Int. Agrophysics, 2005, 19, 19-25

INTERNATIONAL
Agrophysics
www.ipan.lublin.pl/int-agrophysics

Variable light transmission through four polyethylene colours used for plantain (*Musa* sp. AAB) fruits storage as influencing its postharvest and culinary qualities

K.P. Baiyeri

Department of Crop Science, University of Nigeria, Nsukka, Nigeria

Received February 23, 2004; accepted December 4, 2004

A b s t r a c t. Postharvest wastes of horticultural produce are enormous in Nigeria, requiring increasing efforts to reduce this spate. Therefore, colourless, blue, red and yellow polyethylene bags impregnated with or without sawdust were used for storing green mature plantain fruits. Control treatment was fruits lined on laboratory bench. Sample fruits enclosed in polyethylene were sealed under ambient laboratory conditions and thereafter opened weekly to assess postharvest changes. Inclusion of sawdust was not in any way more beneficial than without it. Relative light transmission through the four colours was expectedly different. Light intensity reduction by the colourless polyethylene was 3.6%, compared to 30-35% reductions by blue and yellow polyethylene. Variation in light intensity transmitted explained about 90% of weight loss in fruits. After three weeks of storage, weight loss from fruit stored in blue polyethylene was about 7% compared to about 45% in the control. Colour of polyethylene also significantly ($P < 0.05$) influenced ripening pattern. Whereas 67% of fruits stored in colourless, yellow and red polyethylene were still green after two weeks of storage, only 8% of the control samples was still green. Organoleptic assessment of steamed boiled fruits after two weeks of storage revealed that fruits stored in blue and red polyethylene combined relatively high textural and general acceptability ratings, while fruits stored in yellow polyethylene had the highest textural rating. The general acceptability rating of fruits stored in yellow, red and blue polyethylene had highest relationship with flavour, but with taste - for fruits stored in colourless polyethylene. Evidences from the study revealed that blue and yellow polyethylene transmitting lower light intensity ensured lowest fruit weight loss, delayed ripening and enhanced culinary quality traits, and are therefore suggested for further evaluation and use under high temperature environment.

K e y w o r d s: eating quality, plantain fruits, polyethylene colours, ripening, weight loss

INTRODUCTION

Postharvest waste is a major problem limiting the availability of banana and plantain (*Musa* sp. AAB) fruits in most *Musa* production states of sub-Saharan Africa. This is essentially associated with incorrect harvesting, poor transportation and poor storage systems. The incorrect harvesting, transport, packaging and storage techniques can lead to either physical or physiological damage of the fruits, the extent of which will determine how much the fruits become downgraded in quality and price (Robinson, 1996).

The storage environment of fruits is probably the most important factor affecting the development of their postharvest quality (Wills *et al*., 1998). Important environmental variables that impact the green-life, rate of weight loss, and development of postharvest diseases are the storage temperature and humidity (Baiyeri 2001; 2003). Storage temperature and humidity are, however, influenced by storage systems employed.

Polyethylene has been used extensively for extending the green life of plantain fruits, although an associated problem with the use is the high incidence of fungal infection due to condensation (Hernandez, 1973; Wills *et al*., 1998). Baiyeri (2001) ameliorated this problem by the use of plant residues which served as moisture absorbent.

Light is a form of electromagnetic radiation that travels in waves. The wavelength determines the colour as well as the energy level (Chapman and Carter, 1976). As such, materials possessing different colours transmit varying levels of light intensity. There are empirical facts that

Corresponding author's e-mail: paulkayodebaiyeri@yahoo.com

different colours reflect different wavelengths of light with consequent effects on physiological behaviour of plant.

In a field experiment, fungi virulence had been reduced by the use of black polyethylene mulch (Brown *et al*., 1989). Similarly, applications of coloured plastic mulches in vegetable crop production systems have resulted in both plant and pest responses. Pale blue or white mulch increased the harvest from potatoes by as much as 15%.

