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Full Length Research Paper

Effect of perforated blue polyethylene bunch covers on selected postharvest quality parameters of tissue-cultured bananas (*Musa* spp.) cv. Williams in Central Kenya

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Banana farming in Kenya has recently moved from subsistence to commercial farming. There is therefore the need to produce high quality fruits that are visually acceptable, have good postharvest quality attributes and therefore sell well in both local and international markets. Technologies such as pre-harvest bunch covers have been shown to improve postharvest quality of banana fruits. However, earlier reports on the effect of bunch covers on postharvest quality of banana fruits in the tropics have been contradictory. This study therefore aimed at understanding the effect of perforated polyethylene bunch covers on the postharvest quality characteristics of tissue-cultured bananas using banana (*Musa* spp.) cv. Williams as the test variety. The trial was carried out in Maragwa region in central province of Kenya, in a complete randomized design and was replicated three times. Perforated dull and shiny blue polyethylene covers were placed when the hands had started to turn upwards. Fruits were harvested at full three quarter maturity. Parameters measured were; bunch weight, finger grade and length, starch, total soluble solids (TSS), sugars, total titratable acidity (TTA), pulp/peel ratio, colour, chlorophyll content, firmness, moisture content, weight loss, green life and shelflife. Banana bunches were also evaluated for cleanliness and bruise marks at harvest. Data were subjected to analysis of variance (ANOVA) using the general linear model (GLM) procedure of SAS statistical programme. The means were compared using Student Newman Keuls' test (SNK) and least significant difference (LSD) at significance level of 5%. Results showed that bunch covers did not influence finger grade, length and bunch weight at harvest. Colour, chlorophyll content, firmness, starch content, TSS, TTA, moisture content, weight loss, individual and total sugars and pulp/peel ratio at harvest and during ripening were not influenced by bunch covers. Bunch covers did not influence greenlife and shelflife significantly. Fruits grown under cover were more visually appealing, cleaner and had minimal bruises compared to the unbagged fruits. However, bunch covers had some detrimental effects on postharvest quality characteristics of banana fruits of the covered bunches compared to the fruits from the control, where few fingers of top hands of some bunches suffered sun burn. The study has shown that perforated dull and shiny blue bunch covers may be used in commercial banana orchards in Kenya to produce high quality fruits especially in the cooler areas.

Key words: Musa *spp*, polyethylene bunch covers, postharvest quality.

INTRODUCTION

In Kenya, banana is a major food and cash crop grown in almost all provinces (MOA, 2006). However, production has mainly been by subsistence farmers who rarely produce high quality fruits due to constraints such as diseases and pests coupled with traditional agronomic practices (Qaim, 1999; Acharya and Mackey, 2008). With the introduction of the tissue culture technology which availed virus disease-free plantlets, commercial banana production has greatly increased with a resultant increase in its volume and value. In 2006, 1,058,018 metric tonnes (MT) valued at KES 9,298,122,000 was produced in the country (MOA, 2006) compared to 1,024,360 tonnes (T) produced in 1996 to 1997 period (Qaim, 1999). Recently, farmers have been uprooting coffee due to problems in marketing in central and eastern provinces of Kenya. In Rift Valley of Kenya, farmers have also been uprooting citrus due to the greening disease to replace with banana orchards (Acharya and Mackey, 2008). This has translated into large volumes of the crop being produced at a commercial level. Establishing a tissue culture banana orchard is expensive compared to establishing an orchard using conventional suckers. This is attributed mainly to the high cost of the tissue culture planting material which is about seven times the average cost that the growers incur in acquiring conventional suckers (Qaim, 1999). There is therefore the need to produce high quality fruits of banana that are visually acceptable, have good postharvest quality attributes and therefore sell well in both local and international markets.

External appearance, internal quality and market quality of bananas are influenced by several factors, including pre-harvest production practices. The external appearance includes key attributes such as colour, shape, size and freedom from defects. The internal attributes such as taste, texture, sweetness, aroma, acidity, flavour, shelflife and presumed nutritional values of the fruit are important in ensuring repeat buys for sustained repeat purchase (Hewett, 2006; Shewfelt, 2009). The physical appearance of the peel is especially important in the highly competitive export markets and in some local niche upmarkets like the supermarkets. Buyers in these prime markets require consistent supplies of uniform coloured fruit with blemish-free peels. Banana bunch covers allow for production of high quality banana fruits that are not bruised, and hence have acceptable visual appearance. Consumers use visual quality to purchase fresh produce (Shewfelt, 1999; Shewfelt, 2009). Market returns for bananas in international markets are generally greatest for large fruit that are blemish-free (Johns, 1996).

The supply of blemish-free fruit is difficult due to various types of mechanical injury and insect damage imparted on the delicate peel surface during growth and development, with wind and insects being the principal agents of this damage (Anon, 2003). Pre-harvest insect feeding has been shown to be a main cause of peel damage to banana fruits (Shanmugasundaram and Manavalan, 2002). However, bagging of bananas with bags impregnated with insecticides has been shown to protect fruits from insect attack (Amarante et al., 2002).

Wind blows dust and debris which hits the delicate outer skin causing cellular damage and subsequent fruit scarring. Considerable physical injury and damage to the fruit peels can also be caused by the blowing of adjacent leaves and rubbing of leaf petioles onto the developing bunch (Anon, 2003). This chaffing from leaves during growth has also been reported to be eliminated by bunch covers (Weerasinghe and Ruwapathirana, 2002). Bunch covers of various colours and conditions (perforated and non-perforated) have been extensively used in both tropical and subtropical banana growing countries with the aim of improving yield and quality (Stover and Simmonds, 1987; Robinson, 1996). Improved quality includes appealing skin colour, reduced sunburn, reduced fruit splitting, increased finger length and bunch weight among others (Robinson, 1996; Amarante et al., 2002). Bunch covers have also been used to protect bunches from low temperatures, especially in temperate countries (Gowen, 1995; Robinson, 1996; Harhash and Al-Obeed, 2010). Indeed bagging has been shown to reduce winter stress under supra-optimal condition which resulted in early fruit maturation (Jia et al., 2005). This is due to enhanced physiological and metabolic activities provided by the microclimate created by bagging (Johns and Scott, 1989a).

However, the effect of fruit bagging, especially in the tropics, on size, maturity, skin colour among other postharvest parameters has been contradictory, which may reflect differences in the type of bag used, fruit age at bagging, fruit and cultivar response, prevailing climatic conditions and conditions of holding fruit after harvest (Johns and Scott, 1989a; Amarante et al., 2002; Weerasinghe and Ruwapathirana, 2002; Narayana et al., 2004). Technologies such as bunch covering that enhance production and help realize the benefits of tissue culture technology would go a long way in boosting commercial banana farming in Kenya where bunch covering has not been extensively practiced. Recently, a few farmers have attempted this practice in collaboration with importers of the bunch covers (K. Njiba, commercial banana farmer, personal communication). However, the effect of the covers on the postharvest quality of tissue-cultured bananas in Kenya has not been studied. The objective of this study therefore was to investigate the effect of bunch covering on postharvest quality of tissue-cultured banana fruits using cv. Williams as the test variety.

