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EFFECTS OF STORAGE MEDIA ON THE GREEN LIFE SPAN AND CULINARY QUALITIES OF PLANTAIN (*Musa* sp. AAB) FRUITS

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ABSTRACT

Sawdust (SD) and ricehusk (RH)) used singly or mixed in varying proportions and enclosed in polyethylene were used to study the storage life of mature green plantain fruits. There were two control treatments comprising fruits sealed in polyethylene without plant residue and fruits kept on laboratory shelf. Fruits were sealed in storage media for two weeks under ambient laboratory conditions and thereafter removed and lined on laboratory shelf to monitor ripening pattern. Culinary qualities of samples were evaluated 14 and 21 days after storage. Results showed that only fruits sealed in polyethylene without plant residue or polyethylene impregnated with 100% SD were still completely green after seven days of storage while fruits on the shelf were almost completely ripe. By the 14th day of storage fruits stored in polyethylene without plant residue or polyethylene impregnated with 100% SD were still at preclimacteric phase (and only started ripening 17 days after storage) whereas fruits kept on the shelf or polyethylene impregnated with 100% RH were at senescent phase. Fruits in the former storage systems had the least weight loss after three weeks. Acceptability rating of boiled sample was strongly associated with taste. Fruits stored in polyethylene without plant residue or polyethylene impregnated with 100% SD had high acceptability rating when ripe. The study suggests that fruits could be harvested at full maturity to optimize yield and eating quality. And with a fairly long green life, the storage system could enhance availability and utilization potential of plantain fruits at household and small-scale retailing levels.

Key words: Plantain fruits; postharvest behaviour; modified atmosphere storage

INTRODUCTION

Plantain fruits for local or short distance markets are ideally harvested after attaining the round-full maturity stage (Thompson and Burden, 1995) to enhance yield and ensure optimum visual or eating quality. However, since they are living biological systems they will deteriorate after harvest (Wills *et al.*, 1998). To gain maximum produce life and maintain quality at the retail stage, it is essential to correctly control handling and storage conditions (Beattie *et al.*, 1984). This is because the surrounding environment of fruits is probably the most important factor affecting the development of their post harvest quality (Wills *et al.*, 1998).

The general global warming and climate change suggest that some post harvest studies reported earlier than the 1980's in the tropical sub-Saharan Africa (for example, Ndubizu, 1976 and Olorunda, 1976) should be revalidated (with some modifications) for effectiveness. This is because changes in climactic variables especially diurnal temperatures have increased the rate of biochemical activities of harvested horticultural produce thereby reducing their storage life through faster rate of biodegradation. Ludlow and Muchow (1993) reporting on crop improvement for changing climates concluded that new crop varieties must be bred and improved management developed in order to minimize losses of yield of food, fiber and fuel.

Post harvest study aimed at extending green life of plantain by Ndubizu (1976) used polyethylene and fungicide dips. However, the high toxic residue of fungicide in plant products requires that alternative measures be developed (Reyes, *et al.*, 1998). Besides, fruits used for the study were not fully matured since they were harvested 60 – 72 days after shooting as against the usual 85 – 95 for round-full maturity (Swennen, 1990; Baiyeri, 1998). All fruits reach their best eating quality when allowed to mature and ripen properly (Lamp, 1997).

Plant residues or materials have been used as storage media for extending green life of plantain. Comparing the powder of cocoa pod, cocoa leaf, coffee and ricehusk, Agbo *et al.* (1996) reported that ricehusk powder extended the green life of plantain for more than two weeks under ambient temperature.

Hernandez (1973) reported the effectiveness of polyethylene for extending the green life of preclimacteric plantain fruits but, a major problem in the use of polyethylene is the high incidence of fungal infection due to condensation and thus high humidity buildup. Besides, a prolonged sealing of fruits inside polyethylene beyond certain limits, usually causes green-ripe, a situation where fruit pulp softens while the peel remains green. Such fruits don't ripe any more even after removal.

Post harvest management of *Musa* (bananas and plantains) fruits is underdeveloped in Nigeria. And because of low economic status of the generality of people involved in *Musa* production and marketing, post harvest research in this regard must take cognizance of adaptability to, and compatibility with the target rural farmers who largely produce and market the crop.