High diurnal temperature prevalent in the tropical environment causes high rates of biochemical activities of harvested horticultural produce, thereby reducing their storage life through faster rate of biodegradation (Baiyeri, 2001). Manipulation of light (radiation) reaching harvested produce by using coloured polyethylene may reduce heat built-up in a modified atmosphere storage system, thereby enhancing storage life of produce.

In this study, therefore, the effects of four polyethylene colours impregnated with or without plant residue on the post harvest and culinary qualities of plantain fruits were investigated.

MATERIALS AND METHODS

The study was conducted in the laboratory of the Department of Crop Science, University of Nigeria, Nsukka, Nigeria, between September and December, 2002. Average ambient laboratory temperature during the study was 29 ± 1°C. The light intensity passing through each polyethylene colour was determined at the Energy Research Center of the University of Nigeria, Nsukka, Nigeria, using a solarimeter. Measurements were taken three times per polyethylene colour for two successive days.

Storage materials: Sawdust was impregnated in four polyethylene colours (colourless, yellow, red, and blue). Modified atmosphere storage is a common storage method for most fruits, it involves sealing produce in polyethylene (Wills *et al*., 1998). But associated problem with the method, especially in the tropics, is water vapour condensation which predisposes stored produce to fungal infection. In an earlier study by the author (Baiyeri, 2001) and in this study, sawdust was included as moisture absorbent. The moisture content of the sawdust used was 15.5%. The dimensions of the polyethylene when flattened were 39.4 by 37.3 cm, and it was, on average, about 0.1 mm thick. The quantity of sawdust was one liter, and occupied about one-fifth of the space within the polyethylene.

Plant material: Freshly harvested bunches of French plantain were used. Harvesting in smallholder units 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 a sharp knife and the first nodal clusters at the proximal and distal ends of the bunch were discarded. Fruits were washed in weakly sterile water (0.06% a.i. solution of sodium hypochlorite) and were air-dried under laboratory conditions before storage.

Experimental design: The experiment was a factorial in completely randomized design. There were two factors which included [a] four polyethylene colours (colourless, yellow, red, and blue) and [b] inclusions of sawdust as moisture absorbent or not. There were eight treatment combinations plus a control treatment. The control samples were fruits lined on laboratory table. Each treatment combination had eight fruits replicated three times (*ie* 24 fruits per treatment combination). Thus, 216 fruits were used for the study. The fruits were lined vertically inside the polyethylene and sealed with masking tape.

Data collection and statistical analysis: All the fruits were assessed weekly for three weeks. Initial fresh weight of fruits was taken before the encasement and thereafter measured weekly. Ripening stages of the fruits were determined weekly following Baiyeri (2001) ripening chart (Table 1). Physiological phases (*ie* preclimacteric, climacteric and senescence) of fruits after two weeks of storage were determined and expressed as percentage of the total number of fruits initially stored.

T a b l e 1. 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 - preclimacteric, 2 - climacteric, 3 - senescence.

Culinary quality evaluation: Organoleptic test was conducted using a seven-man panel. A seven-point hedonic scale was applied two weeks after storage to steamed cooked fruits. Two fruits randomly selected (but representative of the ripening phase of each treatment) from each treatment were peeled, sliced into discs and steam cooked. Steam cooking was preferred to direct boiling in water to avoid possible dilution effect that water absorbed could have on the taste and texture of samples. Two coded samples per treatment were served to each member of the seven-man panel. On the whole there were 14 responses to each quality trait per treatment combination. 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.

Data collected were analyzed using analysis of variance procedures for factorials in CRD. Test of significance of treatment means was by Fisher's Least Significant Difference (F-LSD) at 5% probability level.

RESULTS

The light intensity transmitted through the four polyethylene colours used varied markedly (Table 2). Expectedly, colourless polyethylene permitted higher light intensity, while the yellow polyethylene transmitted the least intensity. The light intensity passing through yellow and blue polyethylene was statistically ($P<0.05$) similar (Table 2). Whereas the reduction in light intensity by the colourless polyethylene was as low as 3.6%, reduction by blue and yellow polyethylene ranged between 30-35%.

blue polyethylene without the inclusion of sawdust were at ripening stage 2 (*ie* preclimacteric phase) whereas ripening had commenced in all other treatments (Table 3).