RESEARCH AREA AND MATERIALS

The trial was carried out in an already existing banana orchard in Maragwa District, in central province of Kenya. Nine bunches of banana cultivar (cv.) Williams were randomly selected and tagged. The fruits were grown using the recommended banana growing

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procedures (Anon, 2002). Perforated dull blue and shiny blue bunch covers were applied to the bunches when the flower bracts had hardened and the hands had started to curl upwards. The bunch covers had perforations measuring 8 mm spaced at 10.5 x 9 cm and a thickness of 5µm and were left to hang for about 150 mm below the distal hands and were securely attached to the bunch stalk above the proximal hand using a rubber band. Some of the tagged bunches were not covered and they served as a control.

Experimental layout and design

The treatments were applied randomly and were replicated three times. The banana fruits were allowed to grow to full ¾ maturity stage and were harvested, dehanded, placed in plastic crates and then transported to the postharvest laboratory of Jomo Kenyatta University of Agriculture and Technology.

Data collection and analysis

Parameters measured at harvest were bunch weights, finger grade and finger length. The fruits were also assessed for general visual appearance, dirt, bruises (blemishes), spider webs and bird droppings. The fruits were then washed with tap water and dipped in 100 ppm sodium hypochlorite (Jik, Reckitt Benckiser-East Africa Limited, Kenya) in order to control postharvest rots such as anthracnose and crown rot, and then air dried. The fruits were then ripened in a ripening chamber at 18˚C and 95% RH using ripe purple passion fruit as the ethylene source. Five fingers per replicate were placed on the bench for green life at ambient conditions of temperature (24 ± 1˚C) and humidity (60± 5%). Parameters measured during ripening were: starch, total soluble solids (TSS), sugars, total titratable acidity (TTA), pulp/peel ratio, colour, chlorophyll content, firmness, moisture content and weight loss. The fruits were also evaluated for green life and shelflife. Data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of SAS statistical programme (SAS, 2001). All the means were compared using Student Newman Keuls' test (SNK) except for green life, shelflife and dirt which were compared using Least Significant Difference (LSD). All means were compared at 5% significance level.

Determination of fruit weight, length and diameter (grade)

All three bunches were dehanded and the hands weighed to give the bunch weights. Three fruits from the second hand in the three bunches per plot were weighed with an electronic balance (Type 1240, Shimadzu, Japan) to give the finger weights. Finger length was measured using a tape measure while finger grade was measured with a caliper (CD-20C, Mitutoyo, Japan) as diameter of the middle finger of the outer whorl of the second hand (Stover and Simmonds, 1987).

Evaluation of visual appearance

The fruits were checked for incidences of dirt, which included, dust, bird droppings and spider webs and mechanical injuries (blemishes). They were also checked for general visual appearance. Percentage surface area covered was rated based on the Merz 0 to 6 scale (Merz, 2000), adopted for surface area covered by dirt instead of lesions where, 1=0 to 2%, 2=2 to 5%, 3=5 to 10%, 4=10 to 25%, 5=25 to 50% and 6=>50% of the surface area covered by the blemishes, dust and spider webs.

Determination of pulp:peel ratio

Pulp:peel ratio was calculated after measuring the pulp and the peel weights with an electronic balance (Type 1240, Shimadzu, Japan) for both green and ripe fruits. Three fingers from the equatorial region hands per bunch were peeled and the pulp and peel weighed separately. The ratio was calculated as weight of pulp (g) per weight of peel (g).

Determination of starch content

Starch staining was done by cutting the banana fruits across at the equatorial region of the fruit, applying iodine/potassium iodide (I/KI) (2g/10g) solution and waiting for at least one minute for starch patterns to develop and rating using the Cornell Starch Chart (Watkins, 2006) for comparison. This chart has a scale of 3 to 8 with 3 = all starch and 8 = no starch.

Ripening

Two to three hands per bunch from the equatorial region were ripened in a ripening chamber at 18˚C and 95% RH using ripe passion fruit as ethylene source until ripeness stage 6 when the fruit was fully yellow (CSIRO, 1972; Marin et al., 1996; Paull, 1996; Jiang et al., 1999).

Determination of firmness

This was determined at harvest and during ripening. Both subjective and objective methods were used. Hand firmness assessment was carried out using the scale 1 = hard, 2 = firm, 3 = slightly soft, 4 = moderately soft, 5 = soft and 6 = very soft (Joyce et al., 1993; Jiang et al., 1999). Objective fruit firmness measurement was determined along three equatorial regions of the fruit: at the base, middle and apical sections of the fruit using a rheometer (Model CR-1000, Sun Scientific Co. Ltd, Japan) with an 8 mm probe for fruit at harvest and during ripening. The average of these three measurements was considered as one replicate firmness was expressed as Newton (N) (Joyce et al., 1993; Jiang et al., 1999).

Determination of moisture content

The pulp and the peel were analysed for moisture content from green stage through to fully ripe stage using oven drying method (AOAC, 1996).

Determination of weight loss

Three fingers per treatment were placed on the bench at ambient conditions of temperature (24 ± 1˚C) and humidity (60 ± 5%). Weight loss was determined by weighing the fingers every day from green to yellow stage. The initial weight (W1) of the fruit at day 0 and the weight of the same fruit (W2) at each sampling day were noted. Weight loss in percentage was then calculated as 100X (W1-W2)/W1.

Colour assessment

Subjective colour was determined at harvest and during ripening. Visual colour assessment was carried out using the scale of 1 to 8 where 1 = green, 2 = light green, 3 = half yellow half green, 4 = 3/4 yellow with green, 5 = yellow with green tip, 6 = fully yellow, 7 =

Table 1. Effect of bunch covers on finger grade (mm), finger length (cm) and bunch weight (kg) of tissue culture banana cv. Williams.

Treatment	Grade (mm)	Finger length (cm)	Bunch weight (kg)
Control	30.94 [a]	19.07 [a]	8.62 [a]
Dull blue	33.33 [a]	20.03 [a]	10.44 [a]
Shiny blue	33.44 [a]	20.37 [a]	9.16 [a]
LSD	ns	ns	ns

Values in the column followed by the same letter are not significantly different at p=0.05. Values are means of 3 replicates.

yellow with spots and 8 = yellow with coalesced black spots (CSIRO, 1972; Marin et al., 1996; Paull, 1996; Jiang et al., 1999). Colour of both the pulp and peel at ripeness stage 1 to 6 were measured using a Minolta colour difference meter (Model CR-200, Osaka, Japan) calibrated with a white and black standard tile. Measurements were made on three spots along the equatorial region and the average of these considered as a replicate. The L*, a* and b* coordinates were recorded and, a* and b* values converted to hue angle (H°), where H°= (arc tan(b/a), for first quadrant +a and +b, 180+arc tan (b/a) for second quadrant (-a, +b) and third quadrant (-a,-b) and hue=360+arc tan (b/a) for fourth quadrant (Mclellan et al., 1995).

Determination of chlorophyll content

This was determined using the method of Arnon (1949) with a uv-visible spectrophotometer (Model UV mini 1240, Shimadzu Corp. Kyoto, Japan). Total chlorophyll in the crude extract was calculated using MacKinney's coefficients after measuring absorbances at 645 and 663 nm and calculated as follows:

Total chlorophyll content (µg/g) = $20.2A_{645} + 8.02A_{663}$

Determination of total soluble solids content

Total soluble solids content was measured at harvest and during ripening until colour stage 6. Three fingers from the equatorial region hands were used for TSS determination. Total soluble solids content was determined using Atago hand refractometer (Type 500, Atago, Tokyo, Japan). A scoop of banana pulp from the apical, middle and basal part of the fruit was placed on a muslin cloth separately, and a drop of it squeezed out onto the refractometer. Readings were taken in °Brix.

