Effect of packaging materials on weight loss and nutrient quality changes of rechanded sweet potatoes (*Ipomoea batatas* Poir) during short-term storage

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ABSTRACT

The effects of packaging materials on weight loss and nutrient quality changes of recharged (submerged in clean tap water) sweet potatoes (*Ipomoea batatas* Poir) roots during storage were determined. Sweet potatoes from two genotypes, 'KEMB 10' and 'Yanshu' were recharged for 14 hours and packaged in perforated polyethylene bags (0.02 mm), Kraft paper bags (0.025 mm) and nylon gunnysacks, with roots placed on open plate as control. The packages were then stored at prevailing ambient conditions (23 ± 2 °C, 77.5 ± 5.5 % relative humidity (RH)) for 21 days. During storage the sweet potatoes' change in weight was determined every 3 days. Change in reduced ascorbic acid, ß-carotene, total sugars and total soluble solids contents were determined every 7 days. There was a significant ($p \leq 0.05$) weight loss as well as reduced ascorbic acid loss, but total sugars and ß-carotene contents increased during storage. Although total sugars showed an apparent gradual increase in all packages and genotypes during storage, the increase was not significant ($p \leq 0.05$). Perforated polyethylene bags significantly ($p \leq 0.05$) prevented weight loss (up to 1.8 %) as well as allowed for the most retention in reduced ascorbic acid (13.45 g/100 g fresh weight), and increase in β-carotene (4.9 mg/100 g fresh weight) and total sugar (6.4 g/100 g dry weight) contents than Kraft paper bags and nylon gunnysacks. Roots packaged in Kraft paper bags were not different in weight and nutrient quality changes from those packaged in nylon gunnysacks. The control sweet potatoes always showed the highest losses in weight (up to 27.8 %) and nutrient quality. Packaging materials did not affect total soluble solids content during storage. The results show that packaging in perforated polyethylene bags can improve shelf life of recharged sweet potatoes by 14 days.

KEY WORDS: *Ipomoea batatas*, packaging, weight loss

1.0 INTRODUCTION

In Kenya as in many tropical countries sweet potatoes (*Ipomoea batatas* Poir) storage, handling and marketing conditions are not well developed. Much of the 730, 000 tones produced annually (FAO, 1998) are sold in open-air markets and retail stores where they are exposed to high temperatures and dry air. The produce therefore loses considerable quantities of water, culinary, nutritional and economic quality (Burton, 1982; Picha, 1985a; Van Oirschot, 2000) and hence is rendered unsaleable in short periods of time rarely exceeding a month (Karuri and Hagenimana, 1995; Kihurani, 2003). It is estimated that between 5 to 15 % of sweet potato weight is lost every week through transpiration when exposed to these harsh conditions (Van Oirschot, 2000). One of the ways by which evaporative loss can be minimized, hence quality losses lessened, is by placing a physical barrier around the produce to reduce air movements across its surface (Wills *et al.*, 1998; Mbilinyi *et al.*, 2000). Such a barrier includes the use of packages.

The most common types of packaging materials used for the public for sweet potatoes include perforated polyethylene bags, nylon gunnysacks and Kraft paper bags. Use of perforated polyethylene bags, compared to Kraft or nylon gunnysacks, is more popular with producers and retailers since their use leads to the most reduction in weight loss of produce through transpiration (Gosselin and Mondy, 1989; Wills *et al.*, 1998). The produce also maintains color, firmness, glossiness and freshness when packaged in polyethylene bags (Gorini, 1987). No reports, however, exist on the effects of packaging materials on weight loss through moisture loss during post harvest handling of sweet potatoes in the open-air markets and retail stores of tropical conditions.

Very few reports were found on the effects of packaging materials on the nutritive quality of sweet potatoes. Sweet potatoes are primarily grown for their edible roots, which are high in dietary energy (Woolfe, 1992), minerals (Picha, 1985a) and vitamins (Wanjekeche *et al.*, 2000). The yellow-orange sweet potatoes contain variable, but sometimes large quantities of ß-carotene some of which are precursors of vitamin A (FAO, 1992; Wanjekeche *et al.*, 2000) and their consumption is considered an important food based approach to combat vitamin A deficiency (CIP, 1998, Hagenimana *et al.*, 1999). Consumption of a 150-g baked root can provide enough recommended dietary equivalents of retinal and vitamin A values (Picha, 1985a; Wanjekeche *et al.*, 2000).

Carbohydrates, the primary nutrients for energy, exist in the form of starch and sugars in sweet potatoes. No studies were found on the effects of packaging materials on reduced ascorbic acid, ß-carotene and total sugar contents of sweet potatoes. In potatoes (*Solanum tuberosum* (L.)) use of Kraft paper bags compared to polyethylene bags led to less reduced ascorbic acid loss (Gosselin and Mondy, 1989; Mondy and Koushok, 1990). It has also been shown that more increase in total sugars due to increases in both reducing sugar and sucrose occur in orange-fleshed compared to white-fleshed sweet potatoes during curing and several months in storage (Picha, 1986a). Packaging materials that reduce ascorbic acid, ß-carotene and total sugar content loss during retailing in open-air and retail stores of tropical countries would be beneficial to consumers.

