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Long-term storage of sweetpotato by small-scale farmers through improved post harvest technologies

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Abstract

Sweetpotato (SP) small-scale farmers of Luweero and Mpigi districts were introduced to improved long-term storage methods (pit and clamp) as a way of improving their livelihood. Based on a participatory approach, farmers were involved in a storage study where dry matter, beta-carotene and sugar content parameters were monitored over a 60 day period in Mpigi and 75 days in Luweero district. Pit and clamp stores were constructed by farmers in selected sites of each district. Improved SP varieties (*Ejumula, Naspot 1, Naspot 2, New Kawogo, Semanda and SPK004*) were used for the storage study. Dry matter contents of SP were exceptionally high, particularly for roots from Mpigi district, with Semanda variety having the highest dry matter (41%). High beta-carotene concentrations were recorded for the orange-fleshed varieties, SPK004 and Ejumula, 68 and 125 mg/100 g, respectively. Total sugar contents of the roots were generally low (1.6-3.7 g/100 g), with exception of Naspot 2 (5.7 g/100 g). Changes in dry matter, beta-carotene and sugar contents of SP depended on location, and differed for both districts. No consistent trends in dry matter, reducing and sucrose contents were noted for SP in Luweero district. The decrease in sugar contents noted for Mpigi SP was due to a general decrease in dry matter for these SP. Although beta-carotene generally decreased with storage period for SP in both districts, the residual beta-carotene (2.6-3.4 mg/100 g) in the orange-fleshed SP varieties could be sufficient as the recommended daily allowance intake of vitamin A. Monitoring temperature, relative humidity and atmospheric compositions of the long-terms stores is needed to assess the performance of individual SP varieties.

Key wors Ipomea batatus, Long-term storage, post harvest technologies, long-term storage

Introduction

Uganda is the third largest producer of sweetpotato (SP) after China and Indonesia and the largest producer in Africa (Scott *et al.*, 1998). In terms of SP cultivated area, Uganda ranks second to China (van de Fliert *et al.*, 2000). The current annual production in Uganda is estimated at 2.6 x 10^6 Mt with yields of upto 4.4 x 10^4 Hg Ha^{-1} (FAOSTAT, 2004). Sweetpotato production in Uganda is dominated by small-scale farmers, with a few large-scale farmers cultivating up to 12 acres (Bashaasha and Scott, 2001). Sweetpotato production is mainly concentrated in the densely populated, mid to high altitude region (1,000 – 2,000 m above sea level) and its cultivation is most evenly spread of all the other major crops in Uganda. Acreages are highest in Kabale district most likely due to absence of cassava, yams and rice (Bashaasha *et al.*, 1995; Mwanga, Ocitti p' Obwoya, Odongo and Turyamureeba, 2001). Yields are however reported to be declining due to deteriorating soil fertility. Percaptia production of SP is higher in western Uganda than elsewhere. The crop is second after banana in the central and western regions, and to finger millet in the eastern and northern regions (Bashaasha *et al.*, 1995; Mwanga *et al.*, 2001).

Previous research efforts have emphasized producing improved SP varieties with superior agronomic performance and nutritional characteristics (Hagenimana, K'osambo and Carey, 1998; Mcharo, Carey and Gcihuki, 2001; Ndolo *et al.*, 2001; Ssebuliba, Nsubuga and Muyonga, 2001). In the East African region these improved SP varieties have been disseminated to farmers resulting in increased yields of the crop (Ndolo *et al.*, 2001). However, farmers are still faced with post harvest losses of this perishable crop. More research work is now needed to address post harvest aspects of the SP sub sector. In an effort to address this situation farmers of Central Uganda have been embedded in a SP coalition partnership where they were equipped with SP post harvest technologies. The SP coalition is a result of the Department for International Development (DFID) funded project with the sole purpose of sustainably reducing SP post harvest losses and increasing farmers' incomes from SP and its products in Central Uganda.

The work reported is part of an on-going SP coalition project whereby a crop post harvest-based innovation system has been adopted to improve the livelihood of small-scale farmers of Central Uganda. The objective of this study was to evaluate the effect of two long-term storage technologies (pit and clamp methods) on selected chemical components of SP. The technologies were introduced to farmers who participated in the study.

Materials and methods

Sweetpotato varieties

The varieties of sweetpotato (*Ipomea batatas* L.) provided by farmers for the storage study in Luweero and Mpigi district are shown in Table 1.

Participatory approach adopted for the study

Farmers from Luweero and Mpigi districts were jointly involved in the study with researchers. Farmers provided sweetpotato roots for the storage study from their fields while the researchers introduced the storage methods and assessed the storage parameters of the roots.

Handling of sweetpotato for storage

Sweetpotato roots were harvested a day prior to the date of storage and cured by spreading on the ground under shade overnight. Roots were sorted to remove mechanically and weevil-damaged roots. Sweetpotato roots clogged with soil were washed before the curing process. No chemical agents (anti-sprouting or antibacterial) were applied to the roots before and during storage.

