is less complete than in dessert bananas and varies between cultivars (MARRIOTT *et al.*, 1981). The starch content of the fruit pulp is generally measured as an average of the total pulp disregarding the different tissues present. The localised total depletion of starch from the locule tissue may contribute significantly to the variable starch values quoted by other workers for different cultivars at the same apparent physiological age. The total loss of starch from areas of the locule commencing at the degenerate ovules has been observed before in dessert bananas (GARCIA and LAJOLO, 1988). The significance of a differential rate of starch degradation in a distinct region of cells in

the pulp was not commented on, the change merely being described as occurring in the inner pulp. The distinctive nature of the cells of the locule has been described by RAM *et al.*, (1962). The cells are elongated and are the result of an inward growth of chains of loosely packed cells into the ovarian cavity commencing from the tissues of the pericarp which border the locule.

Differences between the cultivars could be detected in the coordination of changes in starch degradation, texture and ripeness (judged by peel colour or pulp : peel ratio). In Obino L'Ewai the initial visible change in starch staining coincided with the major decrease in resistance to compression at stage 6. In Agbagba and Ubok Iba however the change in starch staining was only visible at stage 8 whereas the major decrease in texture occurred at stage 6 in Ubok Iba and at stage 5 in Agbagba. These differences suggest that there may be considerable variation between plantain cultivars in the timing of the changes in texture and starch breakdown. Both these factors are important in determining the acceptability of plantains since they are consumed as a source of carbohydrate and their use requires a firm texture to be retained during cooking. Differences in the timing of the changes in peel coloration and pulp softening may also provide a means of identifying fruit with a greater post-harvest potential.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the assistance of Drs HAHN, SWENNEN and EGGLESTON of The International Institute of Tropical Agriculture, Nigeria, and the provision of facilities by The Institute during this research.

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EVOLUCION DESPUES DE COSECHA DE TRES CULTIVARES
DE PLATANO (*MUSA* SPP. GRUPO AAB).

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Fruits, Mar.-Apr. 1991, vol. 46, n° 2, p. 137-143.

RESUMEN - Estudio en tres cultivares de plátano, de la evolución de la fruta después de la cosecha bajo los aspectos siguientes : grado de madurez, pérdida de peso, textura de la pulpa y repartición del almidón. Los cultivares comprendían un French plantain Obino el Ewai), un False Horn (Agbagba) y un Horn (Ubok Iba) ; la maduración difiere según el caso ; la misma es más rápida en Obino el Ewai y más lenta para el Agbagba. La pérdida de peso después de 11 días era más significativa en el primero ; se registraron diferencias en lo que concierne tanto a la evolución como a la intensidad del reblandecimiento de la pulpa ; este apece más rápidamente en Ubok Iba. En todos los casos la ausencia de respuesta al test del yodo (identificación del almidón) es observada en primer lugar en los tejidos locales, mientras que la cascara del Obino el Ewai es amarilla la de los otros dos cultivares es negra.