One way to maintain quantity and quality of root crops is to harvest them at high moisture content (Shibairo *et al.*, 1998a). A high carrot (Shibairo *et al,* 1998b) and sweet potato (Shikuku, 2001) moisture content has also been achieved through immersing the freshly harvested roots in water (recharging). Upon recharging the roots gained weight and had extended subsequent shelf lives. However, the effects of packaging materials on nutrient quality changes of recharged sweet potatoes have not been determined.

This study was conducted to examine the effects of three different packaging materials (Kraft paper bags, nylon gunnysacks and perforated polyethylene bags) on weight and nutrient quality changes of sweet potatoes during short-term storage.

2.0 MATERIALS AND METHODS

2.1 Plant materials

Sweet potato (*Ipomoea batatas* Poir) roots of genotypes 'KEMB 10' (deep yellow flesh) and 'Yanshu' (white flesh), which are commonly grown by Kenyan farmers, were used in the study. Vine cuttings of the two cultivars were procured from the sweet potatoes germplasm collection plot maintained by International Potato Centre (CIP), Nairobi, Kenya. They were grown at the Field Station of the University of Nairobi, Kabete Campus between November 1998 and June 1999 (Experiment I) and again between February and July 1999 (Experiment II).

The sweet potato vines were planted in a randomized complete block design consisting of four blocks. The plots measured 7.5 m X 3.0 m with vines spaced at 0.30 m and the ridges

spaced at 0.90 m. Overhead irrigation was used to supplement rainfall and no fertilizer or pesticides were used.

The sweet potato roots were harvested on reaching market size (250-300 g) after eight months in experiment I. Sweet potato roots in experiment II reached market size earlier possibly due to the prevailing warm temperatures (data not presented) and were therefore harvested after six months. The roots were harvested manually by digging out whole plants from the middle two rows of each plot and separating the vines from the roots. The roots were placed in nylon gunny bags, the farmers' usual packaging method for transport over long distances, and transported to the Crop Science laboratory at the University of Nairobi, Kabete Campus within 1 hour (h). Roots showing evidence of skin damage sustained during harvesting or from presence of insect damage and diseases were selected and discarded. Market size roots were selected and used for the laboratory studies. Roots used for each experimental treatment were then selected randomly, washed in cold water and blotted dry with a cotton cloth.

2.2 Packaging materials

Kraft paper bags (0.025 mm) with twenty 12 mm diameter holes, nylon gunnysacks and perforated polyethylene bags (0.02 mm) with twenty 12 mm diameter holes were all purchased from supermarkets in Nairobi. Packaging materials were perforated to simulate conditions similar to those commonly used in markets. Perforation is necessary for air circulation and to prevent mold formation and decay in the roots.

2.3 Preparation of sweet potatoes for packaging

The sweet potato roots were removed from the nylon gunny bags and washed in tap water with gentle agitation to remove any adhering soil and debris. They were marked to allow for identification and immediately kept under ambient conditions (23 ± 2 °C, 77.5 ± 5.5 % relative humidity (RH)) before recharging. Recharging of the roots was achieved by dipping the roots in 15 l tap water (pH=6.5, sodium=0.01ppm, calcium=0.01ppm, potassium=trace and magnesium=trace) contained in 20 l plastic buckets at room condition for 14 h. The roots were then removed from the water, drained and blotted dry with cotton cloth. The sweet potatoes from each genotype were then divided into groups of four roots

for determining weight gain and loss and six roots for nutrient quality analysis (reduced ascorbic acid, ß-carotene, total sugar and total soluble solids contents). The groups were replicated four times and roots placed on open plate, Kraft paper bags, nylon gunnysacks and perforated polyethylene bags. All the sweet potato roots were then stored under ambient conditions. During the short storage period of up to 21 days the sweet potatoes change in weight was determined every 3 days. Change in reduced ascorbic acid, ß-carotene, total sugars and total soluble solids contents were determined every 7 days.

2.4 Analytical methods

Weight gain and weight loss of the sweet potatoes were determined before recharging and immediately after recharging and thereafter every 3 days during storage by using a top loading balance (Model XL-1810, e=0.01, Denver Instrument Company of range 0 -1810 g). These roots were then put in the various packages before placing on the bench at ambient conditions (23 ± 2 °C, 77.5 ± 5.5 % RH). The gain or loss in weight of the sweet potato roots was calculated as a percentage of the initial weight.