Weight (moisture) loss from fruits clearly varied with treatments (Fig. 1). Weight loss from fruits stored in blue polyethylene was significantly ($P<0.05$) lowest, irrespective of time (second or third week) of assessment. Whereas fruits stored in blue polyethylene lost about 7% of their initial weight at the end of three weeks of storage, fruits lined on the laboratory shelf lost about 45%. The intensity of light transmitted by the different polyethylene colour had about 90% coefficient of determination on moisture loss from the fruits (Fig. 2). Thus, the amount of the intensity of light transmitted by the different colours effectively predicted fruits' weight loss with low (0.53) standard error.

Polyethylene impregnated with sawdust or not affected the physiological distribution of fruits into preclimacteric, climacteric and senescence phases (Table 4). About 67% of fruits stored in colourless, yellow and red polyethylene without the inclusion of sawdust were still green after two weeks of storage as against only eight per cent of the control samples. There was an equal distribution of fruits into the three ripening phases when blue polyethylene was used. All the fruits in yellow polyethylene impregnated with sawdust and those of the control samples had senesced at the end of two weeks. Post-storage ripening pattern of fruits remaining after three weeks of storage showed that fruits previously stored in blue polyethylene had longer green life (Table 5). Whereas ripening had commenced in all other fruits, fruits previously stored in blue polybag were still completely green (stage 1) after 22 days of storage.

T a b l e 2. Light intensity passing through the four polyethylene colours at noon

Polyethylene colour	*Light intensity (W m^{-2})	Reduction in intensity (%)
Colourless	706.8	3.6
Red	593.2	19.1
Blue	513.7	29.9
Yellow	479.5	34.6
$LSD_{(0.05)}$	84.9	-

*Average direct sunlight intensity received during the same period = 732.9 W m^{-2}

Evaluation of ripening pattern of fruits as influenced by polyethylene colour and the inclusion of sawdust or not is shown in Table 3. After one week of storage all fruits stored without the inclusion of sawdust were green whereas fruits stored in sawdust impregnated in colourless polyethylene and the control fruit samples were at ripening stage 4 (mid climacteric phase). At the end of the second week of storage, most of the fruits were generally at the respiratory climacteric phase. However, evaluation of fruits remaining till the third week of storage revealed that fruits stored in

The colour of polyethylene and the inclusion of sawdust or not affected culinary traits of fruits steam boiled after two weeks of storage (Table 6). Taste panelists rated fruits previously stored in yellow polyethylene (not impregnated with sawdust) lowest except in texture. But fruits stored in blue and red polyethylene combined fairly high textural and general acceptability ratings. Study of culinary traits interrelationships and identification of traits most associated with general acceptability rating of steam boiled fruits in each polyethylene colour was examined with correlation

T a b l e 3. The effects of polyethylene colours impregnated with or without sawdust as moisture absorbent on ripening stages* of plantain fruits during storage

Week 1 after storage

Sawdust inclusion[γ]	Colourless	Yellow	Red	Blue	Control	Mean
-	1	1	1	1	4	1.6
+	4	3	2	2	4	3.0
Mean	2.5	2.0	1.5	1.5	4	-

$LSD_{(0.05)}$ comparing main effects of: colour = 0.6, sawdust inclusion = 1.1.

Week 2 after storage

Sawdust inclusion[γ]	Colourless	Yellow	Red	Blue	Control	Mean
-	3	3	3	6	6	4.2
+	9	9	6	5	6	7.0
Mean	6.0	6.0	4.5	5.5	6	-

$LSD_{(0.05)}$ comparing main effects of sawdust inclusion = 2.1.

Week 3 after storage**

Sawdust inclusion[γ]	Colourless	Yellow	Red	Blue	Control	Mean
-	4	5	6	2	7	4.8
+	7	8	8	7	7	7.8
Mean	5.5	6.5	7.0	4.5	7	-

*Ripening stages (see interpretation on Table 1) were estimated from 24 fruits per treatment combination. **After two weeks of storage, fruits at ripening state 10 (complete senescence) were discarded. Ripening stages three weeks after storage were estimated from fruits remaining. [γ]Sawdust inclusion: +, -: with or without sawdust, respectively.