Selection of sites

Purposive sampling was used to select three sites located in the sub counties of Kalagala and Zirobwe, Luweero district, and Nkozi sub county, Mpigi district. The sites selected for construction of the stores were located under shades of trees or banana plants, and at locations that were free of rats and termites. The sites were also places that did not flood in rainy seasons. The temperature and humidity of the storage environment depended on the ambient conditions of the sites for the whole storage period.

Construction of stores and placement of sweetpotato

Pit stores were constructed by digging pits, of about 1m width and 1m depth, in the ground and lined with dry spear grass (*Imperata cylindrica*). The grass acted as an insulating material maintaining cool conditions in both the pit and clamp stores and prevented water and soil from reaching the roots. The clamp store was constructed by flattening mounds on the ground. Thereafter lined with dry grass before placing the roots on top in dry grass and wrapping again with dry grass and then soil.

Sweetpotato roots were carefully placed in the pit or on the clamp storage structures avoiding damage. The roots were then covered with dry grass and later soil. Grass thatched roofs were placed on top of each of the pit and clamp stores. The thatched roofs protected the stored roots from the rainwater and direct heat from the sun, maintaining ambient conditions in the storage structures. Figures 1 and 2 show the construction of the pit and clamp stores, respectively and placement of the roots in the stores by farmers.

Quality assessment of sweetpotato roots

Sweetpotato samples (4-6 roots per variety) were drawn from stores every 15 days for analysis. Roots were immediately transported to the laboratory and frozen at -20°C prior analysis. All values reported are means of at least three measurements unless other wise stated.

Dry matter content

Dry matter content was determined by drying 10 g samples of grated SP in a forced-air oven (Gallenkamp 300 series, UK) at 105°C to constant weight in approximately 20 h.

Trans β-carotene content

Trans β-carotene content of the root samples was determined by high-performance liquid chromatography, HPLC (Class-VP, LC-10ATVP, Kyoto, Japan) using a slightly modified method of van Jaarsveld *et al.*, (2001). Roots were washed under running tap water, peeled with a stainless knife and thoroughly washed again under tap water. Roots (2-4) were chopped into 4 equal pieces, pooled and macerated using a blender to obtain a pulp. The extraction procedure used was modified from AOAC (1995). Sweetpotato pulp (0.1-1.0 g) was repeatedly refluxed (5 times) in a rotary vacuum evaporator (Heidoph rotavator, Germany) with 2 ml of pure cyclohexane (AnalaR) and a clear extractant passed through a silica gel column. An aliquot of 10 ?l was injected into a C18 HPLC column (Shim-pack CLC–NH2, Shimadzu, Kyoto, Japan), containing the eluent or mobile phase constituted of cyclo-hexane (100) and iso-propanol (4), set to flow at a rate of 1.5 ml min^{-1} at 25°C. The beta-carotene signal from both the test sample and beta-carotene standards (Shimadzu, Kyoto, Japan) was detected by a UV detector at 450 nm. Beta-carotene content was recorded in mg /100 g (dwb) after computing using the formulae below

$$\beta - carotene(\mu g/100g) \equiv {A_1}/{wA_2} \times 100C$$

where A_1 = area of test sample; A_2 = area of standard; w = weight of sample; C = concentration of standard).

Sugar content

Sugar content in the SP samples (sucrose, maltose, glucose and fructose) were measured according as described by Picha (1985) using high-performance liquid chromatography, HPLC (Class-VP, LC-10ATVP, Kyoto, Japan). Sugars were separated column (Bio-Rad Labs (Shimadzu, Kyoto, Japan). Sugar standards used standard curve preparation were analytical grade supplied by Shimadzu (Kyoto, Japan) distributors.

Results and discussion

Selected chemical components of Sweetpotato roots
Sweetpotato varieties used in the study ranged from white-fleshed to the deep orange-fleshed SP (Table 1). All the SP were improved varieties, except for Dimbuka which is a local variety. Table 1 shows dry matter, beta-carotene and sugar contents of sweetpotato (SP) at day zero of the storage study. Values of these components depended on location, maturity and variety of SP. Dry matter contents that ranged from 31.4 to 41.6% (Table 1), with the exception of Naspot 2 (24.6%), were generally higher than dry matter for other SP varieties (<30%) reported elsewhere (Oboh, Ologhobo and Tewe, 1989). Sweetpotato varieties from Nkozi Sub County, Mpigi district had the highest dry matter content (39.3-41.6%). These SP varieties are among the improved varieties disseminated by International Potato Centre (CIP) and Namulonge Animal and Agriculture Research Institute researchers bred for improved agronomic performance and nutritional value.