Reduced Ascorbic acid was determined by selective oxidation with N-bromosuccinimide (Barakat *et al.*, 1955). About 50 g of the sweet potatoes was weighed accurately and placed in a blender together with 150 ml of 20 % solution of trichloroacetic acid (TCA). The mixture was blended at high speed for 1 minute; then filtered through Whatman No. 41 filter paper. Five milliliters of the filtrate was pipetted into a 100-ml conical flask and to this was added 5 ml of 4 % potassium iodide (KI) solution, followed by 1 ml of starch indicator solution. The mixture was then titrated with freshly prepared 0.01 % N-bromosuccinimide solution to a faint blue or violet colour, which persisted for at least 15 seconds. The reduced ascorbic acid content was calculated as g per 100 g of the sample.

ß-carotene of the roots was determined by the method of Astrup *et al.* (1971). A 2 g sample and 10 ml acetone in a mortar was ground gently with a pestle, to extract the yellow coloured carotenoids. The extraction was repeated until the yellow-green colour did not show up in the extract. The extracts were combined in a 100-ml round-bottomed flask and evaporated at 60 °C to near dryness in a vacuum rotary evaporator (Heidolph, Type 51111, W. Germany). The residue was dissolved in about 4 ml of petroleum ether (40-60 °C (boiling point)) and quantitatively spotted on a 15 cm chromatographic column packed with

silica gel. The sample was eluted with the petroleum spirit and collected in a 25 ml volumetric flask until the first yellow band came out of the column. The elute was made to volume with petroleum ether. The absorbance of the elute was determined at 450 nm using a UV-VIS spectrophotometer (CE 4400 Doublebeam Scanning Spectrophotometer, England). The ß-carotene concentrations were calculated using a standard curve prepared from pure ß-carotene solutions in petroleum spirit as standard, and expressed as mg per 100 g of the sample.

Total sugars were determined by a colorimetric method attributed to Dubois *et al.* (1956). A sample of the sweet potato root was finely chopped. Approximately 1 g of the sample was weighed and dried in an oven at 60 °C. The sample was then milled using a micro-miller (Type DFH, Upm 6000, Glen Creston Stanmore, and England) to pass in a 0.5 mm flour sieve. Then 100 mg of the sample were weighed into a boiling tube, 25 to 30 ml of hot ethanol (80 °C) added then mixed by vortexing. The material was left to settle for 20 to 30 minutes, and then filtered through Whatman No. 41 filter paper. Repeating the above procedures 3 to 4 times attained complete extraction of the sugars. The extract was evaporated on a hot sand bath to near dryness and the residue dispersed in about 10 ml distilled water. The mixture was quantitatively transferred into a 100-ml volumetric flask and made to 100 ml distilled water. One ml of the solution and 1 ml distilled water to act as blank were each placed into a labeled test-tube, and to each 1 ml of 5 % phenol added and thoroughly mixed. To each test-tube were added 5 ml of 96 % sulphuric acid, mixed thoroughly by vortexing and the tubes cooled to 25 °C in running tap water. A golden color developed whose absorbance was determined at 490 nm using a UV-VIS spectrophotometer (CE 4400 Doublebeam Scanning Spectrophotometer, England) and the total sugars calculated as percent glucose equivalents from glucose standard curves.

Total soluble solids of the roots were determined as °Brix. A root sample of approximately 5 g was crushed manually and squeezed through cheesecloth. A drop of the clear solution was placed on the glass of a hand refractometer (Kruss HRN 16, W.Germany) and the °Brix measured at 20 °C (A.O.A.C., 1984).

2.5 Statistical analysis

The data was subjected to analysis of variance and regression analysis using the SYSTAT software (Wilkinson *et al.*, 1992). Means obtained were compared by the least significant difference (LSD) method.

3.0 Results and Discussion

Results for experiment I and II were similar; therefore only the experiment II data are presented.

Sweet potatoes of both genotypes gained 3.8 % of their weight upon recharging (Figure 1). Weight loss of the sweet potatoes differed among packaging materials and genotypes. Weight loss was higher in the unpackaged, up to 27.8 % for 'KEMB 10' and 22.5 % for 'Yanshu', at 21 days of storage, than in the packaged roots. However, weight loss was not significantly different ($P \leq 0.05$) between the Kraft paper bags and nylon gunnysacks. Roots packaged in perforated polyethylene bags lost the least weight, 1.8 % for 'KEMB 10' and 1.2 % for 'Yanshu', at 21 days of storage. Between the two genotypes, 'KEMB 10' had slightly higher mean weight loss than 'Yanshu' in all packages. The rate of sweet potatoes weight loss increased up to 7 days of storage. Weight loss increased at a decreasing rate thereafter.