In this study therefore, sawdust and ricehusk used singly or mixed in varying proportions and

Table 1: An outline of the seven media combinations evaluated for storage of plantain fruits

Storage media	Description
100% RH	Fruits embedded in only rice husk enclosed in polyethylene
100% SD	Fruits embedded in only sawdust enclosed in polyethylene
50% SD + 50% RH	Fruits embedded in equal (v/v) combination of sawdust and ricehusk thoroughly mixed together and enclosed in polyethylene
75% SD + 25% RH	Fruits embedded in medium mixture containing one quarter (v/v) ricehusk and three quarters sawdust enclosed in polyethylene
25% SD + 75% RH	Fruits embedded in medium mixture containing three quarters (v/v) ricehusk and one quarter sawdust enclosed in polyethylene
Polyethylene	Fruits stored in polyethylene without plant residue
Shelf	Fruits stored on laboratory shelf (without any enclosure)

SD: Sawdust. RH: Ricehusk

enclosed in polyethylene were evaluated for storage of round-full green mature plantain fruits. The sealed polyethylene ensured modified atmosphere for storage, while the plant residues were to serve as absorbent for condensed moisture inside the sealed polyethylene. The specific objectives were to evaluate effectiveness of polyethylene impregnated with plant residues for maintaining green life of plantain fruits sealed for two weeks, and the ripening pattern of the fruits thereafter, and to evaluate the culinary qualities of these fruits immediately and one week after removal from polyethylene.

Table 2: Peel colour changes for identifying ripening stages in plantain fruits

Physiological phases*	Ripening stages	Description of peel colour
1	1	Green
1	2	Pale green
2	3	Pale green with yellow tips
2	4	50% yellow 50% green
2	5	More yellow than green
2	6	Pure yellow
3	7	Yellow with black coalescing spots
3	8	50% yellow 50% black
3	9	More black than yellow
3	10	Pure black

*Physiological phases: 1: pre-climacteric; 2: climacteric; 3: Senescence

MATERIALS AND METHODS

French plantain grown in a subsistence forest farming system in Nsukka agro-ecology (an area around Lat. 6° 52'N, Long. 7° 24'E) were used. *Musa* fruits for export trades are traditionally harvested at about three-quarter round stage to ensure extended green life and to avoid transit ripening (Stover and Simmonds, 1987; Robinson, 1996). Such early harvesting compromises potential yield for longer green life gained. However, in smallholder units, harvesting is usually done when the fruits are fully mature, because this is the consumer preference and it is important to maximize fruit mass for subsistence purpose (Robinson, 1996). Thus, bunches used for this study were harvested at the round-full maturity stage (Thompson and Burden, 1995) to maximize yield. Bunches were de-handed with sharp knife and the first nodal clusters at the proximal and distal ends of the bunch were discarded. The experiment was conducted under ambient temperature (averaged 29.8°C) in the laboratory of the Department of Crop Science, University of Nigeria, Nsukka, Nigeria.

There were seven storage media (see Table 1 for details) laid out as completely randomized design (CRD). Plant residues (sawdust (SD) and ricehusk (RH)) used singly and or mixed in varying proportions and enclosed in polyethylene were used for storage of round-full matured green plantain fruits. Two control treatments were fruits sealed in polyethylene without plant residue and sample fruits kept on laboratory shelf. Fruits were surface sterilized with 0.15% sodium hypochlorite (NaOCl) before storage.

Fifteen (15) fruits constituted the experimental unit, that is, each storage medium had three replicates of five fruits. The polyethylene was sealed with masking tape. Polyethylene used was plane and transparent, and was 0.1 mm thick. When laid flat it had dimensions of about 45 x 45 cm.