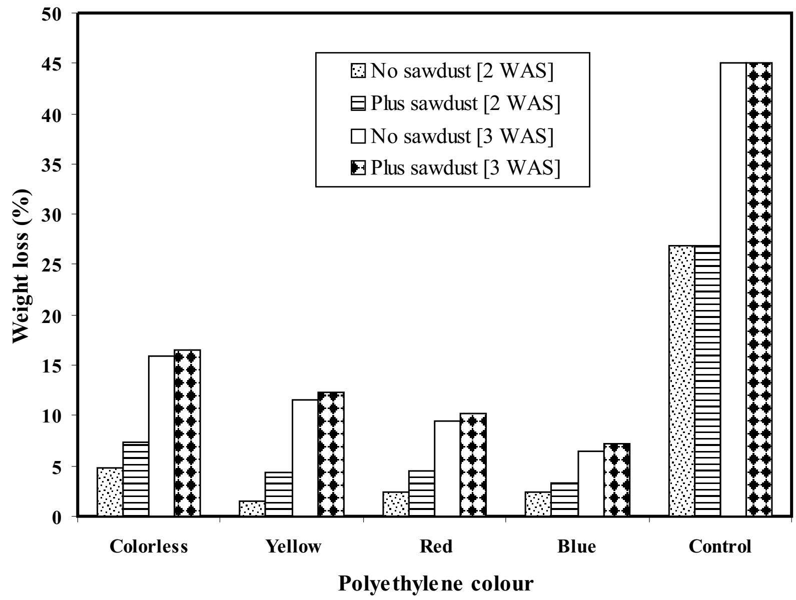

Fig. 1. The effects of polyethylene colour and inclusion of sawdust as moisture absorbent on weight loss in plantain fruits after two and three weeks after storage [WAS].

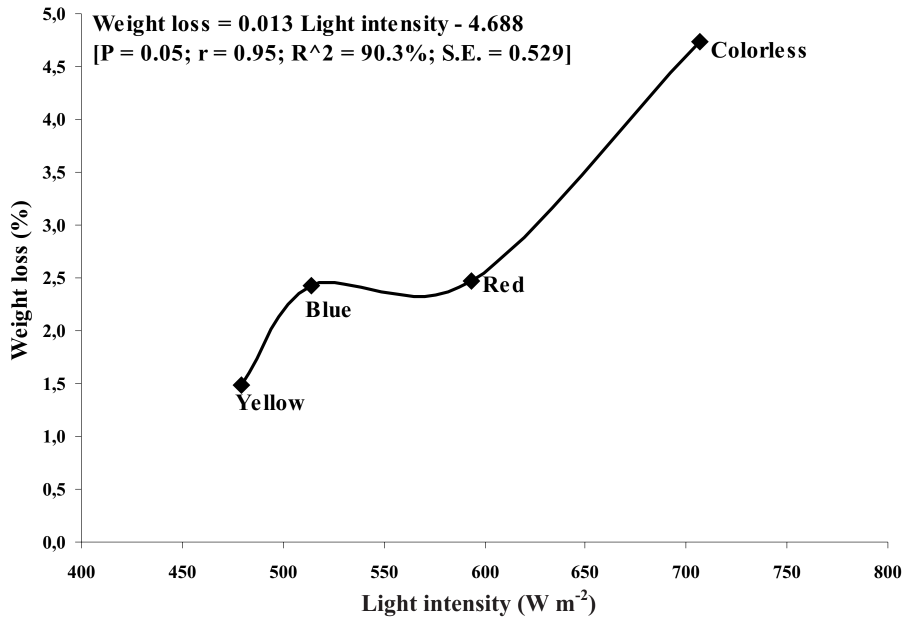

Fig. 2. The relationship between fruit weight loss two weeks after storage and light intensity transmitted by different polyethylene colours.

