Darkening in open-air sun dried orange-fleshed sweetpotato products being promoted for their high pro-vitamin A carotenoid content

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Abstract

Pro-vitamin A carotenoid retention studies are vital in the process of promoting orange-fleshed sweetpotato (OFSP) as a staple in communities affected by vitamin A deficiency. Drying is the affordable processing technology in sub Saharan African rural settings. This paper presents issues pertaining to darkening in open-air sun dried products in relation to carotenoid content and retention levels. OFSP varieties (*Ejumula*, SPK004, SPK004/6 and SPK004/6/6) were open-air sun dried to two types of products (*amukeke* and *inginyo*). All *trans*-β-carotene content in raw OFSP was highest for *Ejumula* (261.4±29.9 μg/g dwt) and lowest for SPK004 (93.4±9.4). Overall *inginyo* scrapped exhibited the highest carotenoid retention (72.9±10.5%) compared to *amukeke* (22.7±6.3%). Among the *inginyo* products, *Ejumula* contained the highest carotenoid content (193.0±2.2 μg/g dwt) while among *amukeke* products SPK004/6 had the highest content (106.2±2.4 μg/g dwt). As expected all open-air sun dried sweetpotato products darkened due to phenolic and enzymatic activities found in sweetpotato. *Inginyo* scrapped, $A_{(450)}$=0.31-0.64, and un-scrapped products, $A_{(450)}$ = 0.49-0.76, exhibited highly darkened appearances ($p<0.05$) compared to *amukeke*, $A_{(450)}$ =0.29-0.51. The un scrapped *inginyo* was unacceptably darkened compared to the scrapped *inginyo* and required the method to be modified. Ejumula darkened the most ($p<0.05$) implying it contained the highest phenolic content and enzymatic browning phenomenon. SPK004/6 and SPK004/6/6 are improved OFSP varieties exhibited in-between darkening. Darkening is an attribute that can be addressed in the ongoing breeding activities of OFSP varieties. Modifications of specific traditional processing technologies should be pertinent to the promotion process for wider utilization of OFSP.

Keywords: carotenoid, darkening, orange-fleshed sweetpotato, open-air sun dried.

Introduction

In Uganda, sweetpotato fresh roots are mainly consumed boiled or steamed (Owori *et al.*, 2007). In the dry season, sweetpotato is stored as *amukeke* (dried sliced storage roots) and *inginyo* (dried crushed storage roots) more so in Northern and Eastern Uganda (Bashaasha and Scott, 2001). Therefore chipping, drying and storing orange-fleshed sweetpotato (OFSP) for year round use can overcome seasonal shortages of vitamin A in many low income households during the dry season. In order for rural communities to benefit from the high pro-vitamin A content of the OFSP there is need to ascertain the pro-vitamin A retained from the traditional or indigenous processing methods. It is evident that data relating to the form in which the foods are consumed by the population are urgently needed and the influence of processing on pro-vitamin A levels has to be determined. Simulation of the actual traditional handling and processing techniques is necessary to determine how much pro-vitamin A is retained as a result of these processes.

There is an on-going effort to promote and disseminate the OFSP among Ugandan farmers. Pro-vitamin A carotenoids are highly susceptible to degradation during preparation and processing (Rodriguez-Amaya and Kimura, 2004). Furthermore inadequate knowledge exists on the retention of pro-vitamin A carotenoids after traditional processing of OFSP. Present knowledge on retention is variable and inconclusive in particular for rural processing techniques. This is of great concern as the ultimate success of the OFSP in alleviating VAD lies in the amount of β-carotene retained after processing prior to consumption. With the current promotion of the OFSP in Uganda it is imperative that retention studies are carried out to establish the β-carotene content of traditionally processed OFSP. Most the processing operations in the rural communities are rudimentary and result in varied qualities of the end product.

The objective of the study was to compare retention levels of pro-vitamin A carotenoid in traditionally sun dried OFSP products and determine the extent of darkening (discoloration) of the dried OFSP products among varieties.

Materials and methods

Materials

Four orange-fleshed sweetpotato (OFSP) variety of seven months maturity were harvested from Namulonge Agricultural and Animal Production Research Institute (NAARI), Uganda.

All reagents used were of analytical grade, unless otherwise stated, and obtained from BDH suppliers in Kampala, Uganda. Carotenoid standards (All–*trans*-β-carotene and 8'-Apo-β- carotenal) were purchased from CaroteNature (Lupsingen, Switzerland).

