
Full Length Research Paper

Effect of sun- drying on nutrient content of orange fleshed sweet potato tubers in Tanzania

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Accepted 8 November, 2015

The aim of this study was to assess the impact of traditional processes practiced in Maswa district Tanzania, on nutrient content of orange fleshed sweet potato tubers. The nutrients content was studied in four dried sweet potato varieties (*Jewel*, *Karoti dar*, *Kabode* and *Ejumula*), subjected to blanching and cooking. Chemical analyses were carried out on orange fleshed sweet potato tubers to establish levels of nutrients in its fresh and processed forms, using official methods of analysis. β -carotene content was also determined by spectrophotometric method, to see how these nutrients were affected by processing and storage. Results were analysed using R-statistical package version 3.1.2 (2014-10-31) software and means were separated using turkey test. The composition of fresh sweet potato tubers were protein 1.9-2.7%, fat 1.1-1.67%, crude fibre 3 - 3.6%, ash 2.77- 4.2%, carbohydrate content 18 - 26.8% and beta carotene 24.2 - 73.9mg/100g on dry matter basis and moisture content 65 - 70.4%. For dried samples, the nutrient composition on dry matter basis were protein 4.89-9.29%, fat 0.56-1.93%, crude fibre 3.19-6.07%, ash 1.95-3.54%, carbohydrate content 72.36-80.33% and beta carotene 8.2- 59.8mg/100g. Retention of beta carotene content of dried chips during storage showed that *Matobolwa* and blanched solar dried chips had highest retention compared to *Michembe* after six months of storage. Blanched solar dried should be adopted in the place of *Michembe* because blanched solar dried chips retain more beta carotene, have longer shelf life and the technology is simple to be implemented by famers.

Key words: Orange fleshed sweet potato, nutritional value, *Michembe*, *Matobolwa*, blanched solar dried chips.

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam.) is a perennial tuber crop. It is a member of the Convolvulaceae family, which also contains the morning glory. Flowers can be white or purple, and leaves can be green or purple. The flesh can be white, cream, yellow, orange, or purple (Woolfe, 1992; Bovell-Benjamin, 2007) with orange, white and cream the most commonly grown and eaten. Both leaves and the tuberous roots are more commonly eaten (Woolfe, 1992; Bovell-Benjamin, 2007).

Sweet potato is a major staple food and income source in several regions of Tanzania and elsewhere in East Africa and is among under-exploited food crops (Ndunguru, 2003). It is one of the most important food security crops, especially in those regions prone to drought and with poor soils (FAO, 2004). It is an

important subsistent crop grown in almost all agro-ecological zones of Tanzania (Masumba et al., 2004). It is mainly grown in Shinyanga, Mara, Mwanza, Kagera, Kigoma, Tabora, Morogoro and Mbeya (Kapinga et al., 1995). Sweet potato is the third most important root and tuber crop in the country after cassava and round potato (Kapinga et al., 1995).

Sweet potatoes are grown mainly for human survival. The average yield of sweet potatoes is approximately 5 - 6 metric tonnes per hectare on dry weight basis (Ndunguru, 2003). However, the low yield in Tanzania is caused by many factors including susceptibility to pests and diseases, declining soil fertility, moisture stress, low level of crop husbandry and management and poor accessibility to markets (Ndunguru, 2003). The crop provides a sustainable food supply when other crops fail. In other parts of the world, yields are much higher than in Tanzania.

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Traditional Tanzanian methods of processing sweet potatoes are often limited to washing, peeling and boiling and can also be processed by grating, drying and then milling (Schmidt, 2013). In Tanzania, sweet potato is processed into two main products namely: *Michembe*; where the roots are withered, then cut into slices and dried and *Matobolwa*, where the roots are boiled, sliced and dried. Both of these products last for 5 to 10 months. Other products that can be prepared from sweet potatoes in Tanzania include cake, chapattis, doughnut, *kalimati*, meal flour, porridge and crisps (Githuki et al., 2005).