Determination of sucrose, fructose and glucose contents

Sugars were analysed using the AOAC method (1996). Sugars were measured at harvest and during ripening to the fully ripe stage. Ten grams of the fruit was refluxed in ethanol for one hour. The sample was then concentrated with rotary evaporator and diluted with 75% acetonitrile. The individual sugars were analyzed using a high performance liquid chromatograph (HPLC) (Model LC-10AS, Shimadzu Corp., Kyoto, Japan) using a refractive index (RI) detector. Conditions included oven temperature, 35°C, recorder speed: 3, attenuation: 2, range: 4 and flow rate: 0.5 ml/min.

Determination of total titratable acidity

Total titratable acidity (TTA) was measured at harvest and during ripening using the AOAC method (1996). Total titratable acidity was determined by titration with 0.1N NaOH in the presence of phenolphthalein indicator and expressed as percent malic acid.

Determination of green life

Fifteen fingers from the equatorial region hands were placed on a bench at ambient conditions of temperature (24 ± 1˚C) and humidity (60 ± 5%). Five fingers served as a replicate. Green life was determined as the number of days taken by half of the fruits of one hand to progress from green stage to turning to a yellow tinge as described by Peacock and Blake, (1970) and Dadzie and Orchard, (1997).

Determination of shelflife

Fifteen fingers from the equatorial region hands were placed on a bench at ambient conditions of temperature (24±1˚C) and humidity (60± 5%). Five fingers served as a replicate. Shelflife was then determined as the number of days taken by the fruit to progress from ripeness stage 6 to 8 (CSIRO, 1972; Marin et al., 1996; Paull, 1996; Jiang et al., 1999).

RESULTS AND DISCUSSION

Effect of bunch covers on grade, finger length and bunch weight

Bunch bagging had no significant (p>0.05) effect on grade, finger length and bunch weight (Table 1). This confirms earlier findings (ShihChao et al., 2004) that polyethylene bunch covers do not influence grade, finger length and bunch weights. Similar observations had earlier been reported (Vilela et al., 2001). This contradicts earlier findings where, for banana cv. robusta grown under high density production system, finger diameter (grade) and weight were significantly increased by polyethylene bunch covers (Reddy, 1989). Also, in South Africa, a 16.5% increase in 'Williams' bunch mass was recorded due to a 10% increase in finger length. This may have been due to increased temperatures (0.5˚C) under blue covers that favoured growth (Robinson, 1996). Banana bunches sealed with polyethylene bags had increased fruit size at harvest (Amarante et al., 2002; Weerasinghe and Ruwapathirana, 2002). However, bagging some fruits such as lychee and mangoes had no effect on fruit weights (Amarante et al., 2002). Research

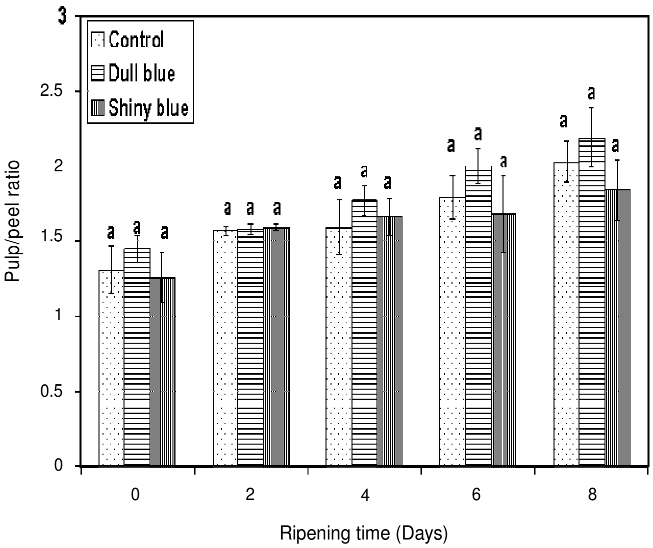

Figure 1. Pulp/peel ratio during ripening of cv. Williams fruits. Vertical bars represent SE of the mean of 3 replicates**.** Means denoted by the same letters in the same day have no significant difference at p=0.05.

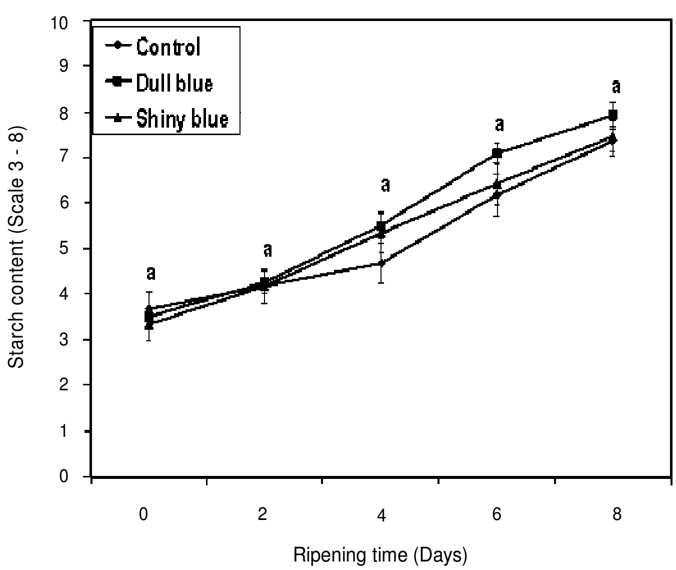

Figure 2. Effect of bunch covers on starch content of cv. Williams banana fruits using the Cornell Starch Chart scale 3 to 8 where 3= all starch and 8= no starch. Vertical bars represent SE of the mean of 3 replicates. Same letters at different periods indicate no significant difference at p=0.05.

reports on bagging of fruits have given contradictory information on the effect of bagging on both physical and compositional quality of fruits (Amarante et al., 2002) which may reflect differences in cultivar, bagging material and climatic conditions. In the current study, the covers were perforated and may not have increased the temperatures considerably to influence the parameters.

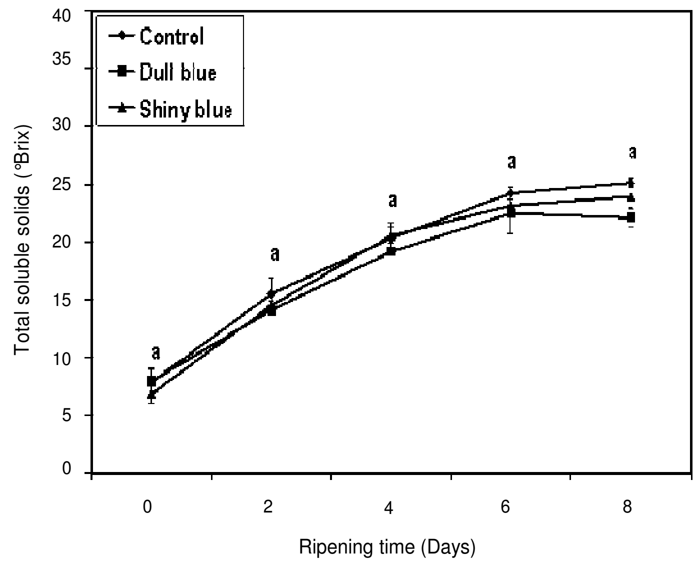

Figure 3. Effect of bunch covers on total soluble solids content (º Brix) of cv. Williams banana fruits during ripening. Vertical bars represent SE of the mean of 3 replicates. Same letters at different periods indicate no significant difference at p=0.05.