Initial fresh weight of fruits was taken before encasement and thereafter measured weekly. Ripening stages of the fruits were determined weekly for two weeks and thereafter daily following a modified ripening chart of Chukwu (1997) (Table 2). Media temperatures were taken before and two weeks after sealing polyethylene. Pulp to peel ratio, dry matter content and pH were determined two weeks after storage. To determine pH, five grams of ground dry fruit pulp was added to 50 ml of distilled water and stirred for ten minutes. Readings were thereafter taken with a CONSORT P107 digital pH meter. Organoleptic test was conducted using a ten-man panel. A seven-point hedonic scale was applied two and three weeks after storage. Three fruits randomly selected from each treatment were peeled, sliced into discs and steam cooked. Steam cooking was preferred to direct boiling inside water to avoid possible dilution effect that water absorbed could have on the taste and texture of samples. Three coded samples per treatment were served to each member of the ten-man panel. In the whole there were 30 responses to each quality trait per treatment. The quality traits evaluated were taste, colour, flavour, texture and general acceptability. The higher the quality rating (value) for any sample the better the sample for the specific trait. The data were analyzed using analysis of variance procedures for CRD. Test of significance of treatment means was by Fisher's Least Significant Difference (F-LSD) at 5% probability level.

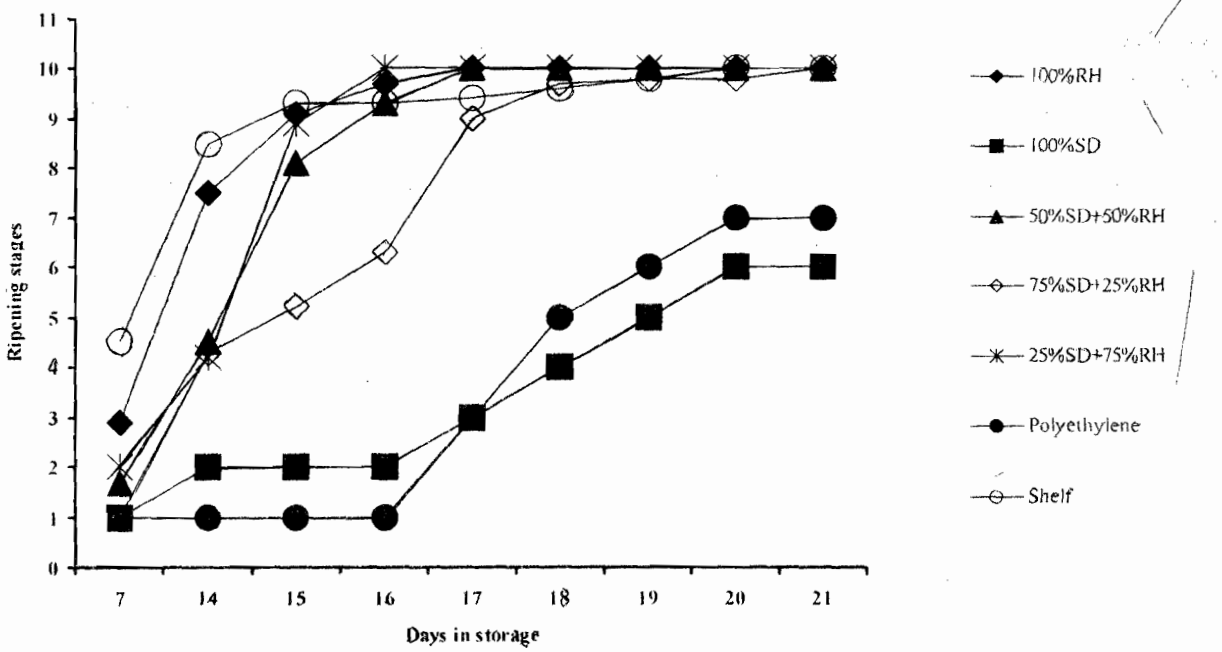

Fig. 1. Effect of storage system and duration of storage on the ripening pattern of plantain fruits.