Dried chips are often of various shapes, sizes and compactness and its losses depends on feeding habits of the pest (Agona et al., 1999). For instance, sedentary insects *Rhyzopertha dominica* (Fab.), *Prostephanus truncus* (Horn) and *Dinoderus minutus* (Fab.), always feed internally of the chips and there is extensive tunneling and release of powdery wastes. On the other end, the more vagile insects like *Araecerus fasciculatus* (Degeer), *Sitophilus zeamais* (Motsch.) and *S. oryzae* (L.) feed externally on the chips and always emerge out the chips leaving distinct emergence holes and powdery waste products which are common features of infested dried chips (Agona et al., 1999).

Sweet potato is a very important crop in developing world but less important crop in some parts of the developed world. Sweet potato roots are bulky and perishable unless cured. This limits the distance over which sweet potato can be transported economically (FAO, 1990). Moreover, production is highly seasonal in most countries, leading to marked variation in the quantity and quality of tubers in market and associated price swings (Oke and Workneh, 2013).

Small quantity of orange-fleshed sweet potato may contain 300 to over 3,000 µg retinol equivalent per 100 g fresh weight. This can provide the recommended daily allowances while also serving as a rich source of other vitamins and nutrients (Woolfe, 1992). Due to this reason, orange-fleshed sweet potatoes can be used to alleviate vitamin A deficiency.

MATERIALS AND METHODS

Materials

Four varieties of orange fleshed sweet potatoes (*Kabode*, *Jewel*, *Ejumula* and, *Karoti Dar*) used in this research were collected from Ukiliguru Research Centre Mwanza. The samples were randomly sampled based on the soil colour and crop performance.

Preparation of samples

Fresh samples were prepared in accordance with Rodriguez Amaya and Kimura (2004). The fresh roots were arranged in a line and after five roots, the root was

picked. The picked roots were peeled, quartered and two opposite sections were combined and blended to a fine pulp using a thermomix™ multi-purpose household food processor (Vorwerk, Germany). The pulp obtained was used for analysis of β-carotene and proximate contents.

Drying

The flesh colour of sweet potatoes can be white, cream, yellow, orange or purple. Sweet potatoes with orange flesh have high beta carotene content and were used in this study so as to assess the effect of different processing method used by villagers on nutrients. Orange fleshed sweet potato varieties were sliced into dices about 1.5 mm thick. Some sliced pieces were blanched with boiling water at 90°C for 2 min. and then solar dried (blanched solar dried chips). The remaining portion of the sliced pieces were sun dried to prepare *Michembe*. Small portion of OFSP roots was boiled, cooled, then peeled to prepare *Matobolwa* which were sun-dried and solar dried (tunnel dryer maximum temperature 54°C).

After drying, the samples were divided into three portions. The first portion was analyzed at zero storage for proximate composition and beta carotene content. The remaining two portions were packed in airtight plastic bags and stored in a box at room temperature. The stored samples were analyzed for beta carotene and moisture content after three and six months respectively (Figure 1).

Determination of moisture content

The moisture content was determined by oven dry method (AOAC, 1995). The sample was weighed and oven dried at 105°C till constant weight was attained. The amount of moisture was calculated and expressed in percentage.

Determination of protein content

Kjeldahl procedure was used for the determination of protein using block digestion and steam distillation (Kjeltec™ 8200 Auto distillation unit 2012) (AOAC, 1995). 0.25 g of the sample was weighed and transferred into a digestion flask to which approximately 2g of catalyst mixture (CuSO₄, K₂SO₄) was added followed by approximately 6 ml of concentrated sulphuric acid. The contents of the flask were digested in a fume chamber and then the resultant fume chamber content was connected to the nitrogen distillation unit. The distillate was titrated with 0.1M HCl until the colour change from blue to dirty green or orange endpoint. The volume of acid used for neutralization was noted. The percentage of crude protein was calculated using the following formula:

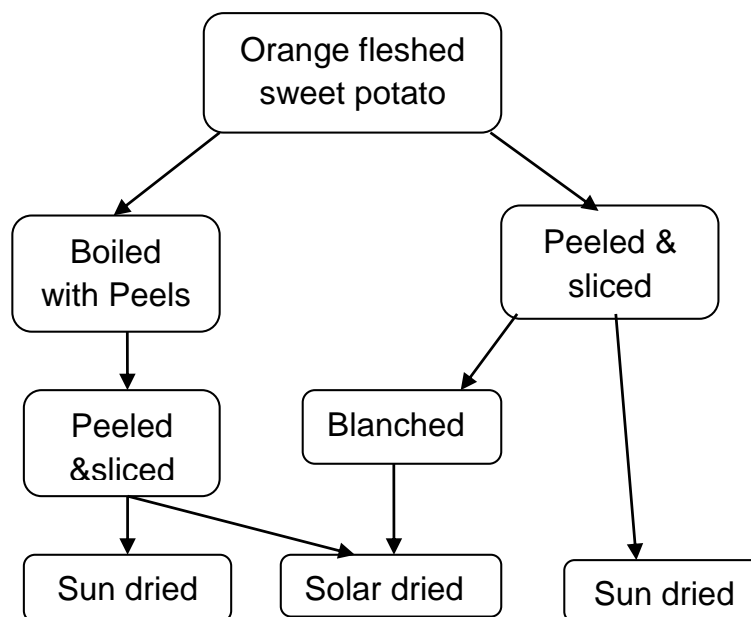


Figure 1. Processing flow chart of orange fleshed sweet potato Storage.

$$\% \text{ Nitrogen} = \frac{1.401 \times (\text{titre} - \text{blank}) \text{mls} \times \text{Concentration of acids in molarity}}{\text{sample weight (g)}}$$

$$\% \text{ crude protein} = \% \text{ N} \times \text{conversion factor}$$

Determination of fat/ lipid content

The fat content was determined by solvent extraction method using Soxtec™ 2055 (AOAC, 1995). About 3 g each of the samples were taken into extraction thimble and covered with defatted cotton wool. The thimble support holder was used to insert the thimbles into the extraction unit, then the cup holder was used to insert the extraction cup containing 70 ml of solvent (40- 60°C petroleum ether). The extraction process involved three stages; boiling (15 min), rinsing (45 min) and recovery (10 min). The cup containing extracted fat was dried in an oven at 105°C for 30mins, cooled in a desiccator and then weighed. The fat content was expressed in percentage.

Determination of ash content

The ash content was determined by heating a sample in a muffle furnace (AOAC, 1995). Five grams of sample was weighed and transferred to a furnace at 550°C. The ash was weighed and content expressed as percentage of the original sample weight on dry weight basis.

Determination of crude fibre

Crude fibre was determined using dilute acid and alkali hydrolysis using Fibertec 2010 by Weende method. Exactly 1.00 g of the sample was accurately taken into glass crucible and about 200 ml of boiled 1.25% H₂SO₄ was poured into the flask and the mixture boiled for 30 minutes under reflux condenser. The insoluble matter was washed with boiling 4 times until the residue was free from acid. About 200 ml of boiling 1.25% KOH solution was added into the residue and then heated for 30 min. under reflux condenser. The residue was filtered, washed with boiling water and then the crucible was transferred to the cold extraction unit and washed with acetone. After digestion, the residue was dried at 105°C in an air-convectional oven, cooled in a desiccator until constant weight was obtained. The residue was incinerated in an electric furnace at 525°C until all the carbonaceous matter was burnt. The crucible was left to cool down to below 250°C, then removed from the furnace and transferred to the desiccator, cooled to room temperature and weighed. The crude fibre was calculated and expressed as percentage (European community, 1992).

Determination of carbohydrate

The carbohydrate content was determined by difference method as follows:

Table 1. Proximate and β -carotene composition of sweet potatoes.