Recharging by dipping produce in water may increase its turgidity, making longer storage possible. The results of this study are in agreement with those of Shibairo *et al.* (1998b) and Shikuku (2001) who reported weight gain following recharging of carrots and sweet potatoes, respectively. Genotype KEMB 10 had its shelf life extended by 13 days following recharging (Shikuku, 2001). Depending on the packaging materials used in this study, it took different days of storage for the sweet potatoes to attain their original weights (before recharging); suggesting extension of storage life. It took about 14 days for perforated polyethylene packaged sweet potatoes. For Kraft paper bags and nylon gunnysack packaged roots it took 4 to 6 days, respectively, to reach their original weights. In contrast the control took the shortest time of 2 days to reach their original weights. Packaging following recharging can, therefore, be used to extend the storage of sweet potatoes.

The contribution of respiratory carbon to total weight loss during storage of sweet potatoes is small, ranging from 2.1 % (Picha, 1986b) to 10 % (Van Oirschot, 2000). It can,

therefore, be assumed that most of the weight loss in this study was due to evaporative loss of water. The package accords a physical barrier to moisture loss of a commodity, thereby reducing evaporative loss (Wills *et al.*, 1998). The degree to which the rate of water loss is reduced is dependent on the permeability of the package to water vapor transfer. Materials such as polyethylene film can be considered to be relatively good vapor barriers, since their rate of water transfer is relatively low (Wills *et al.,* 1998). This was confirmed in this study as the roots packaged in perforated polyethylene bags showed the least weight loss. Kraft paper bag has a higher permeability to water vapour than perforated polyethylene paper. Paper derivatives have been known to absorb much water before becoming visibly damp creating a higher water vapour pressure deficit hence more movement of moisture from produce to the environment. Such absorption could have occurred in the Kraft paper bag package, hence leading to more increased moisture loss by the roots packaged in it. The nylon gunnysacks also led to more water loss than perforated polyethylene bags due to a lot of perforations they have thus allowing excessive air movement around produce. The results of this study agree with those of Gosselin and Mondy (1989) who observed significantly ($p \leq 0.5$) less weight loss in potatoes packaged in polyethylene bags than those packaged in mesh or paper bags.

It is not clear why a decrease in rate of weight loss of the sweet potatoes was observed after 7 days in storage. One factor that can cause differences in weight loss among root plants is natural root curing. It is assumed that curing occurs naturally when roots are harvested in warm weather, when the environmental conditions are similar to those recommended for artificial curing, 27-33°C and 85-95% RH (Ojijo, 1991 and Woolfe, 1992). It is possible that the sweet potatoes in this study completed natural curing after 7 days in storage and this led to lower subsequent rates of moisture loss.

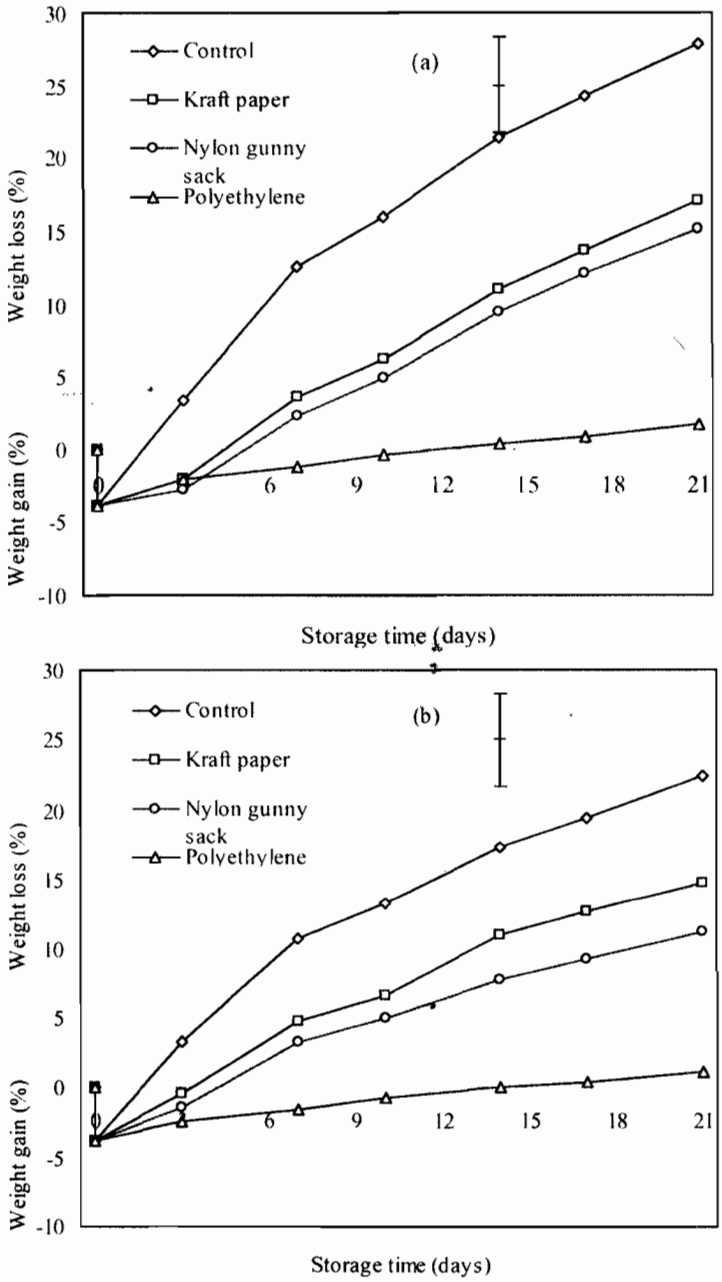

Figure 1. Effect of packaging materials on weight gain and loss of (a) 'KEMB 10' and (b) 'Yanshu' sweet potato genotypes during short-term storage. Vertical bars are overall S.E. of mean