Sampling protocol and handling of sweet potatoes

A two stage sampling plan was used, where sound medium sized OFSP roots were randomly selected from 3 subplots in the NAARI research field to constitute a pooled sample for each variety. The pooled samples were placed in black polyethene bags and transported to the Food Science and Technology Laboratory, Makerere University. Sweet potato roots in each pooled sample were gently mixed by shaking in sisal bags (5 times), laid out in a straight line and roots selected using systematic random sampling to obtain a field sample of 40 roots for each variety. Intact roots were stored in the laboratory at *ca*. 22◦C in subdued light prior to drying.

Open-air sun drying to produce amukeke and inginyo

Figures 1 and 2 were processes used to produce the open-air sun dried products (*amukeke* and *inginyo*). Small sized roots (< 200 g) were selected for drying to *inginyo* and medium to large sized roots (> 200 g) dried to *amukeke*.

Parameters measured

Moisture content was determined on triplicate samples each for the unprocessed and processed sweetpotato by drying in a Gallenkamp hot box oven fitted with a fan (Model SG93/08/850, UK) at 70◦C for 20 hours to constant dry weight.

The degree/ extent of darkening (discoloration) of the dried products was measured according to Walter and Purcell's (1980) method. Ten grams of sample was mixed in 50 ml of a cold buffer (pH 6.3) constituted of 0.05 M phosphate and 0.15 M sodium chloride. The contents were held at 5◦C for 2 hours and centrifuged at 4,000*g* for 10 minutes. The supernatant was collected, filtered through a 0.2 µm filter and filtrate kept in an ice bath. A portion was allowed to warm to room temperature and its absorbance measured at 450 nm recorded as degree of darkening / browning.

All *trans*-β-carotene content was measured using the HPLC technique as described by Mulokozi and Svanberg (2003) and Rodriguez-Amaya and Kimura (2004). Percent true carotenoid retention was computed based on the all *trans*-β-carotene content.

All unprocessed and open-air sun dried samples were flushed with nitrogen and packaged using a Mini Jumbo vacuum sealer (HENKELMAN 3000711837/2007, Netherlands). Samples stored in a freezer at -55◦C prior subsequent analyses.

Experimental design and statistical analysis

The study design was a 4 x 2 factorial experiment where factor one was the Orange-fleshed sweet potato variety (*Ejumula*, SPK004, SPK004/6 and SPK004/6/6.) and factor two type of open-air sun dried product (*inginyo* and *amukeke*). SPSS statistical programme (ver. 12) was used for data analysis, ANOVA for testing significant differences among variety and product type at 0.05%.