Variety/Treatment	Moisture (%)	Fat (%)	Fiber (%)	Protein (%)	Ash (%)	CHO (%)	B carotene (mg/100g)
Jewel							
Fresh	70.4±0.17 ^d	1.7±0.08 ^d	3.6±0.08 ^a	1.9±0.08 ^a	4.2±0.07 ^d	18.3±0.07 ^a	73.9±5.84 ^d
Blanched	12.1±0.45 ^c	0.98±0.08 ^{ab}	4.7±0.05 ^c	6.8±0.52 ^b	2.6±0.05 ^b	72.9±0.58 ^b	52.4±0.51 ^b
Cookedso	11.3±0.16 ^b	1.00±0.12 ^{bc}	5.5±0.19 ^d	7.0±0.73 ^b	2.1±0.19 ^a	73.1±0.44 ^b	59.8±0.04 ^c
Cookedsu	10.7±0.21 ^b	0.82±0.00 ^a	6.1±0.20 ^e	5.8±0.84 ^b	2.0±0.07 ^a	74.7±0.58 ^c	59.6±0.05 ^c
Michembe	9.3±0.33 ^a	1.2±0.02 ^c	4.0±0.01 ^b	5.9±0.26 ^b	3.3±0.22 ^c	76.4±0.38 ^d	39.9±0.99 ^a
Karoti Dar							
Fresh	65.1±0.15 ^e	1.6±0.07 ^b	3.3±0.01 ^a	2.7±0.41 ^a	3.5±0.12 ^c	23.8±0.37 ^a	32.1±0.52 ^d
Blanched	11.8±0.20 ^d	0.6±0.01 ^a	3.2±0.02 ^a	5.1±0.69 ^b	2.5±0.11 ^b	76.8±0.61 ^c	19.8±0.06 ^b
Cookedso	10.9±0.38 ^c	0.8±0.06 ^a	4.3±0.24 ^b	5.7±0.16 ^{bc}	2.5±0.13 ^b	75.9±0.3 ^{bc}	19.2±0.04 ^b
Cookedsu	10.4±0.16 ^c	1.1±0.16 ^a	3.7±0.11 ^b	6.2±0.33 ^b	2.3±0.03 ^b	76.3±0.36 ^c	18.4±0.55 ^b
Michembe	6.2±0.09 ^a	1.8±0.18 ^b	3.3±0.13 ^a	6.9±0.44 ^{cd}	2.6±0.08 ^b	79.2±0.42 ^d	14.8±1.58 ^a
Kabode							
Fresh	65.4±0.10 ^d	1.1±0.02 ^a	3.0±0.05 ^a	2.2±0.05 ^a	3.5±0.11 ^d	24.8±0.11 ^a	24.2±1.52 ^c
Blanched	9.6±0.23 ^b	1.9±0.02 ^b	4.7±0.09 ^c	9.3±0.88 ^d	2.1±0.07 ^{ab}	72.4±0.85 ^b	22.4±0.01 ^c
Cookedso	8.3±0.04 ^a	1.9±0.07 ^b	4.8±0.04 ^c	8.0±0.31 ^c	2.0±0.09 ^a	74.9±0.33 ^c	28.0±0.68 ^d
Cookedsu	8.8±0.24 ^b	1.7±0.03 ^b	4.1±0.18 ^b	7.6±0.47 ^d	2.1±0.10 ^a	75.6±0.29 ^b	23.1±0.64 ^c
Michembe	8.1±0.32 ^a	1.6±0.28 ^b	3.2±0.18 ^a	5.5±0.06 ^b	3.2±0.02 ^c	78.4±0.50 ^d	8.2±0.52 ^a
Ejumula							
Fresh	64.5±0.32 ^c	1.1±0.06 ^a	3.4±0.02 ^a	2.1±0.05 ^a	2.8±0.01 ^d	26.1±0.04 ^a	31.4±0.07 ^d
Blanched	10.7±1.38 ^{ab}	1.5±0.31 ^a	4.4±0.13 ^c	5.4±0.22 ^b	2.4±0.03 ^b	75.6±0.34 ^c	21.0±0.08 ^b
Cookedso	12.0±2.17 ^b	1.4±0.28 ^a	4.7±0.25 ^d	6.9±0.27 ^c	2.1±0.04 ^a	72.8±0.65 ^b	31.5±0.47 ^d
Cookedsu	10.4±1.49 ^{ab}	1.8±0.47 ^a	4.8±0.04 ^d	6.0±1.02 ^{bc}	2.2±0.03 ^a	74.8±1.47 ^{bc}	28.7±0.69 ^c
Michembe	6.99±1.97 ^a	1.3±0.03 ^a	3.8±0.03 ^b	4.9±0.49 ^b	2.7±0.02 ^c	80.3±0.53 ^d	18.1±0.75 ^a

The values are means \pm SD. Means in the same column bearing different superscripts are significantly different ($p < 0.05$).

