The effects of morphology, maturity and cultivar on the ripening and susceptibility of plantains (AAB) to mechanical damage

RSB Ferris
Plantain and Banana Improvement Programme
International Institute of Tropical Agriculture
Oyo Road, PMB 5320
Ibadan, Nigeria

H Wainwright
Natural Resources Institute
Chatham Maritime, Chatham
Kent, ME4 4TB
United Kingdom

AK Thompson
Department of Postharvest Technology
Silsoe College, Cranfield Institute of Technology
Silsoe, Bedfordshire
MK45 4DT
United Kingdom

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ABSTRACT
Plantain (*Musa* AAB) is an important staple food crop grown in the lowland humid tropics of sub-sahara Africa. Marketing surveys in Ghana and Nigeria indicate that levels of plantain losses can range from 20 to 80% during transportation and retailing. Mechanical damage, which promotes early ripening, is considered to be a major factor contributing towards these losses. This study investigated the response of three plantain cultivars, Ubok Iba (True Horn), Agbagba (False Horn) and Obino l'Ewai (French plantain), at two harvest maturities (fully mature and immature), to impaction, abrasion and incision damage. The effect of damage on plantain indicated differences in cultivar response and suggested that ripening was accelerated by different mechanisms of climacteric initiation.

KEYWORDS
Plantains, postharvest losses, damage, ripening, weight losses, varieties, maturity, agronomic characters.

Influence de la morphologie, de la maturité et du cultivar sur le mûrissement de la banane plantain et sur sa sensibilité aux dégâts mécaniques.

RÉSUMÉ
La banane plantain (*Musa* AAB) est une culture alimentaire de base dans les plaines des régions tropicales humides de l'Afrique sub-saharienne. Des enquêtes effectuées au Ghana et au Nigéria montrent que 20 à 80% de la production peut être perdue lors du transport et de la vente des fruits. Certains dégâts mécaniques semblent être à l'origine de ces pertes. Les recherches présentées ont comparé les conséquences d'accidents mécaniques (chocs, frottements ou entailles), subis par des bananes plantains de trois cultivars (Obino l'Ewai, French plantain ; Ubok Iba, Vrai Corne ; Agbagba, Faux Corne), récoltées à deux stades de maturité (fruits entièrement matures et immatures) sur leur mûrissement. Les dommages ont été différents selon le cultivar étudié et suggèrent que le mûrissement a été accéléré par différents mécanismes qui amorcent la période climactérique.

MOTS CLÉS
Banane plantain, perte après récolte, dégâts, mûrissage, perte de poids, variété, maturité, caractère agronomique.

Influencia de la morfología, de la madurez y del cultivar sobre el maduramiento del plátano y sobre su sensibilidad a los daños mecánicos.

RESUMEN
El plátano (*Musa* AAB) es un cultivo alimentario de base en las llanuras de las regiones tropicales húmedas del'Africa sur-saharian. Unas encuestas efectuadas en Ghana y en Nigeria muestran que 20 a 80 % de la producción se puede perder durante el transporte y la venta de las frutas. Algunos daños mecánicos parecen ser la causa de estas pérdidas. Las investigaciones presentadas han comparado las consecuencias de accidentes mecánicos (choques, rozamientos o cortaduras), sufridos por plátanos de tres cultivares (Obino l'Ewai, French plantain ; Ubok Iba, Vrai Corne ; Agbagba, Faux Corne), cosechados en dos fases de madurez (frutas completamente maduras e inmaduras), sobre su maduramiento. Los daños tuvieron efectos diferentes según el cultivar estudiado y sugieren que el maduramiento fue acelerado por diferentes mecanismos que inician el período climactérico.

PALABRAS CLAVES
Plátano, pérdidas postcosecha, maduramiento, pérdida de peso, variedades, madurez, daños, características agronómicas.

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introduction

Plantain (*Musa* AAB) is a major staple food grown throughout the humid lowland tropics. In sub-Saharan Africa, plantain provides up to 25% of the carbohydrate intake for more than 70 million people. In addition to being a staple food for rural and urban consumers, plantains are also an important cash crop for smallholders (WILSON, 1987).