T a b l e 4. Physiological status of fruits after two weeks of modified atmosphere storage in four polyethylene colours impregnated with or without sawdust

Polyethylene colour	Sawdust inclusion	Number of fruits	Percent of fruits that was:		
			Green	Ripe	Senesced
Colourless	-	24	66.7	33.3	0.0
	+	24	0.0	33.3	66.7
Yellow	-	24	66.7	33.3	0.0
	+	24	0.0	0.0	100.0
Red	-	24	66.7	33.3	0.0
	+	24	33.3	66.7	0.0
Blue	-	24	33.3	33.3	33.3
	+	24	33.3	33.3	33.3
Control	LS	24	8.3	25.0	66.7
Mean		24	34.3	32.4	33.3

Sawdust inclusion +, -, with or without sawdust, respectively.

analysis. Taste had the highest association with general acceptability for fruits previously stored in colourless polyethylene, as against flavour for fruits stored in yellow, red and blue polyethylene (data not shown). The colour of polyethylene and the inclusion of sawdust influenced the coefficient of trait interrelationships.

DISCUSSION

The results of the study evidently showed significant polyethylene colour effects on the postharvest behaviours of plantain fruits. This was due to differences in light intensity transmitted by the polyethylene colours. Variability in the intensity of light transmitted probably also caused variation in heat build up in the different polyethylene bag. Temperature is the single most important factor governing the maintenance of postharvest quality in fruits (Wills *et al*., 1998). As such, variability in internal temperature of storage polybag due to differential light transmission explains most of the significant polyethylene colour effects.

The rate of biochemical changes in fruits after harvest is essentially associated with preharvest conditions and storage environments. Since fruits used for the study came through similar preharvest conditions, variability in postharvest changes could be associated with the variation in the storage environments (in this regard, changes in the

T a b l e 5. Post-storage ripening pattern of fruits remaining after 21 days of storage in various polyethylene colours without moisture absorbent

Colour	No. of fruits	Ripening stages*, days post-storage				
		1	2	5	6	7
Colourless	12	3	5	7	8	9
Yellow	12	4	5	7	8	9
Red	6	4	5	7	8	9
Blue	6	1	4	4	7	8
Control	8	6	7	7	7	8
$LSD_{(0.05)}$		2.2	1.8	0.8	0.8	n.s.

*Ripening stages see interpretation in Table 1. n.s. - non-significant.

transmitted the lowest light intensity. Variability in light transmission explained 90% of differences in weight loss.

Non-effectiveness of the inclusion of sawdust as reported in this study is at variance with earlier report by Baiyeri (2001). In the earlier study, fruits were completely buried inside the sawdust whereas in the present study sawdust occupied about one-fifth of the volume of the polyethylene. In the earlier study, the sawdust completely displaced free air thereby limiting respiratory rate. In contrast, the four-fifth-volume left in the current study allowed larger quantity of free air, which enhanced respiration and thus shorter green life. 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). Also, controlled atmosphere

T a b l e 6. The effect of polyethylene colours impregnated with or without moisture absorbent on culinary quality traits of steam boiled plantain fruits two weeks after storage

Polyethylene colour	Sawdust inclusion	Colour	Flavour	Taste	Texture	General acceptability
Colourless	-	3.9	5.1	4.5	5.3	5.1
	+	5.1	4.4	5.5	3.1	4.4
Yellow	-	2.5	3.6	2.9	5.7	3.4
	+	5.2	5.1	5.7	3.3	4.9
Red	-	4.0	4.4	4.3	5.2	4.4
	+	5.4	5.3	5.9	3.4	5.4
Blue	-	3.6	5.1	4.7	4.4	5.2
	+	4.6	4.6	4.9	4.4	5.3
Control	LS	4.8	5.0	5.5	3.6	5.4
$LSD_{(0.05)}$		0.4	1.1	1.1	1.3	1.1

Sawdust inclusion +, -, with or without sawdust, respectively.