$\% \text{ Carbohydrate} = \text{DM} - (\text{Crude fibre dmb} + \text{ash content dmb} + \text{lipid dmb} + \text{protein dmb})$

Where

DM -Dry matter content

Dmb -Dry matter basis

Determination of beta β -carotene

About 3 g of sweet potato were transferred into a mortar. The mixture was ground with 50 ml of acetone (acetone refrigerated at 4°C for 2 h prior to use) being added slowly then filtered using cotton wool plugged in a fume chamber. The extraction was repeated until the sample from the mortar was devoid of colour. About 40 ml of petroleum ether was put in a separating funnel and acetone was added. Distilled water was added slowly along the neck without shaking to avoid emulsion formation. The two phases were then left to separate and the lower aqueous layer discarded. The sample was washed 3 - 4 times with distilled water (approx. 200 ml) each time to remove residual acetone. In the last phase, washing was done ensuring that no amount of the upper phase was discarded. Then, the upper layer was collected into 50 ml flask using anhydrous sodium sulphate filter arrangement to remove residual water. The absorbance was determined at 450 nm using UV-visible spectrophotometer model BioMate-6 (sigma Adrich). The

concentration of beta carotene was calculated using the equation of the standard curve (Rodriguez-Amaya, 2001).

Data analysis

The results obtained were in triplicates and were analysed using R statistical package version 3.1.2 (2014-10-31). One way analysis of variance was used to determine the significant difference among treatment and separation of means was done using Turkey's test ($p < 0.05$) (R Core Team, 2013).

RESULTS

The varieties studied shows that there was significant difference between fresh and dried samples ($p < 0.05$) (Table1).

Moisture content

The moisture content of fresh samples for all varieties studied ranged between 64.5 \pm 0.32 and 70.4 \pm 0.17% (Table 1). *Jewel* variety had the highest value and *Ejumula* the lowest. The moisture content of all dried chips of OFSP varieties ranged between 6 - 12 percent on dry matter basis which is a good moisture to inhibit

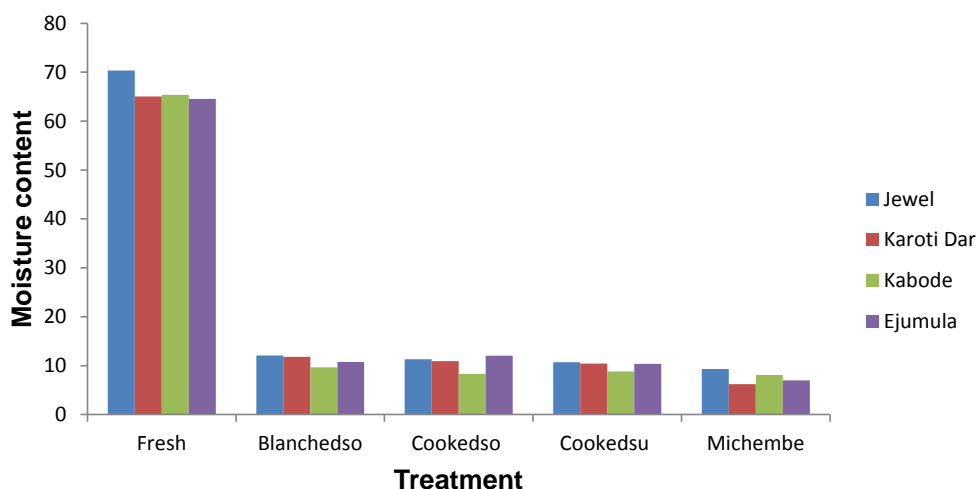


Figure 2. The graph of moisture content of Orange fleshed sweet potato varieties (Blanchedso = blanched then solar dried, cookedso = cooked then solar dried, cooked su= cooked then sundried and Michembe = Dried raw without boiling).