Sweetpotato roots contained varied levels of beta-carotene content, a precursor for vitamin A, ranging from 0.03 to 125.4 mg/100g on dry weight basis (dwb), (Table 1). Beta-carotene varied with location and SP variety. The white to cream fleshed varieties contained low beta-carotene. The orange-fleshed SP varieties, SPK004 and Ejumula, had the highest beta-carotene content, 67.8 and 124.5 mg/100 g, respectively (Table 1). Similarly Dignos, Cerna and Truong (1992) showed that orange-fleshed SP varieties from the Philippines contained high amounts of beta-carotene (39.6 to 42.8 mg/100 g, dwb). A range CIP pathogen tested SP cultivars grown in Kenya and Uganda contain beta-carotene ranging from 2.1 to 7.9 mg/100 g, on fresh weight basis (Hagenimana *et al.*, 1998). The effect of growing season and geographical location on beta-carotene has been shown for SPK004 variety, ranging from 1.6 to 4.9 mg/100 g, dwb, (Ssebuliba *et al.*, 2001).

As expected all SP varieties contained sucrose, glucose and fructose as the typical sugar profile of SP (Picha, 1985; Truong *et al.*, 1986; Susheelamma *et al.*, 1992; Babu, 1994; Takahata *et al.*, 1995). Total sugar content of SP roots ranged from 1.47 to 5.74 g/100g (dwb). Generally, these SP varieties contained lower total sugar content (less than 2.0 g/100g), with the exception of Naspot 2 variety (Table 1), compared to other SP varieties, 5.6-22.7 g/100g, (Truong *et al.*, 1986; Susheelamma *et al.*, 1992; Babu, 1994; Takahata *et al.*, 1995). Sweetpotato, in the tropics, is generally a low-sugar staple food as opposed to the temperate regions where it is consumed as a dessert and typically a high-sugar SP (Martin and Deshpande, 1985).

Effect of storage methods on the chemical components of Sweetpotato
Sweetpotato characteristics that impart a long root shelf-life to the roots during marketing differ from those that render SP suitable for long-term storage (Rees *et al.*, 2003a). Hence, Rees and coworkers (2003a) use the terms 'shelf-life' to refer to the keeping characteristics of SP under marketing conditions and 'storability' to SP root keeping characteristics within long-term stores. This study highlights the storability of SP under long-term stores, typically the pit and clamp storage technologies introduced to small-scale farmers of Luweero and Mpigi districts.

Typical manifestations of SP root deterioration under long-term storage are weight losses, rotting, sprouting, loss of SP taste and infestation by insects (Rees *et al.*, 2003a). Therefore changes in dry matter, sugar and beta-carotene contents of these SP were monitored in the long-term stores to reflect weight losses, changes in the carbohydrate components and nutritional value of SP, respectively.

Dry matter content
Dry matter contents of SP in Luweero and Mpigi districts are shown in Figures 3 and 4, respectively. The change in dry matter content with storage period differed for both types of long-term storage methods (pit and clamp) in Luweero. Dry matter contents for Naspot 1 and SPK004 decreased up to 35 days and thereafter increased, while for Naspot 2 dry matter increased gradually for SP stored by the pit method (Figure 3a). Dry matter contents for SP in the clamp store increased and then decreased with storage (Figure 3b). In Mpigi district a decrease in dry matter content for all SP varieties stored by both the pit and clamp stores was recorded irrespective of the variety (Figure 4). Ravi's (1996) review showed that initially dry matter content of SP decreases, probably due to high relative humidity in the store and later increases steadily due to dehydration of the roots in the store. The differing changes noted for SP in Luweero districts reflect variation in relative humidity conditions in both types of stores, although these stores are usually designed to maintain high relative humidity (Rees *et al.*, 2003b).

Beta-carotene content
Beta-carotene content of SP from Luweero and Mpigi districts are shown in Figures 5 and 6, respectively. Beta-carotene content of SP decreased for all SP varieties stored by both the pit and clamp stores in Luweero district (Figure 5). A contrary trend in beta-carotene content was observed for the storage study in Mpigi district for both methods (pit and clamp), with the exception of New Kawogo where no change was recorded (Figure 6b). This was possibly a pseudo increment registered due to the reduction in dry matter of Mpigi SP roots (Figure 4) as beta-carotene values were computed and reported on a dry weight basis. However, an increased beta-carotene concentration of SP has been

Table 1. Dry matter, beta-carotene and total sugar contents of SP varieties procured

District	Sub county	Maturity age (months)	Sweetpotato variety	Colour of flesh	Dry matter (%)	@Beta carotene (mg / 100 g), dwb	Total sugar (mg / 100 g), dwb
Luweero	Kalagala	5	Naspot 1	Cream	35.9±0.3	2.44±0.00	3.74
			Naspot 2	Off-white	24.6±0.1	2.37±0.00	5.74
			SPK004	Pale orange	36.5±1.2	67.87±0.16	1.59
	Zirobwe	6	Dimbuka	Yellow	32.3±0.3	2.80±0.00	1.62
			Ejumula	Deep orange	31.4±0.6	125.41±0.29	2.06
			Naspot 1	Cream	nd	nd	nd
Mpigi	Nkozi	4	Naspot 1	Cream	39.3±0.2	2.23±1.04	1.49±0.04
			New Kawogo	White	39.9±0.4	0.03±0.01	1.47±0.02
			Semanda	White	41.6±0.1	nd	nd