The supply of plantain is now threatened throughout Africa by the presence of the leaf streak disease, black sigatoka, caused by the fungal agent, *Mycosphaerella fijiensis* Morelet. In the last 15 years, black sigatoka has spread rapidly throughout Central and West Africa reducing plantain yields by 30-50%, (MOBAMBO *et al*, 1993). All plantains tested to date, are susceptible to black sigatoka and resource poor farmers cannot afford fungicides to control this disease. To ameliorate the effects of black sigatoka, improvement programmes throughout the tropics are using a combination of crossbreeding and biotechnology to develop black sigatoka resistant plantain hybrids. However, in order for breeding programmes to develop acceptable cultivars, there is also a need to identify and select for desirable postharvest characteristics of plantains. One such characteristic is tolerance to damage which may reduce loss during transportation and increase the marketing period.

Statistics suggest plantain losses can range from 20 to 80% during traditional African marketing (FAO, 1977; OLORUNDA and AWORH, 1984). Studies conducted in Ghana by THOMPSON *et al* (1972) and KARIKARI *et al* (1988) suggest that damage, inflicted during the handling and marketing of plantain, is a major factor causing early ripening which leads to market loss. This study investigated the response of three plantain cultivars to specific types of mechanical damage on fruits harvested at two stages of maturity. The damage treatments simulated the types of damage observed during traditional retailing and marketing in Ghana and Nigeria.

materials and methods

This study was conducted at Onne high rainfall station, IITA (International Institute for Tropical Agriculture), Nigeria. The experiment was conducted at ambient conditions, the temperature and humidity recorded onto a data logger (Delta T Devices Ltd, Cambridge, UK). Average temperature was 28°C and average relative humidity was 89% RH. Fruit of three cultivars, representative of three main bunch types grown in the region, *viz* Ubok Iba (True Horn), Agbagba (False Horn) and Obino l'Ewai (French plantain), were obtained from a uniform stand. Bunches were harvested at two maturity stages (fully mature and immature) which were determined by the number of days after flowering (DAF). The average dates of harvest for fully mature and immature bunches were as follows: Ubok Iba fruit were harvested at 95 and 79 DAF, Agbagba fruit at 95 and 80 DAF and Obino l'Ewai at 110 and 92 DAF, respectively. After harvest, the plantains were taken directly to the laboratory, where they were systematically damaged, as described later. The fruit used in the experiment were selected from the second and third hands of the bunches fruit were randomly selected for damage treatment.

Impaction was applied using a pendulum which provided an energy density of 0.75 Newton metres (Nm)/cm^2 at the point of impact.

The area of abrasion was 18 cm^2 which corresponded to between 5.7 – 8.2% of the total peel area on each fruit, as described by FERRIS *et al* (1993). The peel was abraded with a scalpel blade, no downward pressure was applied, thereby having no effect on pulp tissue.

Incision damage was applied with a scalpel blade: a 5 cm long incision to a depth of 1 cm was performed along the longitudinal axis of the fruit. Incision caused both pulp and peel damage.

In all cases, damage treatments were applied to the midsection of each fruit, on the flattest available surface.

Morphological and physical differences were assessed by measuring fruit length (cm), peel thickness (mm) and fruit volume as determined by displacement.

Peel surface area (cm^2) was calculated from a regression between fruit weight and surface area, according to the equation:
$y = 0.513x + 131$ (y = surface area, x = fruit weight), $r^2 = 0.75$, described by FERRIS (1991).

Ripening was assessed by monitoring changes in fruit peel colour, according to a visual score from 1 to 10, as follows: dark green (1), pale green (2), pale green with yellow tips (3), 50% green and 50% yellow (4), more yellow than green (5), pure yellow (6), yellow with black spots (7), 50% yellow and 50% black (8), more black than yellow (9) and pure black (10). Measurements of peel colour change used for the ripening studies were terminated when fruit reached peel colour stage 8. Only in the case of peel thickness were measurements continued until peel colour stage 10.

The experiment followed a randomized complete block design with a split plot, in which bunches were considered as blocks, cultivars as main plots, maturity as subplots and damage treatments as split plots replicated on five fruit, each fruit receiving one form of damage treatment *viz* three bunches x three cultivars x two levels of maturity x four damage treatments x five replicates = 360 fruits.

results

Average fruit weight decreased significantly ($P < 0.05$) from Ubok Iba (True Horn), to Agbagba (False Horn) and Obino l'Ewai (French plantain) respectively (table I). This significant trend was repeated for fruit volume and length and was consistent for surface area and surface to volume ratio. Further morphological data showed that peel thickness significantly decreased with time and that Ubok Iba and Agbagba had a significantly thicker peel ($P < 0.05$) than Obino l'Ewai (fig 1). The higher ripening rate of Obino l'Ewai was concomitant with a significantly higher loss in percentage weight after day 4 (fig 2).