Apart from moisture loss control different packaging materials can affect perishable plant products by creating modified atmosphere conditions (Ahrenainen *et al.*, 1998; Habibunnisa *et al.*, 2001). Modified atmosphere conditions attained by packaging have been shown to cause low changes in biochemical constituents such as reduced ascorbic acid, total soluble solids, moisture, carotenoids and total titratable acidity contents, enabling the retention of near-fresh quality pumpkins (Habibunnisa *et al.*, 2001). Changes in sweet potatoes in this study may have therefore occurred due to the modified atmosphere conditions attained by packaging apart from moisture loss.

Reduced ascorbic acid content differed among different treatments over the storage period (Fig. 2). Significant ($p \leq 0.05$) losses in reduced ascorbic acid content, of up to 21.8% in 'KEMB 10' and 14.7 % in 'Yanshu' at 21 days in storage occurred only in unpackaged roots. Although sweet potato roots packaged in perforated polyethylene bags retained the most reduced ascorbic acid, there was no significant ($p \leq 0.05$) difference in its loss among the different packaging materials during the short-term storage. The results of this study are in agreement with those of Gosselin and Mondy (1989) who observed a decreased loss of reduced ascorbic acid in potato tubers upon packaging in paper and mesh bags. The findings also agree with those of Habibunnisa *et al.* (2001) who reported less loss of vitamin C in pumpkin following packaging in polyethylene bags. Vitamin C content of vegetables decreases more readily when they are stored under conditions favorable to wilting than conditions not favorable to wilting (Ezell and Wilcox, 1959). Packaging reduces water transfer from produce by increasing the RH around the produce and this may lower vitamin C loss. Ahrenainen *et al.* (1998) suggested that the observed reduction in vitamin C loss was due to absence of oxygen caused by polyethylene packaging. It is hence suggested that the low reduced ascorbic acid loss observed in sweet potatoes in this study following packaging may have occurred due to low moisture loss or due to the modified atmosphere conditions created.

The perforated polyethylene bag packaged roots that had the lowest moisture loss, also showed the lowest reduced ascorbic acid content loss. It is therefore apparent that packaging that favour moisture loss and/ or a modified atmosphere may also favour less reduced ascorbic loss.

ß-carotene content significantly ($p \leq 0.05$) differed with packaging materials (Figure 3). The highest ß-carotene contents, 4.9 and 4.0 mg/100g of fresh weight for

'KEMB 10' and 'Yanshu', respectively, were observed in perforated polyethylene bags followed by those in nylon gunnysacks and Kraft paper bags and the least in the control at 21 days of storage. Genotypic differences were observed in ß-carotene contents. 'KEMB 10' had higher β-carotene contents than 'Yanshu'. Generally, ß-carotene contents increased with storage.