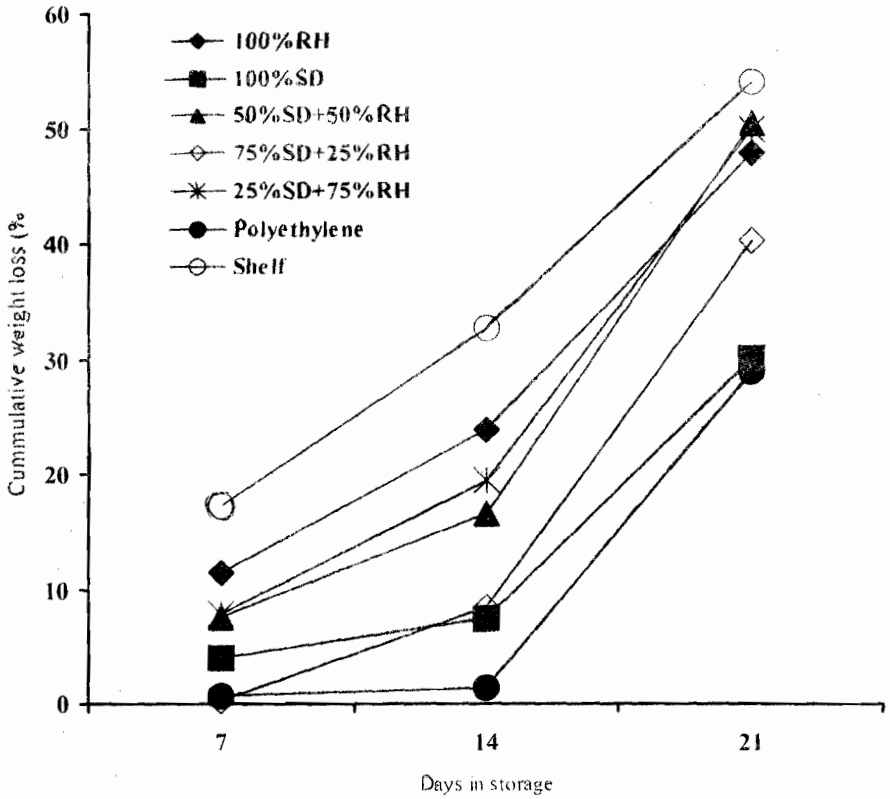

Fig. 2. The effect of storage system and duration of storage on the cummulative percent weight loss in plantain fruits.

RESULTS

Green life and ripening pattern were significantly (P = 0.05) influenced by storage systems (Fig. 1). Only fruits stored on the shelf or in polyethylene impregnated with 100% ricehusk had commenced ripening after seven days in storage. On day 14 of storage, fruits stored in polyethylene without plant residue and those in polyethylene impregnated with 100% sawdust were at preclimacteric (green) phase. Ripening commenced in these fruits on day 17 of storage whereas, fruits stored in the other storage systems had senesced. After three weeks fruits stored in polyethylene without plant residue or in polyethylene impregnated with 100% sawdust had not reached the senescence phase. These fruits had 16 days green life and more than 21 days shelf life. However, the fruits on the shelf had less than five days green life and about 14 days shelf life.

Table 3: Effect of storage systems on rate of weight loss in plantain fruits stored for three weeks

Storage media	Rate (%) of weight loss during:			
	Week 1	Week 2	Week 3	Mean
100% RH	1.64	1.76	3.44	2.28
100% SD	0.57	0.49	3.24	1.43
50% SD + 50% RH	1.05	1.27	4.86	2.41
75% SD + 25% RH	0.04	1.16	4.56	1.92
25% SD + 75% RH	1.11	1.67	4.34	2.34
Polyethylene	0.10	0.10	3.93	1.38
Shelf	2.46	2.21	3.06	2.58
CV (%)	86.27	59.63	17.75	23.56

SD: Sawdust, RH: Ricehusk

Table 4: Effect of storage systems on some physico-chemical properties of plantain fruits two weeks after storage.

		% dry matter				*Tempt. (°C)	
Storage media	Pulp: Peel	Pulp	Peel	pH Pulp	pH Peel	D1	D14
100% RH	4.7	31.4	18.7	4.6	5.0	27.2	26.8
100% SD	2.3	37.9	6.3	5.5	5.0	23.9	26.0
50% SD + 50% RH	4.4	31.7	13.7	4.5	5.0	24.7	26.7
75% SD + 25% RH	3.8	31.3	11.0	4.7	5.1	24.7	26.5
25% SD + 75% RH	4.5	32.8	14.7	4.6	5.1	25.7	26.5
Polyethylene	2.1	38.2	6.9	5.6	5.2	29.0	25.0
Shelf	6.5	33.4	16.6	4.5	5.0	29.5	29.0
F-LSD $_{(0.05)}$	1.1	3.5	7.6	0.6	NS	2.3	1.9

SD: Sawdust, RH: Ricehusk; *Temp.: temperature on day one (D1) and day 14 (D14) of the experiment.