Within damage treatments, only abrasion significantly reduced the mean ripening period compared with the control. The effect of damage on fruit percentage weight loss showed that abraded fruit lost significantly ($P < 0.05$) more weight than with other treatments (fig 3).

Table I
Morphological and physiological differences between the fruit of three Nigerian plantain cultivars.

Cultivar	*Weight (g)*	*Volume (cm^3)*	*Length (cm)*	*Surface area (cm^2)*	*Surface to volume ratio*
Ubok Iba	357.3	343.7	31.8	314.3	0.91
Agbagba	295.0	295.5	26.5	282.4	0.95
Obino l'Ewai	170.9	176.1	21.0	218.7	1.24
LSD ($P < 0.05$)	41.7	43.6	2.8	NA	NA

NA : not analysed statistically. LSD: least significant difference.

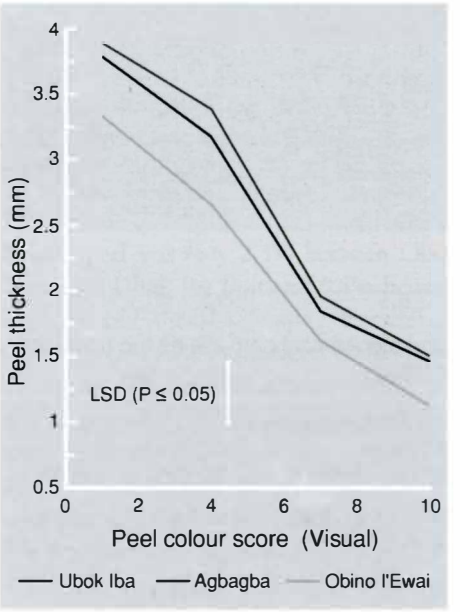

Figure 1
Effect of ripening on the fruit peel thickness of three Nigerian plantain cultivars.

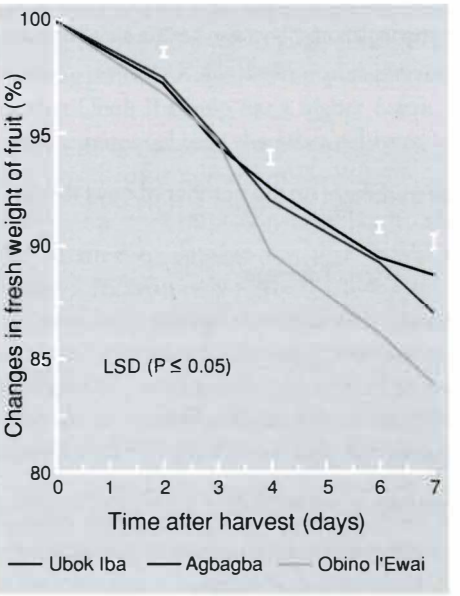

Figure 2
Effect of plantain cultivar on the changes in percentage weight loss during ripening.

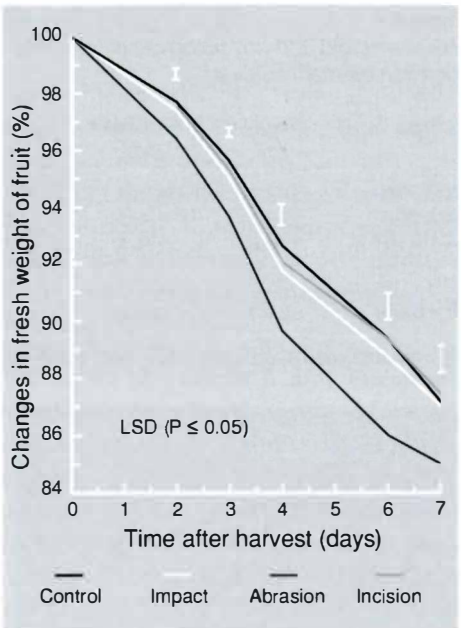

Figure 3
Effect of damage treatments on the changes in percentage weight of three plantain cultivars.

Table II
The effect of maturity at harvest and mechanical damage on the ripening of three plantain cultivars (pooled data).

	Type of damage				
	Control	*Impact*	*Abrasion*	*Incision*	*Mean*
Fully mature	11.0	9.4	9.9	9.8	10.8
Immature	16.2	16.9	13.0	15.1	15.1
Mean	13.6	13.1	11.5	12.4	

LSD ($P < 0.05$) for comparing maturity mean = 1.68; LSD ($P < 0.05$) for comparing treatment mean = 0.90; LSD ($P < 0.05$) for comparing damage x maturity means = 2.02; LSD ($P < 0.05$) for comparing interaction means at the same maturity level = 1.27.