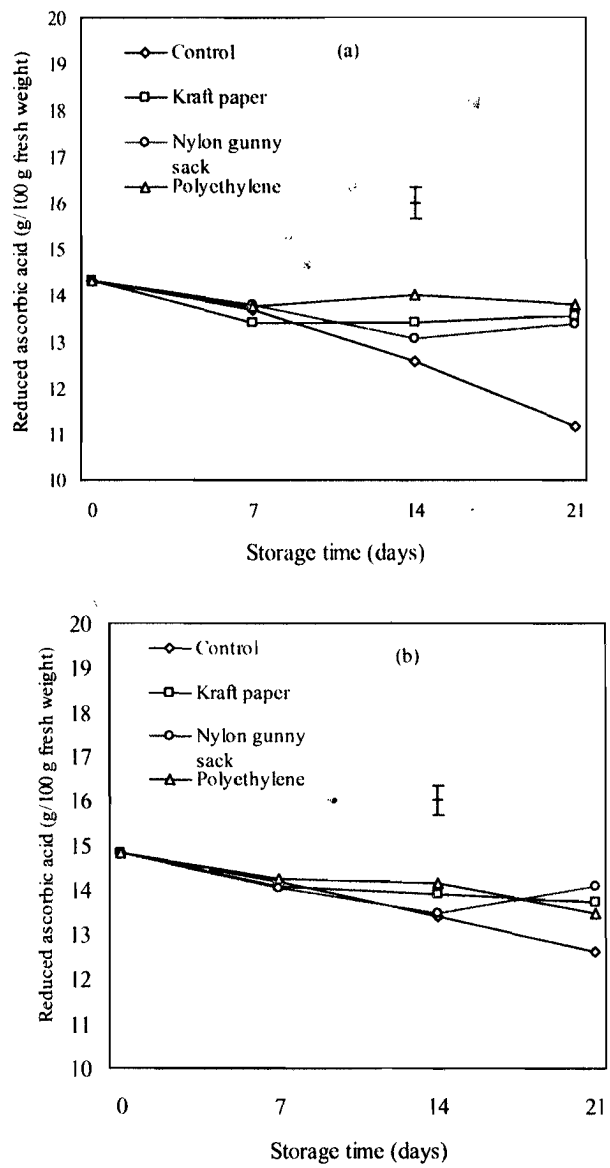

Figure 2. Effect of packaging materials on reduced ascorbic acid content of (a) 'KEMB 10' and (b) 'Yanshu' sweet potato genotypes during short-term storage. Vertical bars are overall S.E. of mean.

The increase in carotenoid pigments in sweet potato roots during storage has been shown to be primarily due to increase in ß-carotene (Yamamoto and Tomita, 1958). Research confirms that carotenoids are not lost during storage and that they may even increase (Picha, 1985b; Habibunnisa *et al.*, 2001). In this study, ß-carotene increased during storage in all sweet potato roots. However, the increase was highest in the roots packaged in perforated polyethylene bags and least in the unprotected roots (control). Thus perforated polyethylene bag, the package that allowed the least water loss from the sweet potato roots, allowed more synthesis of ß-carotene. The mechanism for carotenoid synthesis appears to be controlled by a genetic factor either present or absent in a root. CIP (1998), Hagenimana *et al.* (1999) and Wanjekeche *et al.* (2000) have encouraged consumption of yellow-orange fleshed sweet potatoes since they contain more ß-carotene than the white-fleshed roots. In this study 'KEMB 10", a deep yellow fleshed cultivar showed higher ß-carotene than the white fleshed 'Yanshu' during the short-term storage.

Total sugar content differed with packaging materials over the storage duration (Figure 4). The roots packaged in perforated polyethylene bags had the highest total sugars during the first two weeks of storage in 'KEMB 10' and in the last two weeks of storage in 'Yanshu'. Total sugar content of sweet potatoes packaged in Kraft paper bags was highest in the third week of storage in 'KEMB 10' and after the first week of storage in 'Yanshu'. However, there wereno significant differences ($p \leq 0.05$) in total sugar content in sweet potatoes packaged in perforated polyethylene bags and Kraft paper bags. The unpackaged (control) sweet potatoes followed with those in nylon gunnysacks had the lowest total sugar contents. Total sugar contents increased with storage time. Generally 'KEMB 10' had slightly higher total sugar contents than 'Yanshu'. There were no significant differences ($p \leq 0.05$) in total soluble solids among the different packages and between the two genotypes (Fig. 5). Total soluble solids increased with storage time.