@ trans beta-carotene, (n = 3, ± S.D); nd – not determined, dwb – dry weight basis

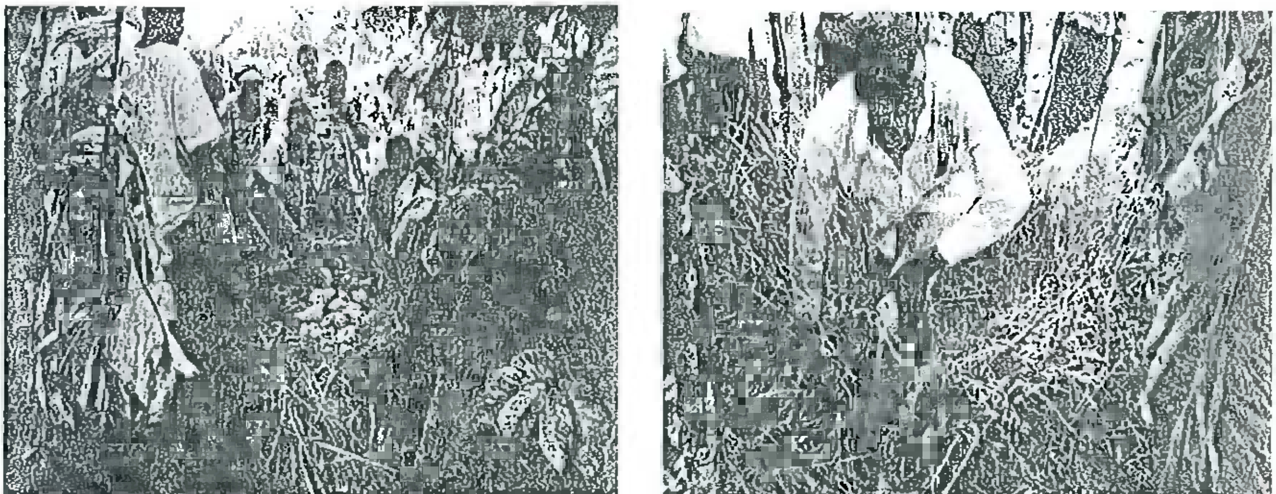

Figure 1. Construction of clamp store (a) Sweetpotato roots being wrapped with dry grass prior to being covered with soil (b) Grass thatched roof being placed on the completed clamp store

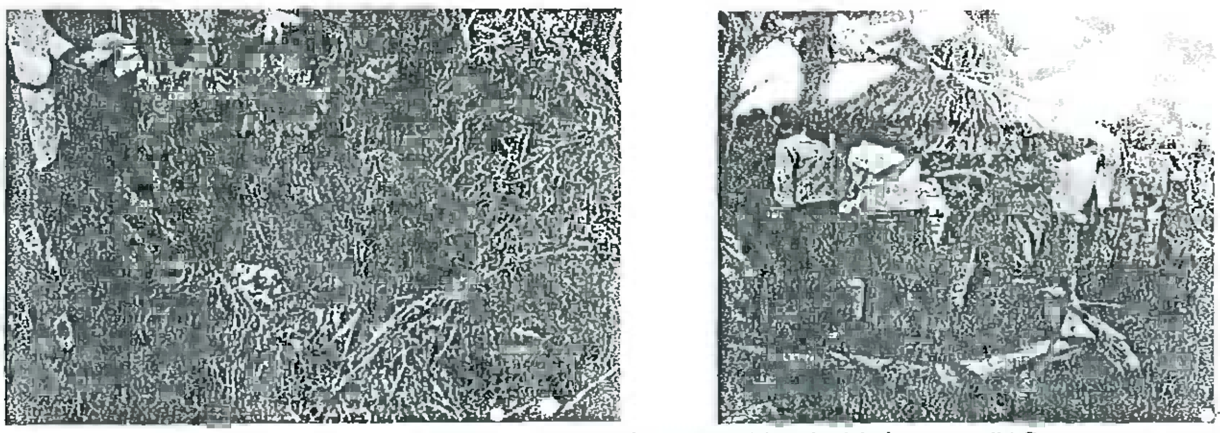

Figure 2. Construction of pit store (a) Pit (1 m width and 1 m depth) lined with dry grass (b) Sweetpotato roots placed in pit prior to wrapping and covering the pit with soil

reported by Ravi (1996) and attributed to the maturity age of SP. A similar observation was reported by Hagenimana and coworkers (1998) where a gradual increase in beta-carotene concentration was noted for SP roots from 12 to 20 weeks, and a decrease occurred beyond 20 weeks.