Table III
The effect of cultivar and damage treatment on the number of days to fruit ripening of three plantain cultivars.

Cultivars	*Type of damage*				
	Control	*Impact*	*Abrasion*	*Incision*	*Mean*
Ubok Iba	15.1	14.6	14.5	13.1	14.3
Agbagba	14.6	14.0	11.7	13.8	13.5
Obino l'Ewai	11.1	10.8	8.2	10.4	10.1
Mean	13.6	13.1	11.5	12.4	

LSD ($P < 0.05$) for comparing damage means = 0.90; LSD ($P < 0.05$) for comparing cultivar means = 2.23; LSD ($P < 0.05$) for comparing damage x cultivar means = 2.48; LSD ($P < 0.05$) for comparing interaction means of the same cultivar = 1.57.

Impact was the only damage treatment which reduced ripening period at the fully mature level. However, the affect of impaction was not significantly different from the other damage treatments. The only significant reduction in the ripening period of fruit harvested at the immature level was caused by abrasion (table II).

Abrasion reduced ($P < 0.05$) the ripening period of Agbagba and Obino l'Ewai but had no effect on Ubok Iba (table III). Although the data in table III show a difference in ripening between abraded Agbagba and Ubok Iba fruit, there was little difference in percentage weight loss when comparing the abraded treatments directly. However, when percentage weight loss caused by abrasion was compared with the control fruit, it was clear that the abraded Agbagba fruit had lost substantially more weight than abraded Ubok Iba fruit (table IV).

The ripening period of Ubok Iba was only significantly reduced by incision but this was not coincident with an increase in weight loss.

discussion

The faster ripening of Obino l'Ewai was considered to be a result of the smaller French plantain fruit having a higher surface to volume ratio and thinner peel than the Horn plantains, Agbagba and Ubok Iba. Fruit size is a common factor causing differences in ripening rates of perishable crops (BAUTISTA, 1990). Smaller fruit lose percentage weight (ie, water) more rapidly than larger fruit as they have a larger evaporative surface area relative to their volume. The thinner peel of the Obino l'Ewai fruit may have provided less resistance to moisture loss than the thicker peel of the Agbagba and Ubok Iba fruit. BURDON *et al* (1991) also found that Obino l'Ewai has a higher stomatal density than Ubok Iba and Agbagba, which would further explain the increased percentage weight loss. It is considered that these factors collectively contributed to a more rapid rate of fruit desiccation which accelerated the fruit ripening of Obino l'Ewai compared with the Horn plantains. Studies by LITTMAN (1972a, b) found a close link between water stress and accelerated ripening of *Musa* fruit.

Table IV
The interaction between cultivar and damage treatments on the percentage weight loss of three plantain cultivars.

Cultivars	*Day*	*Control*	*Damage treatment*				
			Impact	*Abrasion*	*Incision*	*Control abrasion (LSD)*	*%WD**
Ubok Iba	2	2.27	2.22	3.15	2.17		0.88
Agbagba		2.20	2.56	3.44	2.47	0.45**	1.24
Obino l'Ewai		2.39	3.04	4.22	2.82	0.37*	1.83
Ubok Iba	4	7.53	7.39	9.18	7.3		1.65
Agbagba		6.18	7.32	9.04	6.8	1.29**	2.86
Obino l'Ewai		8.39	10.05	12.57	9.76	1.08*	4.18
Ubok Iba	6	10.29	9.87	12.22	10.07		1.93
Agbagba		9.24	10.80	12.71	8.97	1.64**	3.47
Obino l'Ewai		12.50	13.01	17.13	12.62	1.47*	4.63

LSD* ($P < 0.05$) for comparing any interaction means; LSD** ($P < 0.05$) for comparing any mean of the same cultivar; %WD: difference in percentage weight loss between the control and abrasion.

The response of plantain cultivars to damage showed that abrasion at the immature harvest date caused the most serious reduction in ripening period, confirming the results of FERRIS *et al* (1993). Differences in cultivar response showed that Obino l'Ewai and Agbagba were more susceptible to abrasion whereas Ubok Iba was susceptible to incision. Similar variations in cultivar response to damage have also been found with dessert apples (TOPPING and LUTON, 1986). The lower ripening period of the abraded Obino l'Ewai and Agbagba fruit was considered to be the result of increased water stress caused by the disrupted peel tissue compared with the control. Ubok Iba was not significantly affected by abrasion and the weight loss data showed that abraded Ubok Iba fruit lost considerably less water than the other cultivars. This ability to retain water would explain the longer ripening period of the abraded Ubok Iba fruit.