Effect of pre-harvest bunch covers on pulp/peel ratios

Bunch covering had no significant (p>0.05) effect on the pulp/peel ratios of fruits of cv. Williams at harvest and during ripening (Figure 1). In bananas, the pulp portion continues to grow even in the later stages of maturation (Turner, 1997; Nakasone and Paull, 1998).

Effect of pre-harvest bunch covers on starch and total soluble solids

Both starch and total soluble solids (TSS) at harvest and during ripening were not influenced significantly (p>0.05) by bunch covers (Figures 2 and 3). Starch reduced as ripening progressed while TSS increased as expected in ripening banana (Stover and Simmonds, 1987). Unripe bananas have large amount of starch, with a content of 20 to 25% found in the pulp of the fruit (Nascimento et al., 2006). During the climacteric stage, the accumulated polysaccharide is rapidly degraded and most of it is converted into soluble sugars which form a large proportion of TSS in the banana (Marriot, 1980; Seymour et al., 1993).

Bagging, however, did not influence the starch formation during banana growth and starch degradation during ripening considerably in this study. Starch degradation in control fruits grown covered and uncovered proceeded normally in this study. However, in apples, bagging reduced starch content and fruit soluble solids at harvest (Proctor and Lougheed, 1976; Mattheis

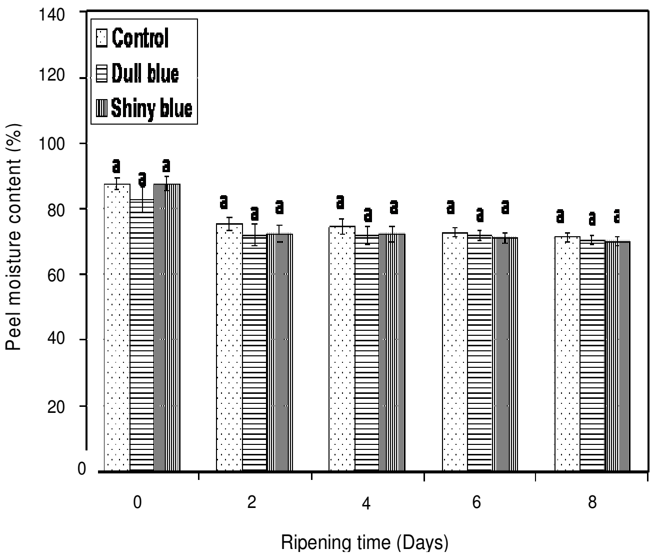

Figure 4. Effect of bunch covers on peel moisture content (%) of cv. Williams banana fruits during ripening. Vertical bars represent SE of the mean of 3 replicates. Means denoted by the same letters in the same day have no significant difference at p=0.05.

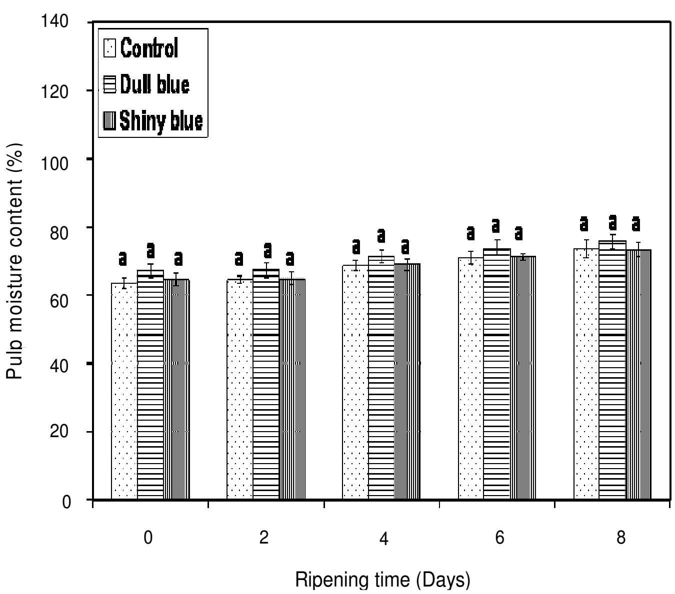

Figure 5. Effect of bunch covers on pulp moisture content (%) of cv. Williams banana fruits during ripening. Vertical bars represent SE of the mean of 3 replicates. Means denoted by the same letters in the same day have no significant difference at p=0.05.

and Fellman, 1999). In other reports, panicle bagging of lychee was found to have no effect on total soluble solids (Tyas et al., 1998). Elsewhere, fruit ripening for mangoes was enhanced by preharvest bagging although there was no effect on TSS and sensory quality at the postharvest stage for the bagged and unbagged fruits (Hoffman et al., 1997).

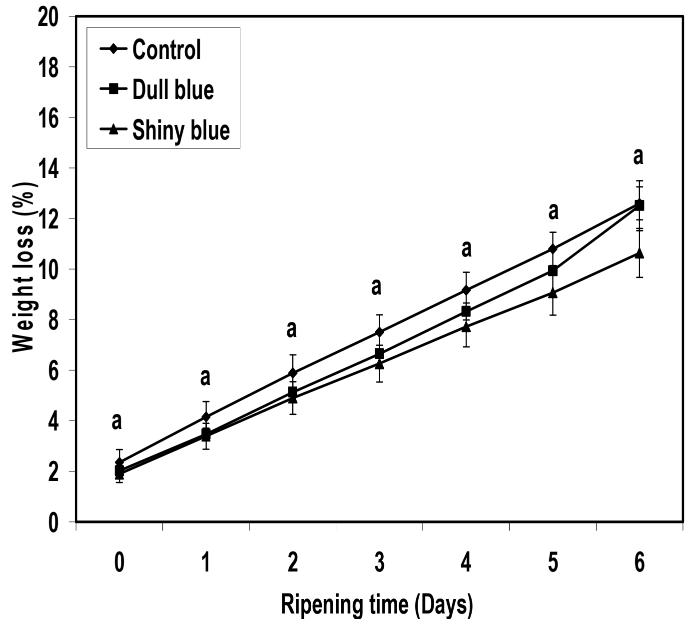

Figure 6. Effect of bunch covers on changes in percentage weight loss of cv. Williams banana fruits during ripening. Vertical bars represent SE of the mean of 3 replicates. Same letters at different periods indicate no significant difference at p=0.05.

Effect of pre-harvest bunch covers on fruit moisture content and weight loss

Fruits from the bagged and non bagged treatments had similar moisture contents for peel (Figure 4) and pulp (Figure 5) at harvest and during ripening. Changes in weight loss of fruits during ripening were not significantly (p>0.05) influenced by bunch covers (Figure 6). Moisture content of the peel reduced gradually during ripening while that of the pulp increased with ripening. Percentage fruit weight loss increased with days of storage in all the treatments. During normal ripening, the banana peel loses water to both the pulp and the atmosphere (Stover and Simmonds, 1987; Burdon et al., 1994).

Fruit weight loss is attributed to physiological weight loss due to respiration, transpiration and other biological changes taking place in the fruit during ripening (Rathore et al., 2007). Fruit surfaces are covered by cuticle covers which restrict water loss through transpiration, also. Fruits from the bagged and control bunches may have had similar cuticle structures (Amarante et al., 2002). Since the bunch covers in the current study had perforations, it is possible that the control and fruits grown under cover had similar humidity environment during growth and after harvesting. Similar observations were recorded in pears between fruits grown under perforated covers and control ones where both the moisture content and weight loss were not significantly (p>0.05) affected by pre-harvest bagging as they had similar skin permeability due to similar wax content of the cuticle (Amarante et al., 2002).