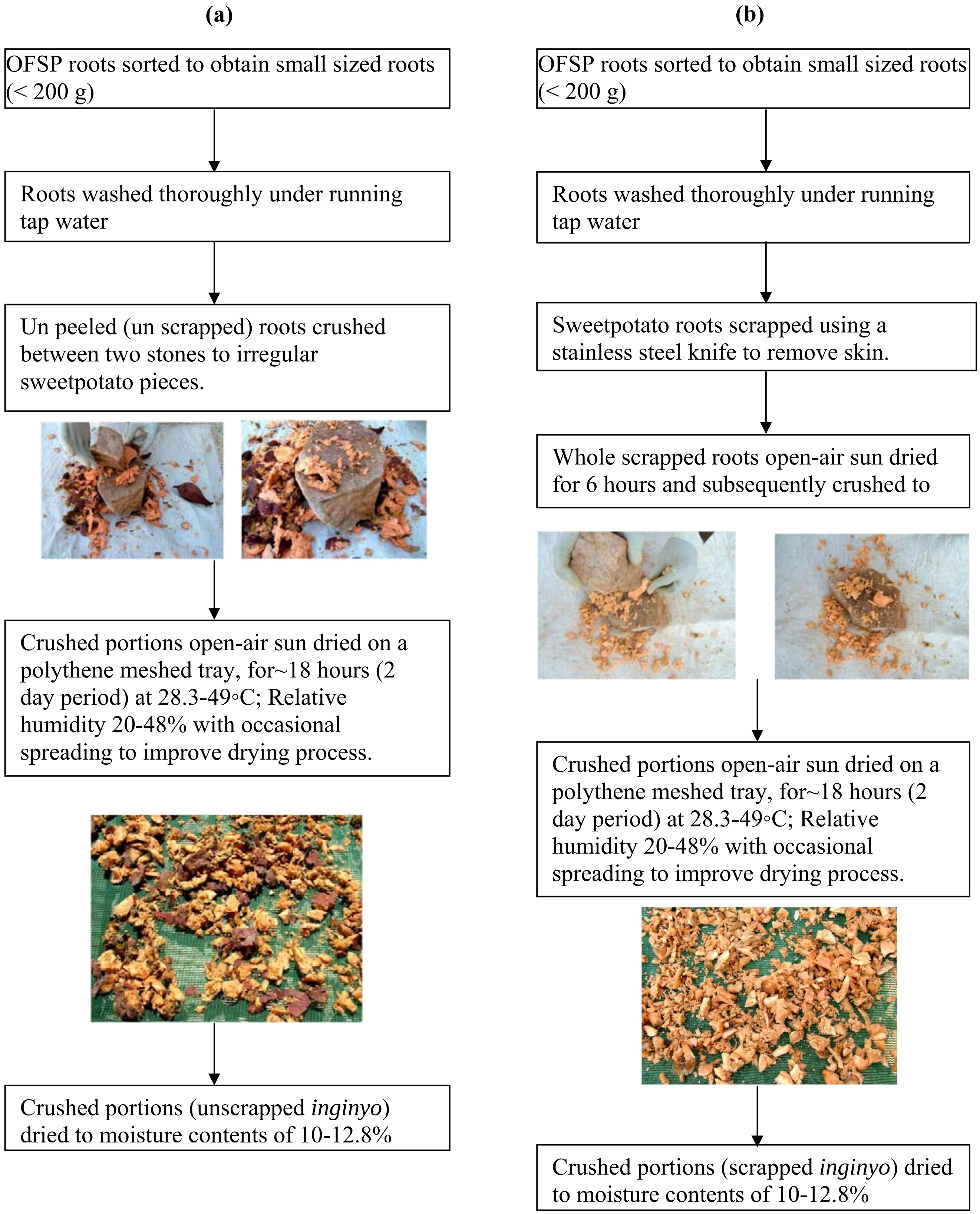

Figure 1 (a) Rural open-air sun drying of small sized sweetpotato to produce (*inginyo*)
(b) Slightly modified method to reduce darkening of *inginyo* products

OFSP were sorted to obtain medium to large sized roots (> 200 g)

↓

Roots washed to remove extraneous matter

↓

Roots peeled using stainless steel knife and quartered longitudinally

↓

Two opposite quarters of each root were retained and washed thoroughly under running tap water

↓

Quartered portions hand sliced to approximately 4 mm slices.

↓

Sliced samples open-air sun dried for ~18 hours (2 day period) at 31.4-50◦C; Relative humidity 18.7-46% with occasional turning to improve the drying.

Figure 2. Rural open-air sun drying of medium to large sized sweetpotato to *amukeke*

Results and discussion

Darkening of open-air sun dried products

Open-air sun drying of sweetpotato is prevalent in Sub Saharan region. *Inginyo* and *Amukeke* constitute main dried sweetpotato products in Eastern region of Uganda. Figure 3 shows *inginyo* products dried from the four OFSP varieties. Figure 3 a shows produced according to the indigenous method of Eastern Uganda and figure (b) using slightly modified method to reduce the darkening appearance.

Figure 3. (a) *Inginyo* products following the indigenous open-air sun drying method (b) *Inginyo* products from a slightly modified method to reduce the darkening appearance

Inginyo is a traditional term in *Ateso* (local language) literally referring to small sized sweetpotato roots and now used to refer to crushed dried sweetpotato. Small sweetpotato roots are difficult to peel and therefore constitute the main raw material for the manufacture of *inginyo*. *Amukeke* in *Ateso* literally refers to peeled and dried sliced sweetpotato chips. Medium to large sized roots are used to produce *amukeke*. Unlike *inginyo*, *amukeke* is not for flour production and there not milled to flour. In Eastern Uganda, traditionally sweetpotato roots are not scrapped or peeled. Whole intact roots may be washed prior to crashing and open-air sun dried.

The extent of darkening of the open-air dried products is shown in Figure 4. Darkening was most pronounced for the *inginyo* products compared to the *amukeke* products (Figure 4). The phenomenon of darkening or the undesirable discolouration in sweetpotato is attributed to the interaction of phenolics and the polyphenol oxidase (Walter and Schadel, 1981). Darkening of the *inginyo* products was observed for all OFSP varieties following the indigenous processing method (Figure 3a). A slight modification of the processing method reduced the darkening appearance (Figure 3b).