There are two possible explanations for these differences in cultivar response to damage and water loss. As the abrasion treatment was applied to a fixed area, the percentage of abraded peel would have been less in the larger Ubok Iba fruit compared with the other cultivars. Consequently, the rate of percentage weight loss would have been marginally lower for Ubok Iba. However, the average differences in area of abraded peel was only 2.5% between Obino l'Ewai and Ubok Iba fruit and 0.8% between Ubok Iba and Agbagba. Despite the small differences in peel area, the abraded Obino l'Ewai and Agbagba fruit showed a 25 and 20% reduction in ripening period compared with their control fruit, whereas the ripening period of the abraded Ubok Iba fruit was only reduced by 4% compared with the control (table III). Although it is possible that the fixed abraded peel area could have caused the differences in ripening response, it seems unlikely that the relatively small increases in abraded tissue would have entirely accounted for such large differences in ripening period. An alternative explanation may be that Ubok Iba pulp has a higher matric or osmotic potential than the other cultivars, but this hypothesis requires more investigation.

Perhaps the more surprising difference in cultivar response to damage was that caused by incision. Incision only affected Ubok Iba but had no effect on weight loss, and this variation in damage susceptibility may indicate two mechanisms causing early ripening. The data supports the view that abrasion accelerated the ripening of Obino l'Ewai and Agbagba by increasing peel permeability to moisture loss, thereby initiating the climacteric and reducing the ripening period due to an increased water stress. In experiments which measured the

resistance of moisture flow from *Musa* peel, it was found that abraded peel was 60 times less resistant to moisture loss compared with undamaged peel (FERRIS *et al*, 1994).

As incision treatment had no effect on weight loss, this treatment may have initiated ripening by inducing sufficient wound ethylene to stimulate the climacteric. MAXIE *et al* (1968) showed that mechanical damage, which injured both peel and pulp, induced a stress ethylene response which significantly reduced the preclimacteric period of banana. Further studies have shown that although peel and pulp produce ethylene in response to physical stress, only damaged pulp tissue exhibits the autocatalytic climacteric response (VENDRELL and McGLASSON, 1971; KE and TSAI, 1988). Although both abrasion and incision caused peel injury, only the incision treatment directly damaged the pulp tissue in this experiment.

While pulp injury may provide a mechanism by which incision reduced the ripening period of plantain, this would not explain cultivar differences. Such a difference would only be possible if the incision treatment caused a significantly greater injury to the Ubok Iba fruit. Indeed, this may have been the case as it was observed that when the Ubok Iba fruit were incised, several fruit of this cultivar subsequently split along their entire longitudinal axis. This tendency for excessive splitting of the peel and pulp was not observed with Agbagba or Obino l'Ewai fruit. Although care was taken to reject the excessively split Ubok Iba fruit, it is possible that the Ubok Iba fruit used in the experiment were exposed to a greater degree of internal pulp damage than the other cultivars. This tendency to split would help to explain the increased susceptibility of Ubok Iba fruit to incision. This fruit splitting characteristic of Ubok Iba is also commonly observed on fully mature bunches, even when attached to the mother plant.

Most research on plantains and bananas has been restricted to recording morphological characteristics for agronomic and taxonomic purposes (SIMMONDS and SHEPHERD, 1955; DE LANGHE, 1961; SWENNEN and VUYLSTEKE, 1987). Although this type of information is important to improvement programmes, it does not consider all the quality parameters which relate to market acceptability. The limitations of agronomic and taxonomic studies were illustrated when NEW and MARRIOTT (1974) revealed that promising, high yielding tetraploid dessert bananas had a significantly lower ripening period (and therefore storage quality) than commercially established triploid fruit. Consequently, the tetraploids were not adopted by the export traders. The information from this study shows there are considerable differences in the response of plantain cultivars to ripening and damage treatments. The data indicates that cultivar susceptibility to different types of damage has a morphological and physiological basis and that certain types of damage may trigger specific mechanisms which can initiate the climacteric response and accelerate early ripening.

Understanding the different processes underlying early ripening provides the opportunity to devise means to overcome such market constraints. Overripening remains an important cause of plantain losses during marketing and any changes which could be made in the transportation and marketing system to reduce the level of damage, particularly that of abrasion to unripe fruit, would significantly extend the marketing period of this crop. The results from this study indicate the potential importance of mechanical damage and the cultivar response. This type of information is useful to both breeding programmes and of interest to the retail sector.

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