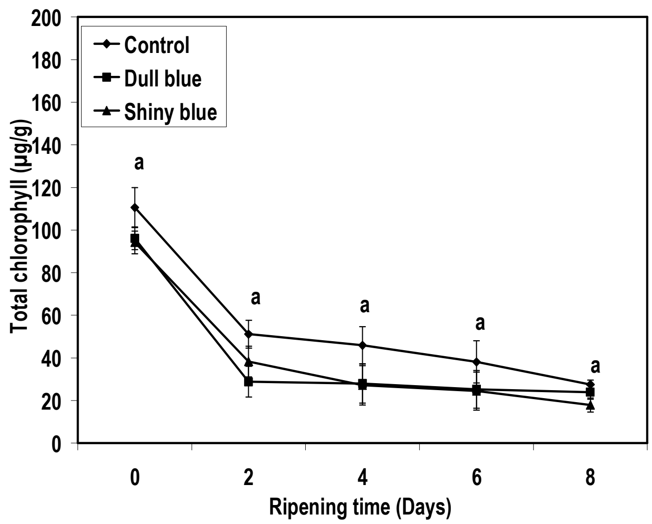

Figure 7. Effect of bunch covers on changes in peel chlorophyll degradation (µg/g) of cv. Williams banana fruits during ripening. Vertical bars represent SE of the mean of 3 replicates. Same letters at different periods indicate no significant difference at p=0.05.

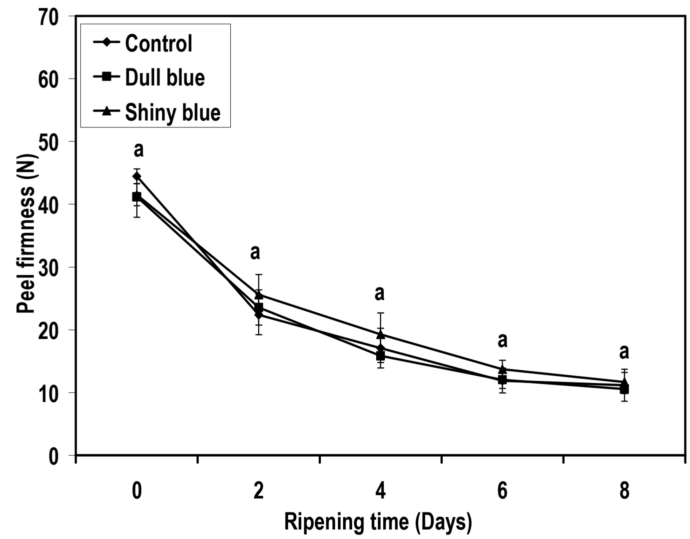

Figure 9. Effect of bunch covers on changes in objective peel firmness (N) of cv. Williams banana fruits during ripening. Vertical bars represent SE of the mean of 3 replicates. Same letters at different periods indicate no significant difference at p=0.05.

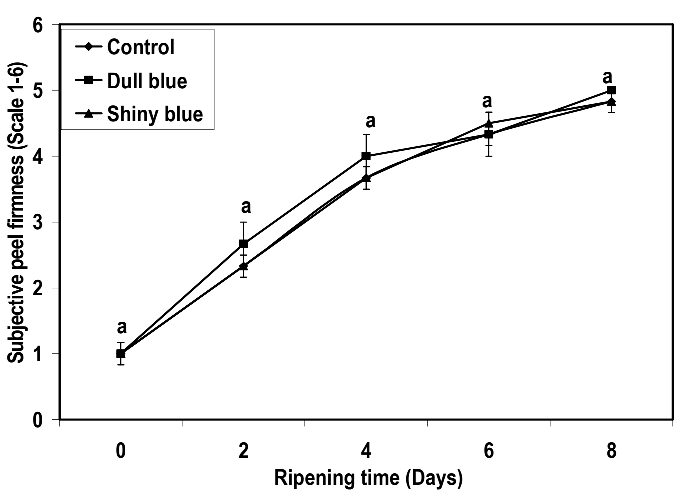

Figure 8. Effect of bunch covers on subjective firmness of cv. Williams banana fruits during ripening using the scale 1 to 6 where 1 = hard, 2 = firm, 3 = slightly soft, 4 = moderately soft, 5 = soft and 6 = very soft (Joyce et al., 1993). Vertical bars represent SE of the mean of 3 replicates. When absent, the SE fall within the dimensions of the symbol. Same letters at different periods indicate no significant difference at p=0.05.

Effect of pre-harvest bunch covers on total chlorophyll content

Effect of bunch covers on total chlorophyll content was not significant at harvest and during ripening (Figure 7). Chlorophyll content generally decreased on ripening as the fruits turned yellow. This is as a result of chlorophyll degradation and/or unmasking of the yellow carotenoids or synthesis of new pigments (Gray et al., 2004). Bunch bagging had no effect on the chlorophyll degradation. The pigment has been shown to be converted to colourless non-fluorescent chlorophyll catabolites in a pathway that is probably active in all higher plants (Gray et al., 2004). Variable results in pigment development in fruits due to bagging have been reported. Bananas grown under non-perforated blue transparent polyethylene, non-transparent blue polythene, non-transparent black polythene and without covers had green, pale green, glossy white and dark green peel which probably affected the chlorophyll content of the peel (Shanmugasundaram and Manavalan, 2002).

Anthocyanin accumulation and red colour development of the skin was reduced by bagging (Hoffman et al., 1997; Joyce et al., 1997; Fan and Mattheis, 1998) while other reports indicate increased red colour development in apples (Wang et al., 2000) and pears (Amarante et al., 2002). This may reflect differences in the type of bagging material and whether perforated or not perforated. In this study, the bags were translucent blue and were perforated and hence allowed light penetration which may explain why bagging did not affect the chlorophyll content.

Effect of pre-harvest bunch covers on peel and pulp firmness

Peel and pulp firmness measured objectively and subjectively were not significantly different (p>0.05) in all the treatments at harvest and during ripening (Figures 8, 9 and 10). Firmness decreased rapidly during ripening, and

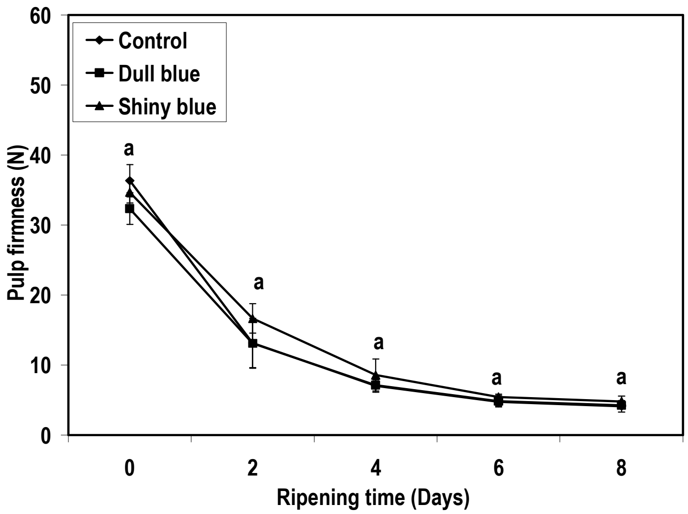

Figure 10. Effect of bunch covers on changes in objective pulp firmness (N) of cv. Williams banana fruits during ripening. Vertical bars represent SE of the mean of 3 replicates. When absent, the SE fall within the dimensions of the symbol. Same letters at different periods indicate no significant difference at p=0.05.