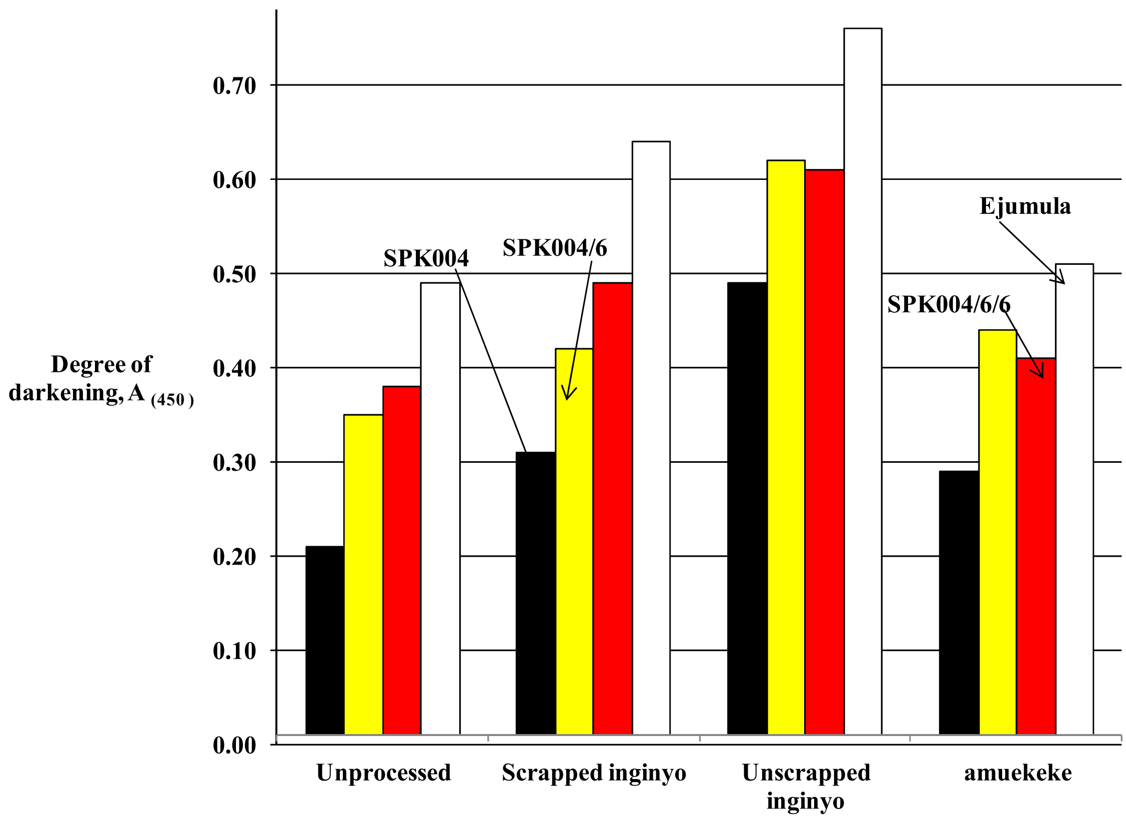

Figure 4 Degree of darkening (discolouration) of open-air sun dried products from four orange-fleshed sweetpotato varieties (SPK004, SPK004/6, SPK004/6/6 AND Ejumula). Absorbance reading at 450 nm was computed as the degree of darkening that had occurred in the products

Among the dried products the unscrapped (not peeled) *inginyo* exhibited the highest degree of darkening and the most undesirable appearance ($p<0.05$) compared to the scrapped *inginyo* and *amukeke* products (Figure 4). This is expected since phenolics are highest or concentrated in the sweetpotato peel, progressively decrease from the skin to inner tissue of the root (William and Schadel, 1992). Among the sweetpotato varieties Ejumula exhibited the highest degree of darkening of 0.49 for the unprocessed to 0.76 for unscrapped *inginyo* and SPK004 the least (Figure 4). SPK004/6 and SPK004/6/6, recently released OFSP varieties, were comparable in relation to degree of (Figure 4).

Pro-vitamin A carotenoid content

The dry matter contents of the OFSP varieties ranged from 31.2 to 39.2% (Table 1). SPK004 and SPK004/6 had the highest and lowest dry matter, respectively. The dry matter measured for all varieties were higher than those reported by Bengtsson *et al.* (2008) for the same varieties and Hagenimana *et al.* (1999) for other six OFSP varieties studied.