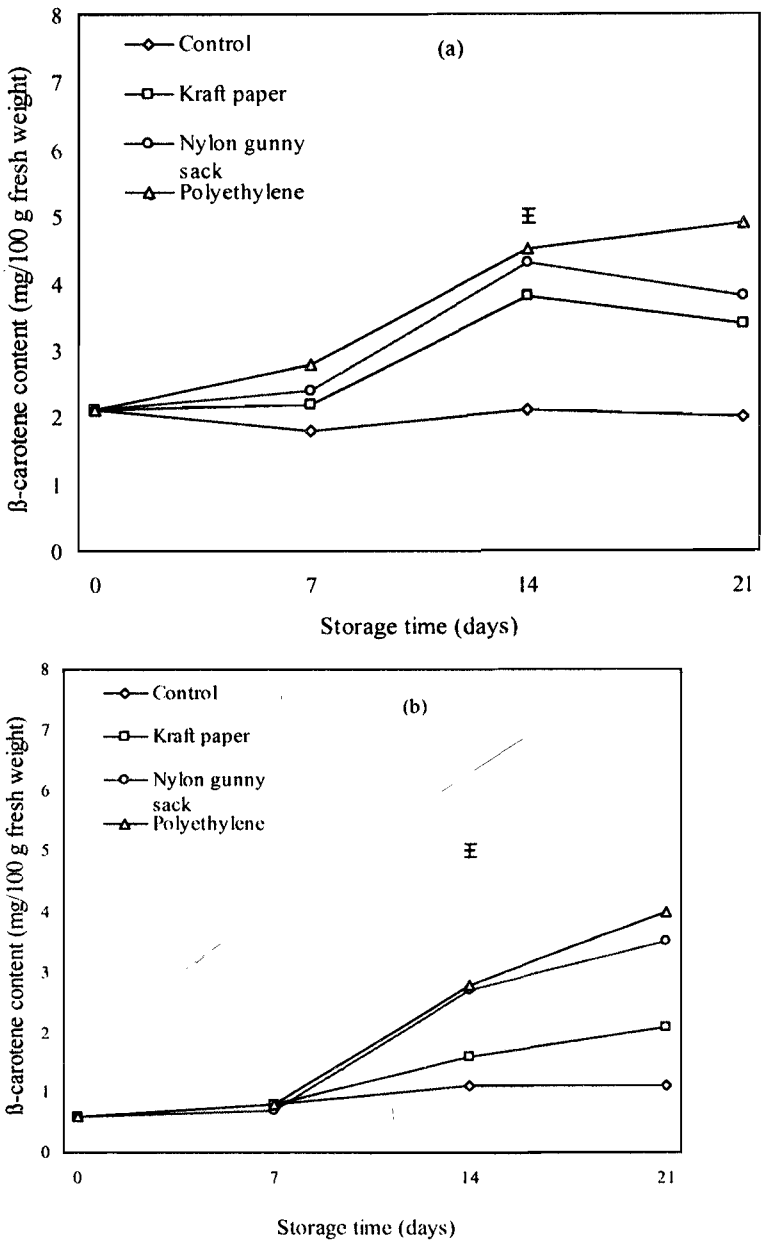

Figure 3. Effect of packaging materials on β-carotene content of (a) 'KEMB 10' and (b) 'Yanshu' sweet potato genotypes during short-term storage. Vertical bars are overall S.E. of mean.

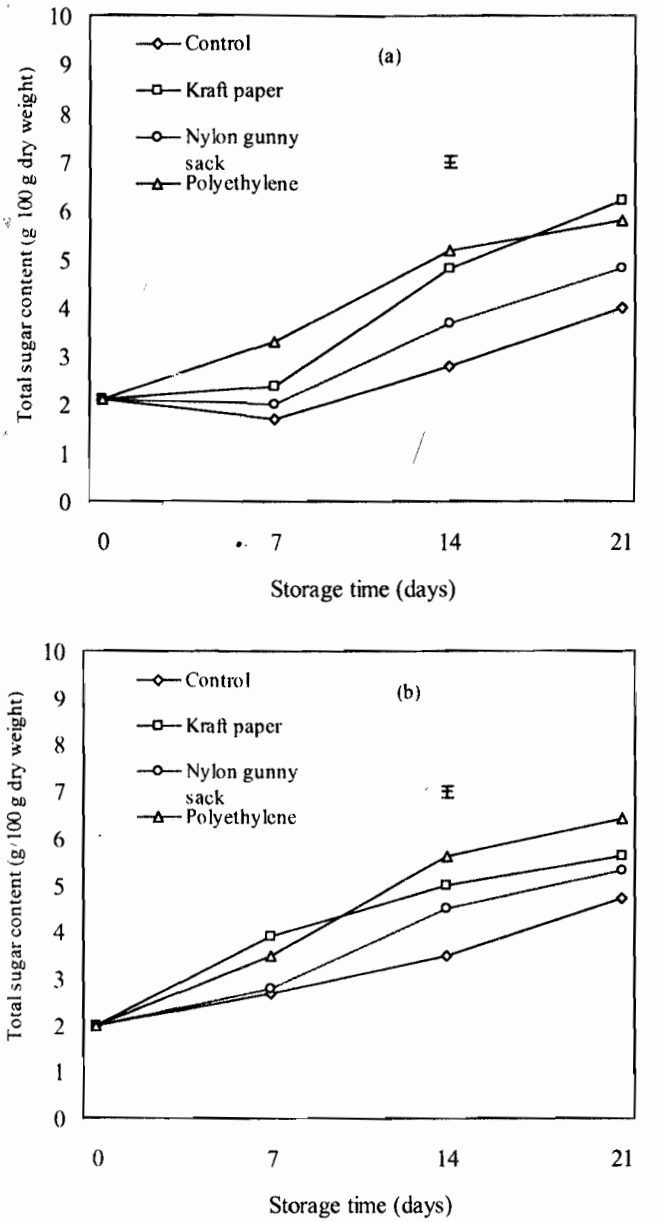

Figure 4. Effect of packaging materials on total sugar content of (a) KEMB 10' and (b) 'Yanshu' sweet potato genotypes during short-term storage. Vertical bars are overall S.E. of mean.