polyethylene colour). The effectiveness of polyethylene for modified atmosphere storage of fruits has been properly documented (Hernandez, 1973; Chaplin and Hawson, 1981; Wills *et al*., 1998; Robinson, 1996; Baiyeri, 2001) but the import of this study was the impact variability in colour of polyethylene could cause. Thus, the significant variations observed were of interest. This is because global climatic changes, which led to tremendous increase in diurnal temperature, have increased the rate of biochemical activities of harvested horticultural produce, thereby reducing their storage life through faster rate of biodegradation (Baiyeri, 2001). As such, any storage medium that will reduce heat build up (as a result of reduction in light intensity) will enhance storage life of produce. This probably explains lowered rate of weight loss and ripening changes in blue and yellow polyethylene which consisting of about 2-5% oxygen and 2-5% carbon dioxide has been reported to delay ripening by reducing respiration and ethylene production (Banana Produce Facts, 1998).

The colour of polyethylene also impacted the taste panelist assessment of the steam boiled fruits, meaning that besides affecting shelf qualities, polyethylene colours could also influence organoleptic responses. Earlier study showed that polyethylene colours impacted both taste and protein levels in leaves. In this study, fruits previously stored in blue and red polyethylene had the best-combined ratings for general acceptability and firmness. Poor organoleptic ratings (except for firmness) of fruits previously stored in yellow polyethylene were probably due to those fruits being still green. Baiyeri (2001, 2003) noted that the most objective organoleptic trait for assessing good storage medium is textural (firmness) ratings. Therefore, very high firmness rating for fruits from yellow polyethylene suggests that it enhanced the green life of the fruits.

CONCLUSIONS

1. Evidence from this study showed that modified atmosphere storage of plantain fruits using polyethylene significantly enhanced the postharvest and culinary qualities of the fruit when compared with the control samples (which represent the traditional storage system).

2. Fruit weight loss and rate of ripening were higher in control sample than in those stored inside polyethylene. After three weeks of storage, fruits stored in blue polyethylene lost only 7% of the initial weight compared to 45% loss by the control fruit samples.

3. Relatively higher postharvest and culinary quality traits of fruits previously stored in blue and yellow polyethylene (due to lowered temperature) suggest that they are better polyethylene colours for fruit storage under tropical environment where ambient temperature is always very high.

REFERENCES

Baiyeri K.P., 2001. Effects of ricehusk, sawdust and their admixture and polyethylene as storage media on the green life span and culinary qualities of mature plantain (*Musa* sp. AAB) fruits. AgroSci., 2(2), 19-25.

Baiyeri K.P., 2003. Plant residues moistened to three levels of wetness influence green life, ripening pattern and culinary quality of matured plantain (*Musa* sp. AAB) fruits. Nigerian J. Hort. Sci., 8, 79-87.

Banana Produce Facts, **1998.** Recommendations for maintaining postharvest quality, pp. 1-3. http:/postharvest.Ucdavis.Edu/produce/producefacts/fruits/banana.html

Brown J.E., Stevens C., Osborn M.C., and Bryce H.M., 1989. Black plastic mulch and spunbounded polyester row cover as method of southern blight control in bell pepper. Plant Disease, 73, 931-932.

Chaplin G.R. and Hawson M.G., 1981. Extending the post harvest life of unrefrigerated avocado (*Persea americana* Mill.) fruit by storage in polyethylene bags. Scientia Horticulturae, 14, 219-226.

Chapman S.R. and Carter L.P., 1976. Crop Production - Principles and Practices. W.H. Freeman Press, San Francisco, USA.

Hernandez I., 1973. Storage of plantains (*Musa paradisiacal*). J. Agric. the University of Puerto Rico, 53, 100-106.

Robinson J.C., 1996. Bananas and Plantains. CAB International, London.

Thompson A. and Burden O., 1995. Harvesting and fruits care. In: Bananas and Plantains (Ed. Gowen). Chapman and Hall Press, London, 403-433.

Turner D.W., 1997. Banana and plantains. In: Postharvest physiology and storage of tropical and subtropical fruits, (Ed. S.K. Mistra). CAB International, London, 47-83.

Wills R., McGlasson W.B., Graham D., and Joyce D., 1998. Postharvest: An introduction to the physiology and handling of fruits, vegetables and ornamentals. CAB International, London.