Table 5: Palatability test by a 10-man panel following a seven-point hedonic scale* two weeks after storage.

Storage media	Taste	Colour	Flavour	Texture	General Acceptability
100% RH	6.4	4.7	4.6	1.8	4.9
100% SD	1.8	1.9	3.2	6.0	2.0
50% SD + 50% RH	5.5	4.9	4.9	3.7	5.4
75% SD + 25% RH	4.9	5.0	4.4	4.1	4.9
25% SD + 75% RH	4.8	4.7	4.7	4.6	5.3
Polyethylene	1.4	2.0	2.8	5.5	1.9
Shelf	6.2	4.7	4.6	2.8	5.5
F-LSD $_{(0.05)}$	1.7	1.5	1.6	1.8	1.5

*The higher the quality rating (value) for any sample the better the sample.

There was a progressive increase in percent cumulative weight loss with increase in days of storage. Fruits lined on the laboratory shelf showed the greatest weight loss, which was always higher than weight loss in the other storage systems (Fig. 2). At the end of three weeks of storage, weight loss in fruits lined on the shelf was 54% of the initial weight as against about 30% lost from fruits stored either in polyethylene without plant residue or in polyethylene impregnated with 100% sawdust.

During the first week of storage, daily weight loss was between 0.04 to 2.46% across the storage systems. A value of 0.10 to 2.21% was observed in the second week of storage (Table 3). After the second week of storage fruits were removed from polyethylene and lined on the shelf to monitor ripening. The rate of weight loss measured thereafter had a closer range of 3.06 to 4.56%. The mean weight loss over a 21-day

storage period was highest in fruits initially lined on the laboratory shelf. The value was lowest in fruits initially stored either in polyethylene without plant residue or in polyethylene impregnated with 100% sawdust.

The physico-chemical properties (Table 4) varied (P = 0.05) with storage system, however, the pH of fruit peel was comparable. The fruits that had extended green life for two weeks (Fig. 1) had the lowest pulp: peel ratio, the highest pulp dry matter and pulp pH. At initial storage, polyethylene impregnated with 100%SD had the lowest temperature (≈ 24°C) as compared to 29°C of the ambient. Temperature within polyethylene without plant residue became ambient temperature. On the 14th day, temperatures within some of the storage systems increased due to respiration of the fruits. The polyethylene without plant residue had internal temperature of 25°C (possibly due to condensation) as against 29°C of the ambient.

Culinary traits were influenced by storage systems (Table 5). After two weeks, fruits stored in polyethylene without plant residue and in polyethylene impregnated with 100% SD had the lowest ratings for colour, flavour, taste and general acceptability. However, fruit from those two storage systems had highest value for texture. By the third week of storage only fruits stored in polyethylene without plant residue and in polyethylene impregnated with 100% SD were tested for culinary qualities because fruits from the other storage systems had become mealy. The result (Table 6) showed that fruits stored in polyethylene impregnated with 100% SD had firmer texture than those stored in polyethylene without plant residue, while both had statistically similar ratings for colour, taste, flavour and general acceptability.

Multiple correlation analysis of the culinary traits measured after two weeks of storage revealed that general acceptability of boiled plantain fruits was strongly positively associated with colour, flavour and taste but negatively associated with texture (Table 7). A multiple linear regression analysis between acceptability and other indices showed that acceptability rating of boiled sample was 90.9% determined by the taste of the sample. Texture contributed the least to acceptability of sample however, factor analysis (data not shown) revealed that texture was the most objective index for identifying effectiveness of storage systems for prolonging plantain green life.

Table 6: Palatability test by a 10-man panel following a seven-point hedonic scale* three weeks after storage.

Storage media	Taste	Colour	Flavour	Texture	General Acceptability
100% SD	6.2	5.6	5.3	3.7	5.7
Polyethylene	5.9	5.2	5.6	2.0	5.4
F-LSD $_{(0.05)}$	NS	NS	NS	1.2	NS

*The higher the quality rating (value) for any sample the better the sample

Table 7: Interrelationships among culinary traits of plantain fruits boiled after two weeks of storage.