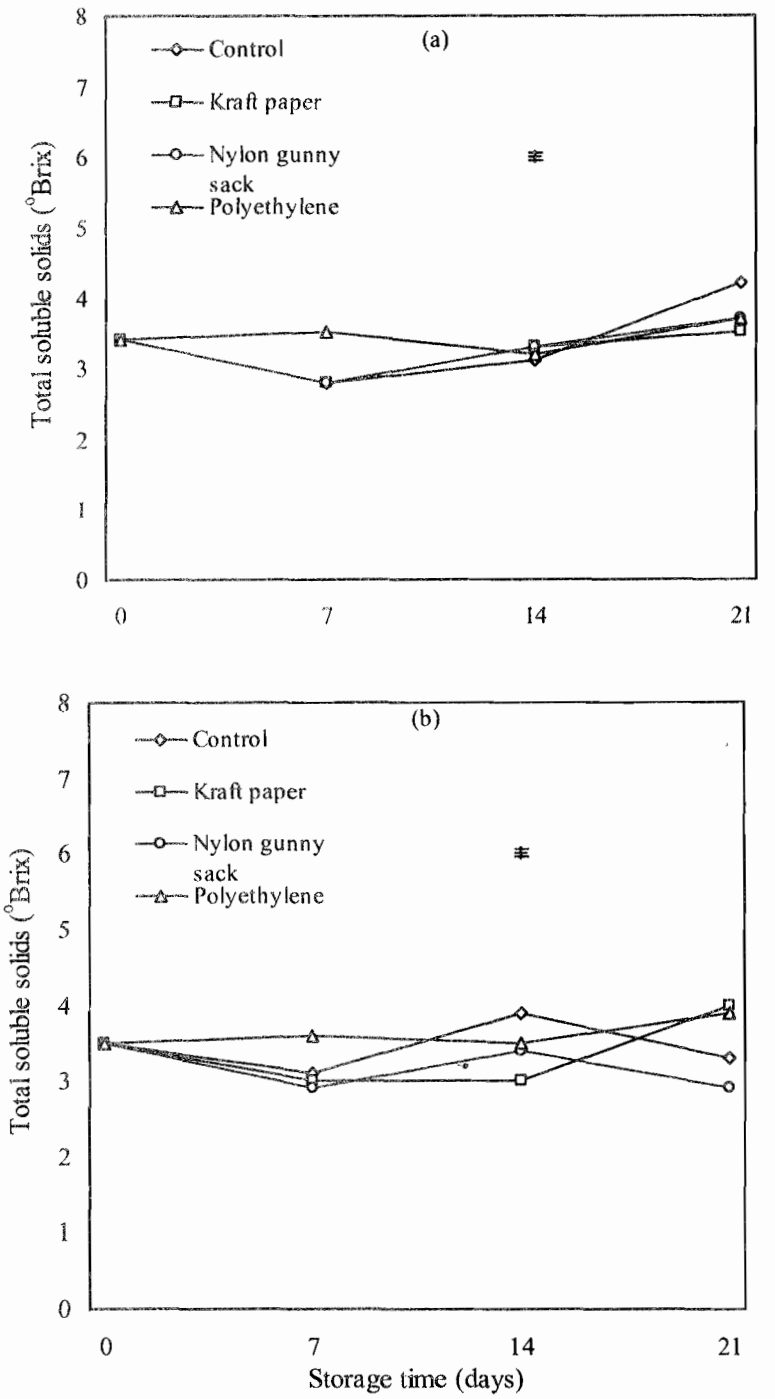

Figure 5. Effect of packaging materials on total soluble solids content of (a) 'KEMB 10' and (b) 'Yanshu'sweet potato genotypes during short-term storage. Vertical bars are overall S.E. of mean

The increase in total sugar content in storage of perishable plant products is due to the increased activity of α-amylase (Walter *et al.,* 1975). The results of this study agree with the findings of Habibunnisa *et al* (2001) who observed an increase in total sugars in pumpkins following packaging in polyethylene bags. Habibunnisa *et al* (2001) suggested that modified atmosphere conditions were responsible for the increase in total sugars. In this study, an increase in total sugars in perforated polyethylene bags packaged roots may have occurred due to the high moisture environment and/ or due to the modified atmosphere. In contrast, the unpackaged roots that lost the most moisture had the lowest sugar contents. Hence packaging materials that lower sweet potato moisture loss and or cause modified atmosphere would be beneficial by lowering the rate of sugar loss. Since total sugars contribute to total soluble solids (Kays, 1991), it is possible that change in total sugars due to packaging was not pronounced enough to cause detectable change in total soluble solids in sweet potatoes in this study.

4.0 Conclusions

This study showed that packaging following recharging could extend the shelf life of sweet potato roots by up to 14 days. Perforated polyethylene bags prevented weight loss the most as well as allowed for the most nutrient (reduced ascorbic acid, β-carotene and total sugar contents) retention compared to Kraft paper bags and nylon gunnysacks. Sweet potato roots packaged in Kraft paper bags were not different in weight and nutrient quality changes from those packaged in nylon gunnysacks. The control sweet potatoes always showed the highest losses in weight and nutrient quality. It is, therefore, suggested that packaging in perforated polyethylene bags following recharging be adopted to minimize changes in weight and nutrient quality of sweet potatoes during short-term storage in open-air markets and retail stores.

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