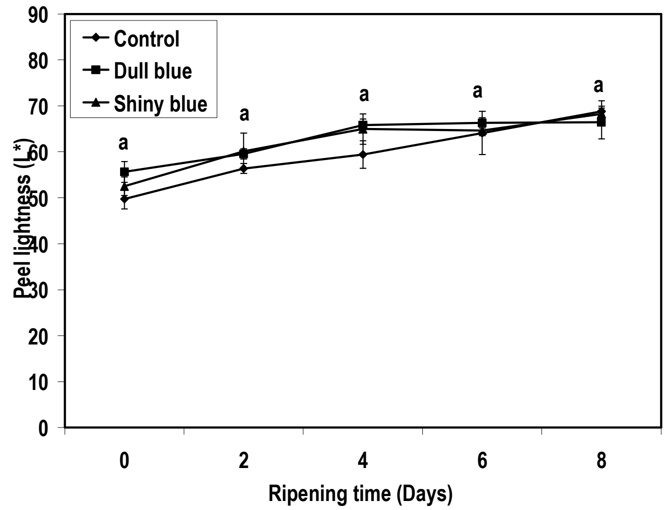

Figure 12. Effect of bunch covers on changes in peel lightness (L*) of cv. Williams banana fruits during ripening. Vertical bars represent SE of the mean of 3 replicates. When absent, the SE fall within the dimensions of the symbol. Same letters at different periods indicate no significant difference at p=0.05.

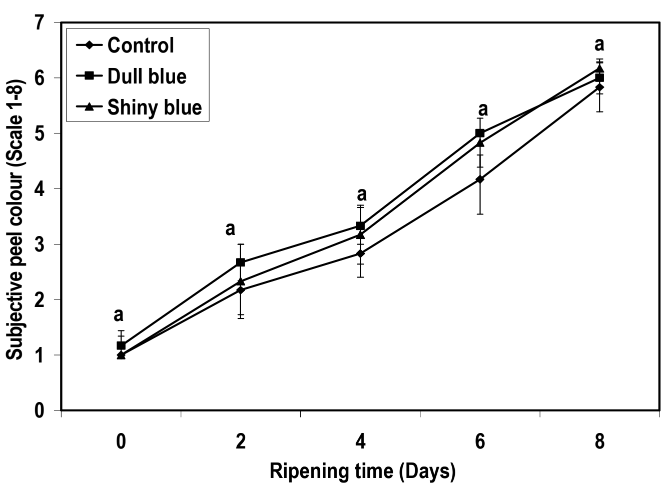

Figure 11. Effect of bunch covers on subjective peel colour of cv. Williams fruits during ripening using the scale of 1 to 8 where 1=green, 2=light green, 3=half yellow half green, 4=3/4 yellow with green, 5=yellow with green tip, 6=fully yellow, 7=yellow with spots and 8=yellow with coalesced black spots (CSIRO, 1972; Turner, 1997). Vertical bars represent SE of the mean of 3 replicates. When absent, the SE fall within the dimensions of the symbol. Same letters at different periods indicate no significant difference at p=0.05.

gradually after ripening of the fruits. Bagging did not change the peel and pulp properties considerably in this study. However, bagging of fruit reduced fruit firmness in the postharvest stage for bananas (Berill, 1956) while it had no effect on firmness at harvest although it enhanced loss of firmness during cold storage for pears (Amarante et al., 2002). The variable results reported on the effect of bagging on fruit firmness at harvest and postharvest stage may reflect differences in the cultivar, type of bag, duration of cover, storage conditions and methods of testing for fruit firmness. In mangoes, opaque white plastic bags hastened softening of the skin while white waterproof paper bags did not have this effect (Joyce et al., 1997). When non-destructive methods of assessing peel firmness are performed over the fruit skin, they mainly reflect the changes in skin properties. Differences in softening may reflect differences in skin composition and structure between treatments affecting loss of cell wall integrity (Amarante et al., 2002). In this study, the bags were perforated and translucent and probably did not change the skin properties compared to the control.

Effect of pre-harvest bunch covers on colour

Subjective colour at harvest and during ripening was not influenced significantly (p>0.05) by bunch covers for both banana cultivars (Figure 11). Likewise, objective colour (L* and hue angle values) of both peel and pulp were not affected by bagging in the current experiment (Figures 12, 13, 14 and 15). The peel changed from green to yellow as the chlorophyll was degraded to unmask the yellow carotenoids (Gray et al., 2004) hence influencing the lightness of the peel positively on ripening. Therefore, L* value increased for the peel but decreased for the pulp on ripening as the peel degreened and the pulp turned from whitish to cream. Hue angle decreased for the peel also due to the change of the peel colour from green to yellow. Several reports have documented that bagging fruit increased skin lightness (Fan and Mattheis, 1998)

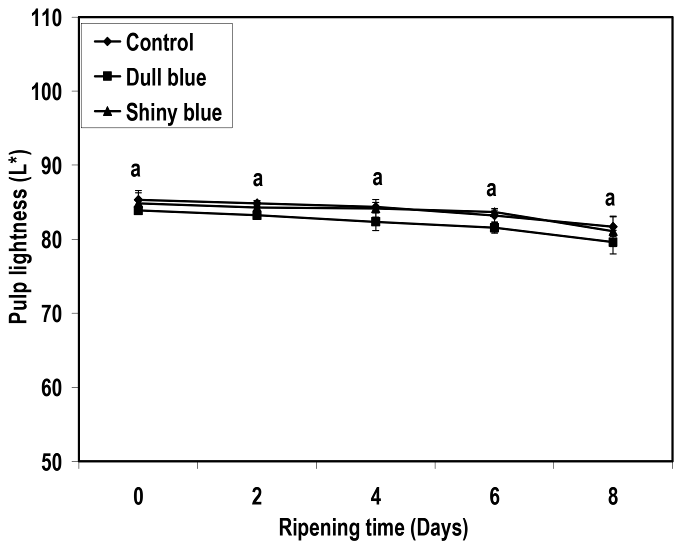

Figure 13. Effect of bunch covers on changes in pulp lightness (L*) of cv. Williams banana fruits during ripening. Vertical bars represent SE of the mean of 3 replicates. When absent, the SE fall within the dimensions of the symbol. Same letters at different periods indicate no significant difference at p=0.05.

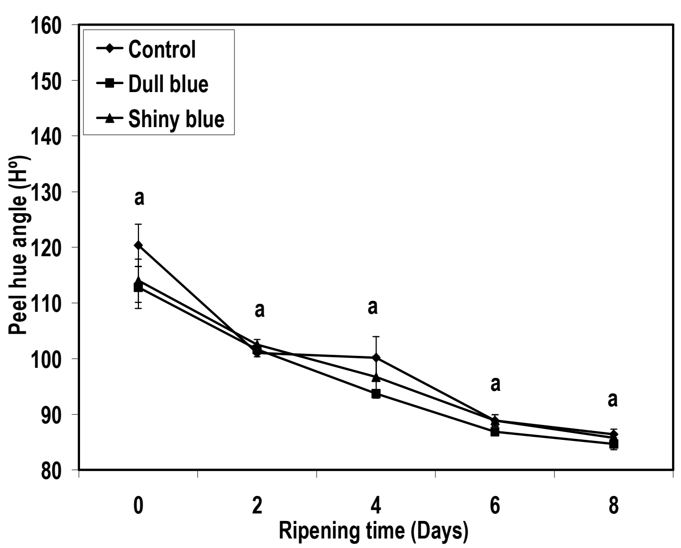

Figure 14. Effect of bunch covers on changes in peel hue (Hº) of cv. Williams banana fruits during ripening. Vertical bars represent SE of the mean of 3 replicates. When absent, the SE fall within the dimensions of the symbol. Same letters at different periods indicate no significant difference at p=0.05.

which shows that bagging has different effects on different fruit cultivars.