	Colour	Flavour	Taste	Texture	Acceptability
Color	-	0.964***	0.937***	-0.758*	0.982***
Flavour		-	0.941***	-0.736	0.982***
Taste			-	-0.914***	0.947***
Texture				-	-0.751
Acceptability					-

*; ***: Significant at P = 5% and 0.1% respectively.

DISCUSSION

Storage deals much with managing green life, the initiation of ripening and subsequent shelf life, usually with the aim of prolonging green life and shelf life (Turner, 1997). The postharvest life of plantain fruits has three sequential phases. These are the preclimactaric (green life), the climacteric (ripening) phase and a senescent phase (John and Marchal, 1995; Robinson, 1996). The green life and total shelf life are to a large extent dependent on the maturity at harvest and the subsequent post harvest handling, especially the packaging and storage techniques. The effect of storage systems on postharvest behaviour of mature plantain fruits in this study was not surprising. The prolonged green life of some stored mature plantain fruits was attributed to reduced rate of weight loss.

The variability in effectiveness of sawdust and ricehusk as moisture absorbent was probably due to differences in surface area of their particles that could have affected both the quantity and movement of air in the polyethylene and consequently respiration rate of the fruits. Although the same volume of plant residues and the same type of polyethylene were used, sawdust had finer particles than ricehusk and would have had better moisture absorbent characteristics. On the other hand, ricehusk with larger air spaces could have permitted more respiration and consequently more weight loss, a characteristic that evidently predisposed the plantain fruits to ripening (John and Marchal, 1995; Robinson, 1996; Turner, 1997).

The moisture gradient between the fruits and the plant residue, the faster air movement and higher temperature in the ricehusk led to its less efficiency as compared with sawdust. It is known that any factor that reduces air movement around the fruit and lowers fruit temperature reduces the rate of transpiration and consequently, lowers biodegradation processes that quicken ripening (Turner, 1997). Rate of biochemical degradation is known to increase with temperature as such the lower temperature in 100% sawdust as against the ambient and 100% ricehusk caused reduced rate of biochem-

ical activities that led to ripening.

A modified atmosphere consisting about 2-5% oxygen and 2-5% carbon dioxide has been reported to delay ripening by reducing respiration and ethylene production (Wills *et al.*, 1998). The encasement of plantain fruits inside polyethylene modified the environment around the fruits and the effectiveness of the methods was judged by the extent the green life of fruits was sustained. The polyethylene without plant residue and polyethylene impregnated with 100% SD are better storage systems than others because they effectively extended green life of mature plantain fruits for about 16 days. The disadvantage of the use of modified atmosphere storage to preserve commodities with high moisture is the buildup of high humidity that supports the growth of spoilage organisms (Hobson, 1994). The use of dry plant residue (especially sawdust) drastically reduced condensed moisture.

The palatability of boiled samples stored for 14 days demonstrated that acceptability was positively associated with taste, flavour, and colour, which are dependent on ripeness of fruits. Ferris *et al.* (1996) and Vuylsteke *et al.* (1997) had reported that acceptability of plantain hybrids was related to the taste of the hybrid. The low acceptability of fruits stored in polyethylene without plant residue or in polyethylene impregnated with 100% sawdust was attributed to the ripeness of the fruits at the time of assessment. The fruits stored for 21 days had high acceptability because they were ripe. However, the fruits stored in polyethylene impregnated with 100% sawdust were firmer for processing (Baiyeri *et al.* 1999).

Fruits stored in sealed polyethylene impregnated with sawdust became fully ripe in six days after they were removed from the polyethylene. The advantage of the use of this preservation technique for plantain at household is that it would allow purchase of large quantities of the produce for storage. The cost effectiveness of removing the fruits and placing them on the shelf weekly ensures controlled ripening and enhances utility and availability within the households. This storage management advantages outweigh those of the traditional management. It extends green life of the fruits and inhibits development of pathogenic microflora that would otherwise cause spoilage.

As judged by the results, storage of the fruits in sealed polyethylene impregnated with sawdust extends the green life of matured plantain fruits for up to 16 days, and had no adverse effects on the culinary attributes. The extended green life further ensures availability all year round and reduces wastage in both household and small scale retailing levels. This study has shown that fully matured harvested fruits preserved in the new storage system maximize yield, quality, availability and consumption.

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