Table 1. All *trans*-•-carotene content and percent retention of open-air sun dried products

Sweetpotato variety	Dry matter (%)	All *trans*-•-carotene (•g/g), dwt			% retention*	
		Un processed	*amukeke*	*inginyo*	*amukeke*	*inginyo*
SPK004	39.2±1.5	93.4 ± 9.4*	21.1 ± 1.8	-	23.4 ± 2.4	-
SPK004/6	31.2±1.0	205.4 ± 28.2	51.8 ± 1.1	106.2 ± 2.4	29.2 ± 0.0	59.8 ± 0.1
SPK004/6/6	36.3±0.7	192.5 ± 28.1	39.4 ± 0.2	130.7 ± 2.4	25.0 ± 0.5	82.9 ± 0.6
Ejumula	33.6±1.6	261.4 ± 29.9	34.4 ± 0.6	193.0 ± 2.2	13.3 ± 0.3	74.6 ± 1.9

*All values are means of triplicate analyses

All *trans*-β-carotene content of the un processed OFSP ranged from 93.4 to 261.4 µg /g, dwb (Table 1) varied considerably ($p<0.05$) among the different varieties. Similar values for Ejumula have been reported by Bengtsson *et al.* (2008) for Ejumula with the exception of the other OFSP varieties that registered lower all *trans*-β-carotene content probably due to different maturity age of the OFSPs used in the two different studies.

Percentage retention of all *trans*-β-carotene was extremely low ($p<0.05$) for *amukeke* (22.7±6.3%) compared to *inginyo* (72.4± 10.5%) products, irrespective of OFSP variety. Percentage retention ranged from 13.3 to 29.2% (Table 1). Scrapping and drying of whole intact roots (for ~ 6 hours) prior to crushing when making *inginyo* appeared to result in greater β-carotene retention compared to *amukeke* production for all cultivars (Table 1). Low percentage retention levels observed for *amukeke* products could be attributed to exposure to direct sunlight and continued oxidative enzymatic activity during drying. Considerable carotenoid degradation has been associated with open-air sun drying compared to other drying methods such as oven and solar drying. Stollman (2005) showed higher β-carotene content values for solar dried Ejumula chips than open-air sun dried chips exposed to direct sun light. She attributed these findings to shorter drying times and minimal exposure to direct sunlight for the solar drying method.

Bengtsson *et al.* (2008), however, registered no significant difference in all *trans*-β-carotene percentage retention for Ejumula slices subjected to forced air oven drying (88.2%), solar drying (91.1%) and open-air sun drying (83.8%). Notable, is the substantially high retention value for open-air sun drying compared to that reported in our study (Table 1). This could be attributed to differences in OFSP chip/ slice thickness and drying conditions. The relatively lower drying temperature (29◦C) and short drying duration as was the case for Bengtsson *et al.* (2008) could probably have enhanced pro-vitamin A retention as opposed to retention levels observed in the present study. Bechoff *et al.* (2009) evaluated the effect of sun drying Ejumula and SPK004 (Kakamega) under wet and dry weather conditions on pro-vitamin A carotenoid retention, where greater losses of carotenoid in the wet weather (11%) compared to dry weather (7%) were recorded.

All OFSP variety processed to *amukeke* are unlikely to meet the recommended Vitamin A (µg RAE / day) intake levels for under five olds (400 µg RAE /day). While OFSP varieties processed to *inginyo*, excluding SPK004, may likely meet the recommended Vitamin A for under five year olds, particularly Ejumula. However, it is important to note that the dried products are primary processed products requiring further processing, usually boiling in Eastern Uganda, will result in further carotenoid losses during preparation. Use of OFSP varieties with high pro-vitamin carotenoid content, irrespective of their percent retention level, such as Ejumula would be most appropriate.

Low *et al.* (2005) evaluated three methods of drying Resisto OFSP by drying chips sliced in a selected Mozambique village as is the norm (approximately ¼-cm thickness and not peeled). Samples dried under the shade of a tree had a higher RAE value (1,050 µg /100 g) than those did that were shaded by a woven mat (975 µg/100 g). The sample dried under a mat covered with black plastic had the lowest RAE value (892 µg/ 100 g, dwt). Direct sun drying has a destructive effect on pro-vitamin A carotenoid. However, OFSP varieties with significant amounts of beta-carotene may retain high amounts of carotene even when dried under direct sunlight (Low *et al.* 2005).

Conclusion

A sizeable amount of data has been collected in regard to retention studies of caroteniods. This study however, has revealed production of *inginyo* dried product had better retention levels compared to *amukeke*. This is vital information for communities where OFSP are being promoted. Despite the darkening appearance of sweetpotato, high retentions were registered for Ejumula variety. The need to complement retention studies with modifying indigenous or traditional processing methods to benefit the communities is crucial.

Acknowledgments

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