Sugar content

Sucrose and reducing sugar contents of SP are shown in Figures 7 and 8, and 9 and 10, respectively for Luweero and Mpigi districts. No consistent trend in sucrose content was noted for SP stored by both stores (pit and clamp) in

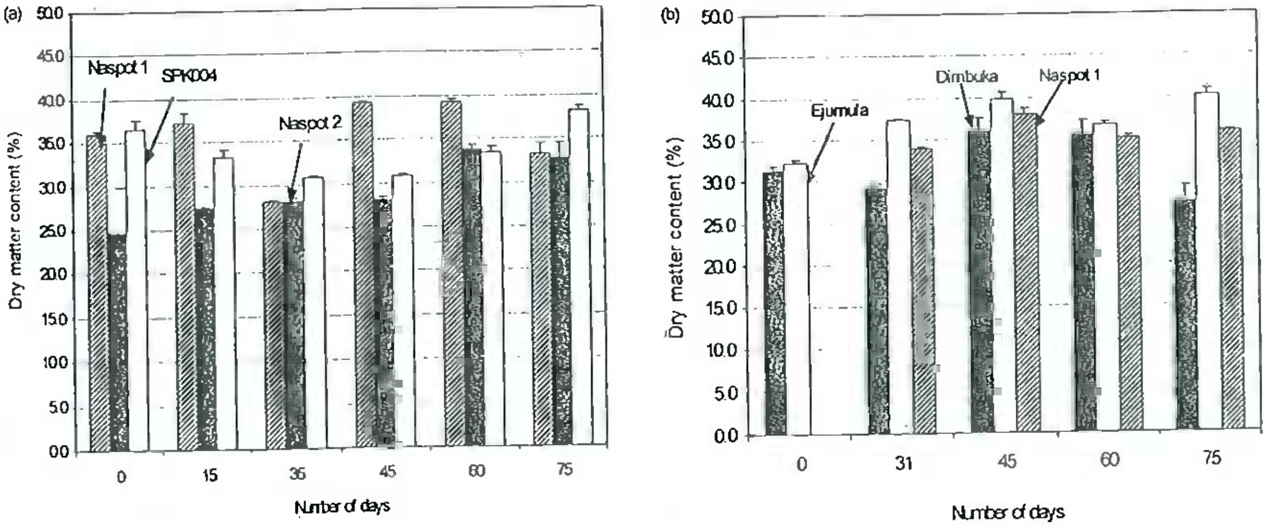

Figure 3. Dry matter content of sweetpotato roots for Luweero district (a) the pit store in Kalagala sub county (b) the clamp store in Zirobwe sub county; (n = 3; ± S.D)

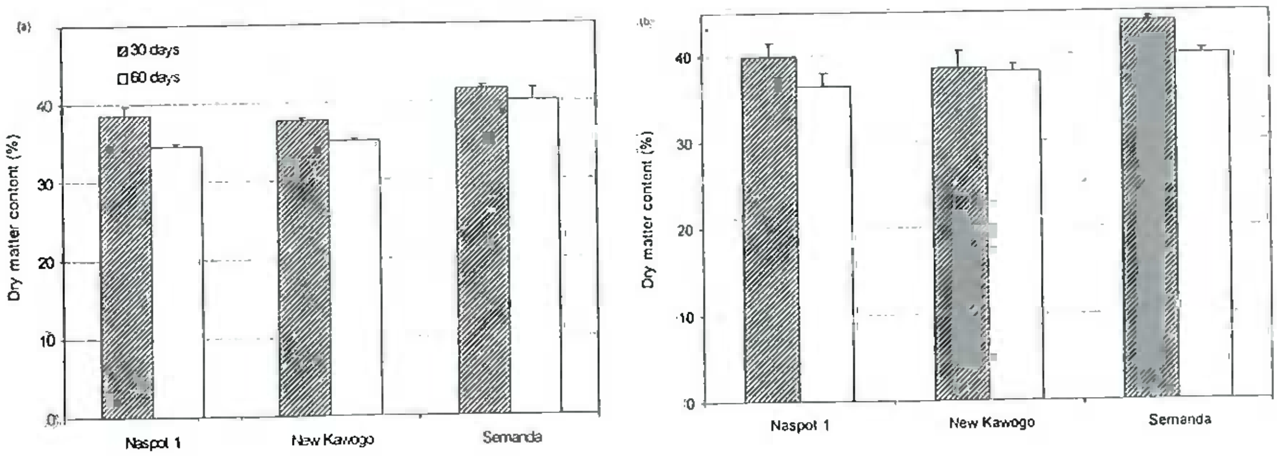

Figure 4. Dry matter content of sweetpotato roots for Mpigi district in Nindye - Nkozi sub county (a) the clamp store (b) the pit store; (n = 3; ± S.D)