The difference in effects on colour may also be dependent on type and duration of bagging. Other workers showed that preharvest bagging of pears with micro-perforated polypropylene bags resulted in fruits with a more attractive light green colour and did not reduce blush on the exposed side of the skin (Amarante

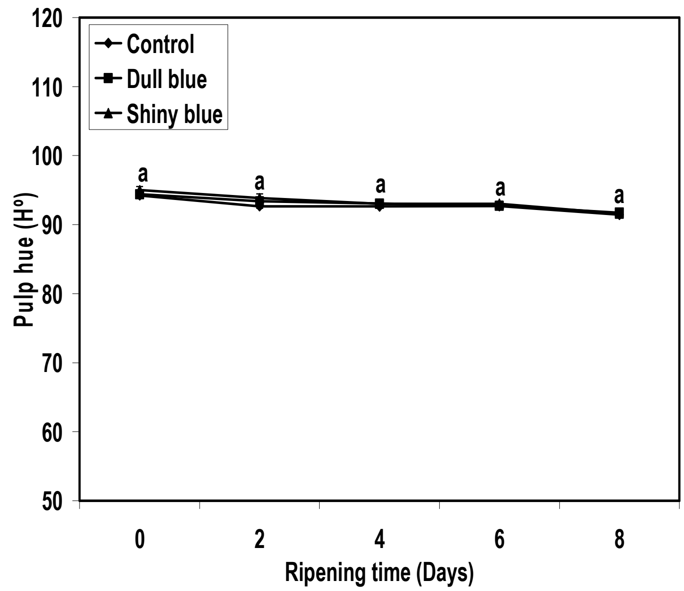

Figure 15. Effect of bunch covers on changes in pulp hue (Hº) of cv. Williams banana fruits during ripening. Vertical bars represent SE of the mean of 3 replicates. When absent, the SE fall within the dimensions of the symbol. Same letters at different periods indicate no significant difference at p=0.05.

et al., 2002). Unbagged lychee fruits had had lower intensity of colour (lower C*) than those bagged for 80 days but not different from those bagged for 20 and 42 days. The covers applied to the banana bunches in the current study were translucent and perforated and therefore did not cause substantial modification of bag internal atmosphere to reduce chlorophyll accumulation and hence colour. Pear fruits bagged with micro-perforated transparent plastic bags had similar anthocynin content hence similar skin colour with control fruits probably due to the fact that the bags did not cause significant changes in internal atmosphere to reduce anthocyanin accumulation (Amarante et al., 2002). When bagging affects fruit colour components significantly, then the visual colour is also affected probably due to the influence of the bag on radiation and temperature and consequently pigment production (Tyas et al., 1998).

Effect of pre-harvest bunch covers on sugar content

Both individual and total sugar contents were not significantly (p>0.05) influenced by covers (Figure 16 and 17). Noro et al. (1989) reported results where only fructose was affected by bagging in apples with bagged fruits having higher content while other main sugars were not affected. Watson et al. (2002) have reported that pre-harvest shading of strawberry fruits caused a significant reduction in sucrose and glucose/fructose contents compared to fruits from unshaded treatments. In the later experiment, shade netting was used which blocked some

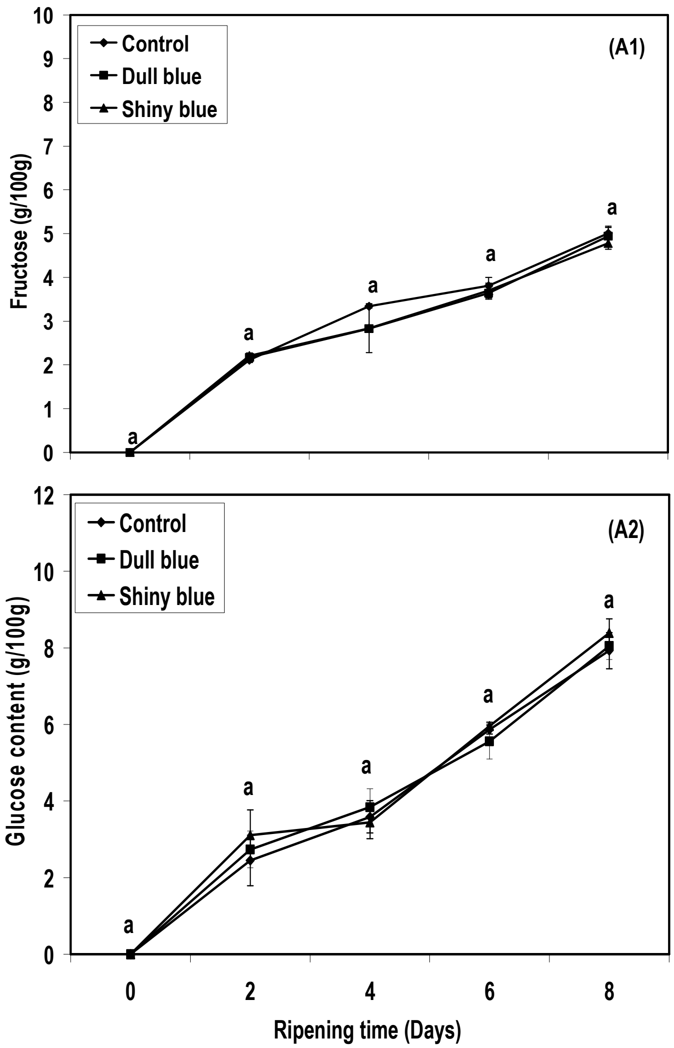

Figure 16. Effect of bunch covers on changes in fructose (A1) and glucose (A2) content of cv. Williams banana fruits during ripening. Vertical bars represent SE of the mean of 3 replicates. When absent, the SE fall within the dimensions of the symbol. Same letters at different periods indicate no significant difference at p=0.05.