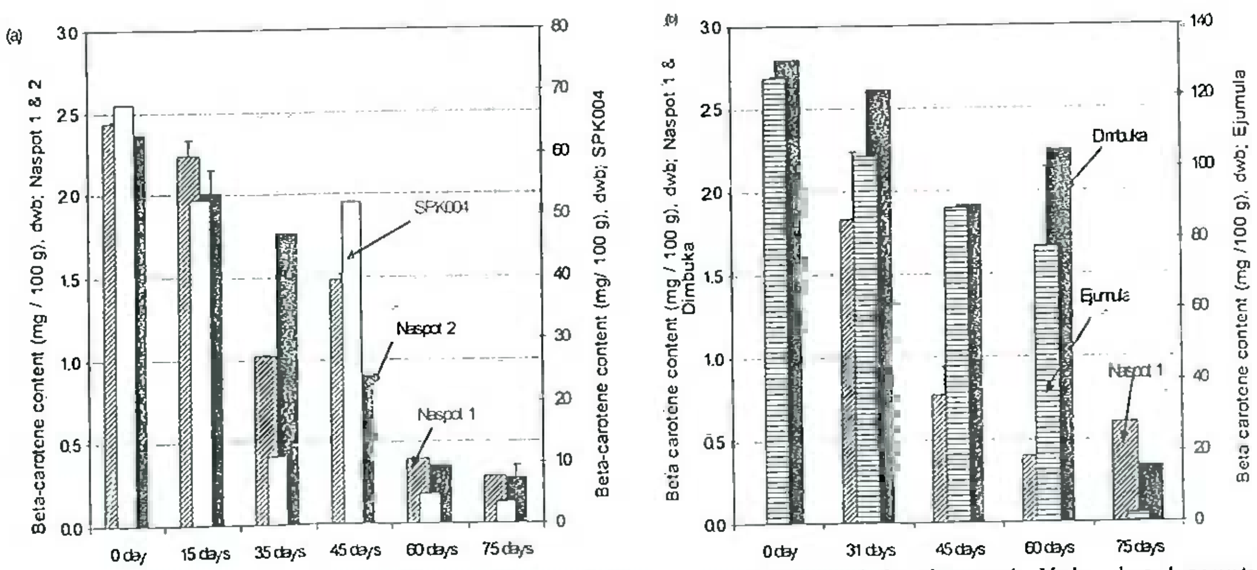

Figure 5. Beta carotene content of sweetpotato roots for Luweero district (a) the pit store in Kalagala sub county (b) the clamp store in Zirobwe sub county; (n = 2; ± S.D)

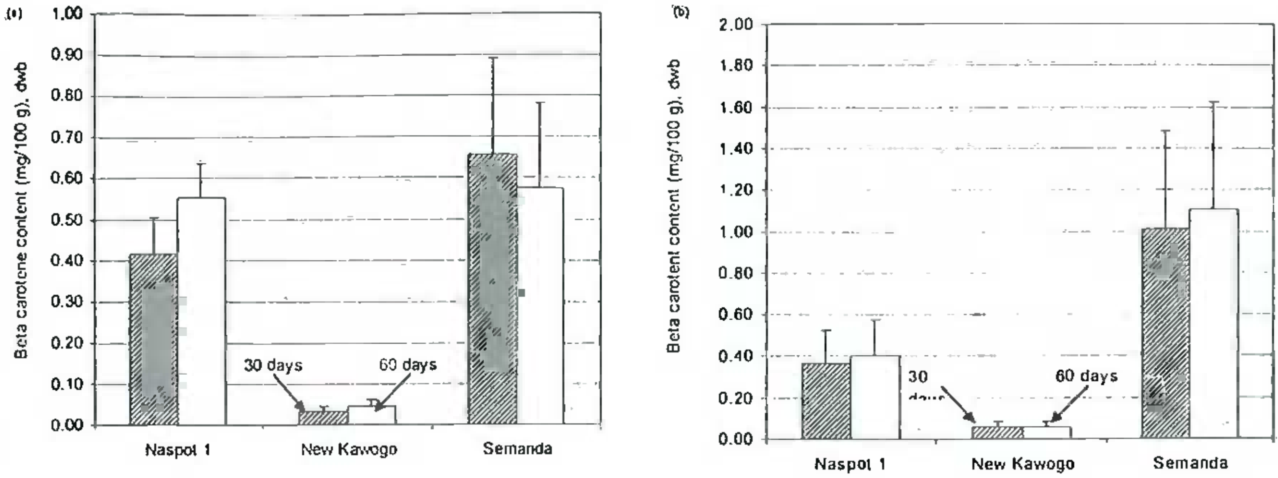

Figure 6. Beta carotene content of sweetpotato roots for Mpigi district in Nindye - Nkozi sub county (a) the clamp store (b) the pit store; (n = 2; ± S.D)

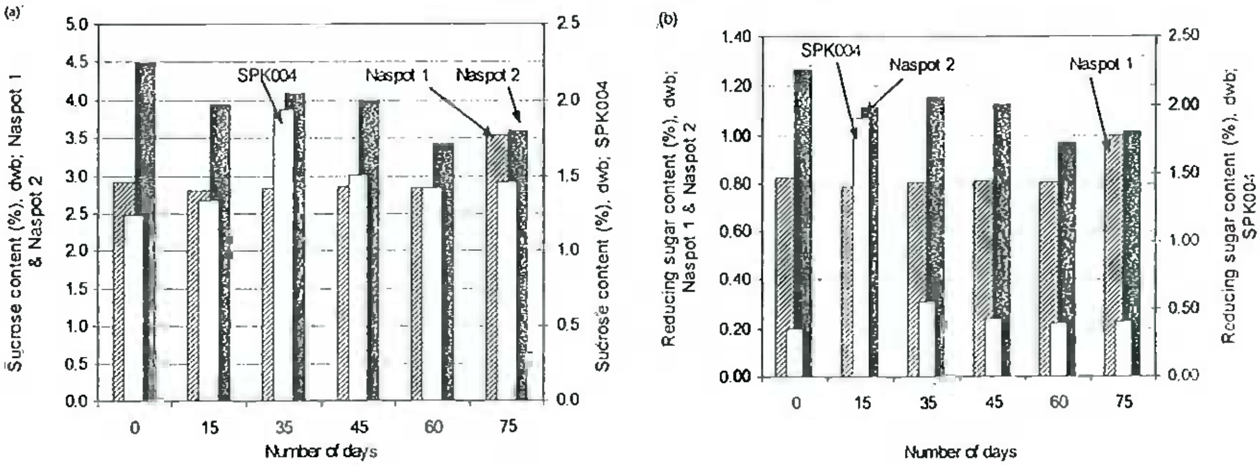

Figure 7. Sugar levels of sweetpotato roots for Luweero district under the pit store in Kalagala sub county (a) Sucrose content (b) Reducing sugar content; (n = 2; ± S.D)

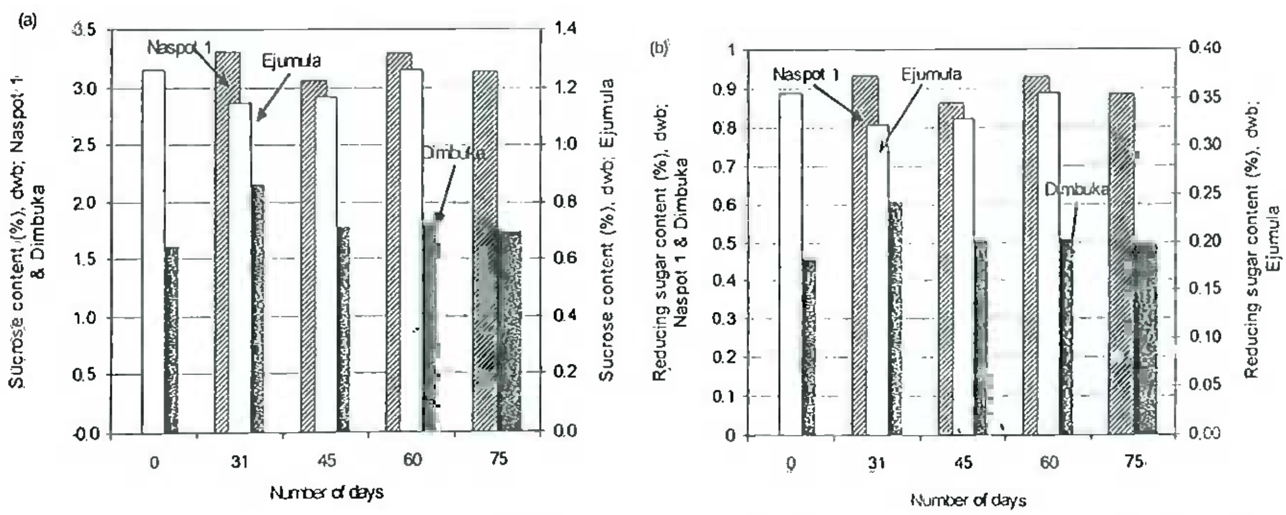

Figure 8. Sugar levels of sweetpotato roots for Luweero district under the clamp store in Zirobwe sub county (a) Sucrose content (b) Reducing sugar content