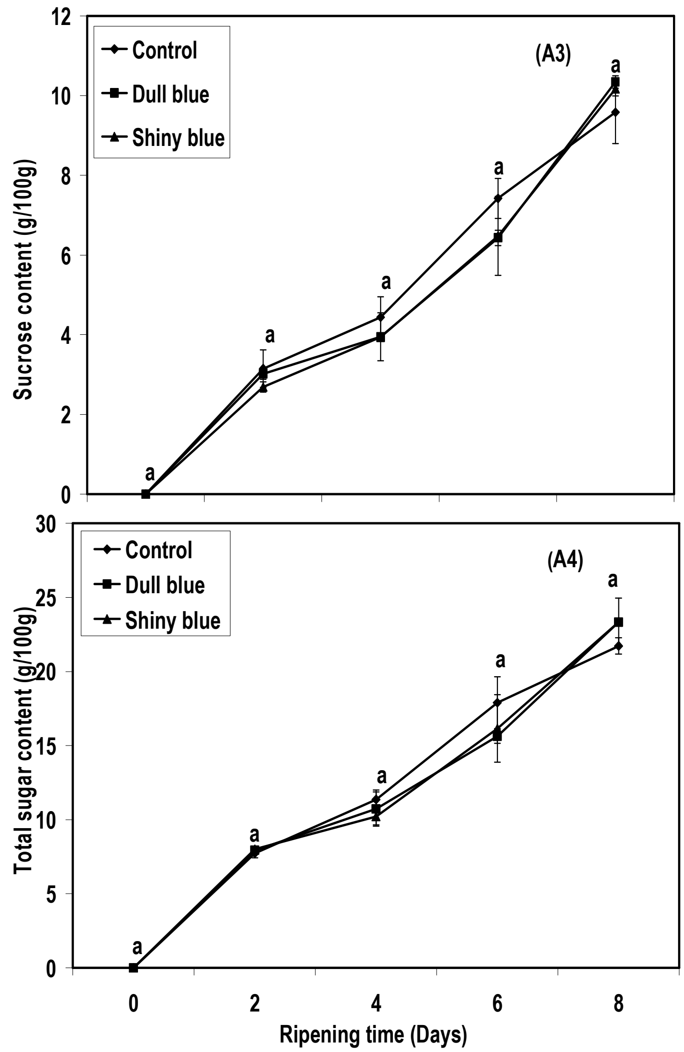

Figure 17. Effect of bunch covers on changes in sucrose (B3) and total sugars (B4) content of cv. Williams banana fruits during ripening. Vertical bars represent SE of the mean of 3 replicates. When absent, the SE fall within the dimensions of the symbol. Same letters at different periods indicate no significant difference at p=0.05.

percentage of light from reaching the crop and hence may have affected such processes as photosynthesis and ultimately sugar synthesis. In the current study, the covers probably allowed enough light and hence did not interfere with starch/sugar synthesis. Blue polyethylene covers have been shown to allow blue-green and ultraviolet lights and also infrared rays (ShihChao et al., 2004). Light exposure of 'Sunscrest'/GF 677peaches resulted in increased reducing sugars content (Watson et al., 2002). Covering grapes with cellulose bags was shown to reduce sugar content in the fruits compared to the uncovered control (Signes et al., 2007). The inconsistent result in effect of bagging on sugar content may be due to different cover materials, fruit cultivars and holding environment after harvest.

Effect of pre-harvest bunch covers on green life and shelflife

Bunch covers did not influence green life and shelflife significantly (p>0.05) (Table 2). Research reports on bagging of fruits have given contradictory information on the effect of bagging on both physical and compositional quality of fruits. Narayama et al., (2004) found bagging of bananas coupled with postharvest hot water treatment and storing with ethylene absorbent to be beneficial in extending shelflife. Elsewhere, banana grown under bunch covers had delayed ripening (Scott et al., 1971; Johns and Scott, 1989a) which may have possibly influenced green life. Fruit bagging has also been shown to adversely affect fruit quality. Sealed plastic covers

Table 2. Storage of tissue-cultured banana cultivar Williams as influenced by bunch covers.

Treatment	Green life (Days)	Shelf life (Days)
Control	14.67 ^{a}	5.33 ^{a}
Dull blue	10.33 ^{a}	3.67 ^{a}
Shiny blue	11.67 ^{a}	4.33 ^{a}
LSD	ns	ns

Values in the column followed by the same letter are not significantly different at p=0.05. Values are means of 3 replicates.

Table 3. Effect of bunch covers on bunch area covered by blemishes, dust, spider webs and bird droppings of tissue-cultured banana cv. Williams using Merz 0-6 scale (Merz, 2000), adopted for surface area covered by dirt instead of lesions where, 1=0 to 2%, 2=2 to 5%, 3=5 to 10%, 4=10 to 25%, 5=25 to 50% and 6= >50% of the affected surface area.

Treatment	Area covered by blemishes (scale 0 to 6)
Control	6 ^{a}
Dull blue	2 ^{b}
Shiny blue	2^{b}
LSD	1.15

Values in the column followed by the same letter are not significantly different at p=0.05. Values are means of 3 replicates.

delayed bunch maturity of bananas (Scott et al., 1971). Fruit ripening for mangoes was enhanced by bagging (Hoffman et al., 1997) which may have affected the green life. Banana bunches sealed with polyethylene covers during fruit growth delayed ripening (John and Scott, 1989b) probably due to delayed fruit development as a result of modification of atmosphere inside the sealed covers (John and Scott, 1989a). The covers used in the current study were perforated and translucent and hence did modify the atmosphere considerably to affect the green life and shelflife significantly.

Effect of pre-harvest bunch covers on visual appeal

Bagged banana fruits in the current experiment had minimal bruises (2 to 5%) and were significantly cleaner from dust, spider webs and bird droppings at harvest compared to the unbagged fruits (>50%) (Table 3) based on the Merz 0 to 6 scale (Merz, 2000). The covered fruits were therefore more visually appealing, cleaner compared to the unbagged fruits (Plate 1). This agrees with Weerasinghe and Ruwapathirana (2002) who found out that banana fruits grown under covers had no blemishes at all and were attractive to consumers at a glance while unbagged fruits had black spots and blemishes caused by thrips and freckle fungi attacks.

Similarly, postharvest fungal attack on lychee fruit was

(A) (B)

Plate 1. Visual appearance of banana cultivar Williams fruits grown unbagged (A) and bagged (B) at harvest.

Plate 2. Sunburn of fruits of top hands caused by shiny blue covers of banana cultivar Williams during growth.

also reduced by bagging (Kooariyakul and Sardsud, 1997). However, a few of the covered fruits suffered sunburn which adversely affected fruit quality (Plate 2) especially during the hot season. This affected the bunches which were not well covered by leaves during growth. Top hands were mainly affected especially those of bunches covered with dull blue covers probably due to more heat absorbed inside the cover compared to the shiny blue covers which may have reflected some heat away.

Elsewhere, bagging of bananas resulted in sun scorching of the fruits irrespective of the colour of the bunch covers (Weerasinghe and Ruwapathirana, 2002). However, this can be overcome by maintaining enough leaves on the plant to shade the plant and also by using reflective blue covers (Anon, 2003). Pulling leaves over the covered bunches during growth may also reduce/

prevent sunburn. Inserting a newspaper on the inside of the bunch covers to cover top hands to prevent them from sun scorch has been shown to work (Linbing et al., 2004). The blue polyethylene covers have been shown to absorb more blue-green and ultraviolet lights which may cause sunburn to banana fruits (ShihChao et al., 2004)

Conclusion

The study has shown that perforated dull and shiny blue bunch covers may be used in commercial banana orchards in Kenya to produce high quality fruits. The physical and biochemical properties of the banana fruits were not adversely affected by the bunch covers. Also, the fruits grown covered were more visually appealing as they were clean and had minimal bruises compared to those grown uncovered which implies reduced water usage during postharvest preparation of the fruits. However, the bunch covers caused sun scald of a few top hands during the hot months. Bunch covers may therefore be useful mainly in the cooler months of the year and also in cooler climates where sunburn may not be a major concern. However, the use of bunch covers should be coupled with proper postharvest handling procedures to ensure that the clean, visually appealing fruits are not bruised during the postharvest period. Such fruits could also be targeted for the export market where they may fetch better prices as the consumer clientele appreciates the visually appealing fruits and are willing to pay more for such fruits. A cost benefit analysis also needs to be done to find out whether banana bagging is profitable in Kenya. This work should also be carried out in other agro-ecological zones in the country such as in Upper midland zones 1 and 2 (UM1 and UM2), especially the cooler banana growing areas in the Meru region in Eastern Province. Other banana varieties may also be tested as they may exhibit differences in the way they are affected by the sun.

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