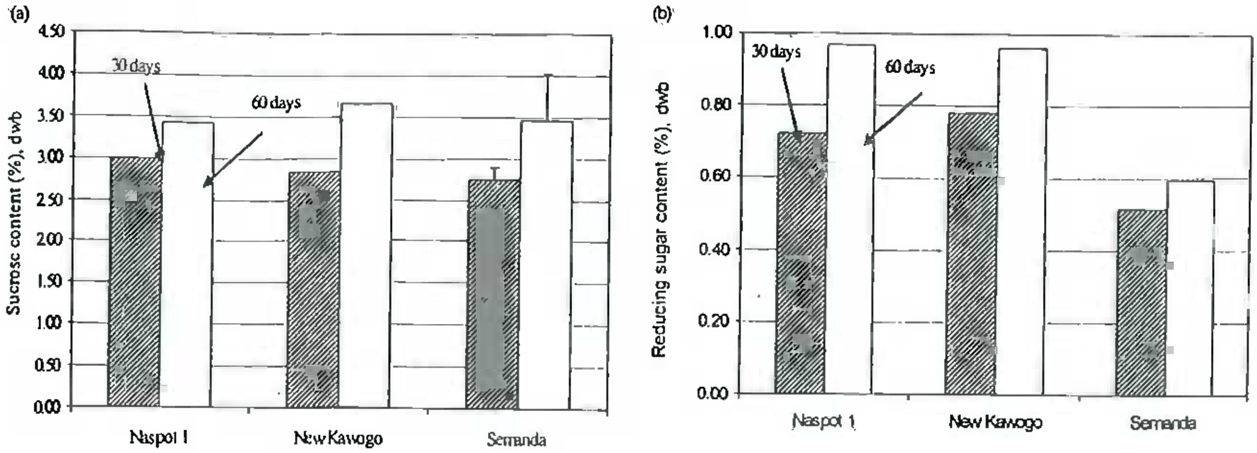

Figure 9. Sugar levels of sweetpotato roots for Mpigi district under the clamp store in Nindye - Nkozi sub county (a) Sucrose content (b) Reducing sugar content; (n = 2; ± S.D)

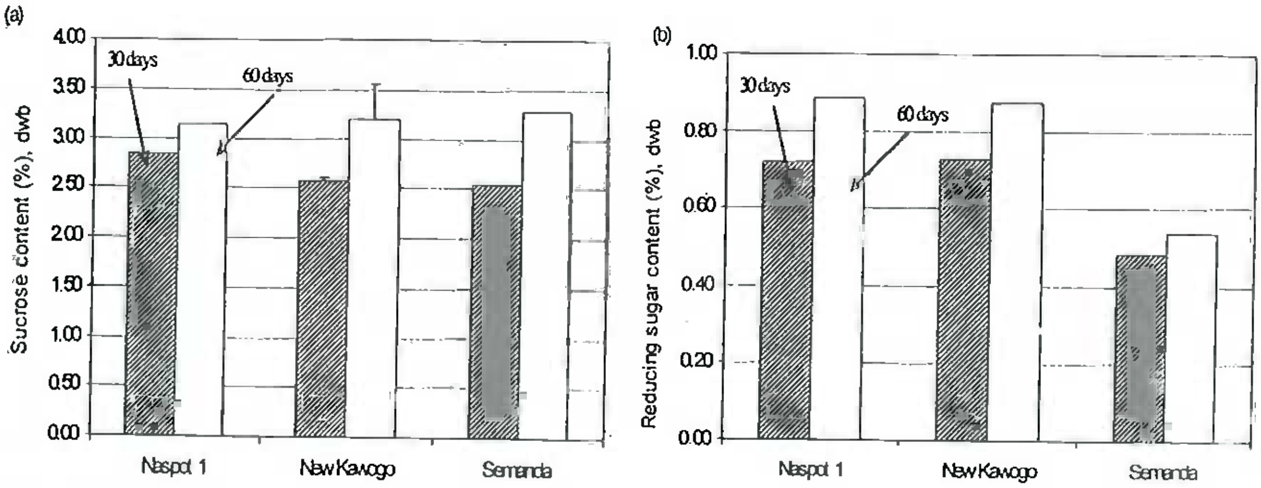

Figure 10. Sugar levels of sweetpotato roots for Mpigi district under the pit store in Nindye - Nkozi sub county (a) Sucrose content (b) Reducing sugar content; (n = 2; ± S.D)

Luweero district (Figure 7a and 8a). While reducing sugar content increased with storage for Naspot 1 and Naspot 2 varieties between 60 to 75 days of storage for the pit storage method (Figure 7b), and similarly for Naspot 1 and Ejumula between 30 to 60 days for the clamp method (Figure 8b). In Mpigi district an increase in both sucrose and reducing sugar contents were recorded for all SP varieties stored by both the pit and clamp methods (Figures 9 and 10). This was a pseudo increase that was recorded based on the dry matter used to compute the sugar data on a dry weights basis. Sugar content of SP has however been reported to vary with storage conditions and duration of storage depending on SP variety (Takahata *et al.*, 1995). However, it is known that increases in glucose and sucrose of SP roots occurs in semi-underground storage at 12-16°C 138 days, due to intensified metabolic activities (Takahata *et al.*, 1995).

Conclusion

Dry matter contents of SP used were exceptionally higher than that reported for other SP varieties in the literature. Varied beta-carotene contents were recorded but highest for the orange-fleshed sweetpotato and lowest for Naspot 1 and Naspot 2. Low sugar contents of SP were determined for these varieties.

The study showed that storage conditions in Luweero stores differed from Mpigi district. Changes in dry matter, beta-carotene and sugar contents of SP depended on SP variety and location of the study site. The contrary trends in selected chemical components of SP recorded for SP stored in Mpigi district were attributed to the reduced dry matter of these SP. Despite the decrease in beta-carotene concentration, the residual beta-carotene in the orange-fleshed varieties (Ejumula and SPK004) could be sufficient to meet the recommended daily intake allowance for vitamin A unlike the white and cream-fleshed varieties (Naspot 1, Naspot 2 and Dimbuka). In order assess storage performance of individual SP varieties temperature, relative humidity and atmospheric composition of the underground storages needs to be monitored.

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