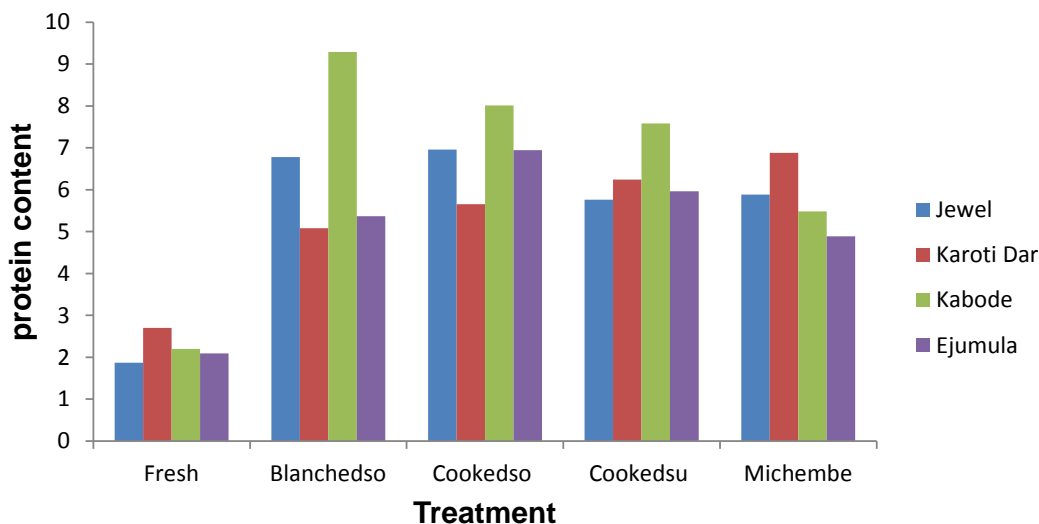


Figure 3. The graph of protein content of orange fleshed sweet potato varieties (Blanchedso = blanched then solar dried, cookedso =cooked then solar dried, cookedsu= cooked then sundried and Michembe = Dried raw without boiling).

deterioration. The moisture content of fresh and dried sweet potato varieties are as indicated in Figure 2.

Protein content

The protein content of fresh samples in all varieties studied ranges between 1.9 ± 0.08 and 2.7 ± 0.41 g/100g on dry matter basis (Table 1). For *Jewel* variety, the treatments subjected to the samples before drying indicate no significant effect on the protein content, although solar dried samples showed higher values (blanched and *Matobolwa*) compared to sun dried samples (*Matobolwa* and *Michembe*). For *Kabode*

variety, solar dried samples had significantly higher values than sun dried samples. In *Karoti dar*, it was observed that sundried samples had highest protein compared to solar dried samples. For *Ejumula*, *Matobolwa* showed significantly higher value of protein content than blanched samples and *Michembe*. The protein content of fresh and dried sweet potato varieties are indicated in Figure 3.

Fat content

Fat content of sweet potato varieties for fresh samples ranged between 1.1 ± 0.06 and 1.7 ± 0.08 % and dried

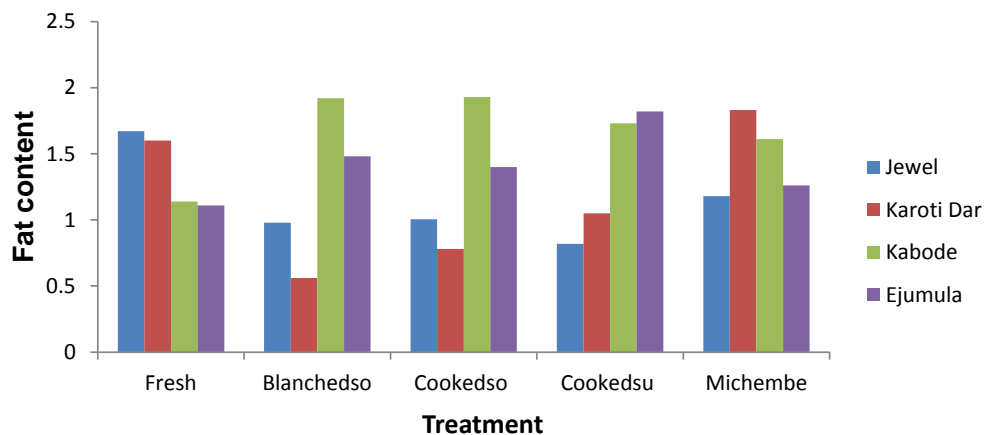


Figure 4. The graph of fat content of orange fleshed sweet potato varieties (Blanchedso = blanched then solar dried, cookedso =cooked then solar dried cookedsu= cooked then sundried and Michembe = Dried raw without boiling).

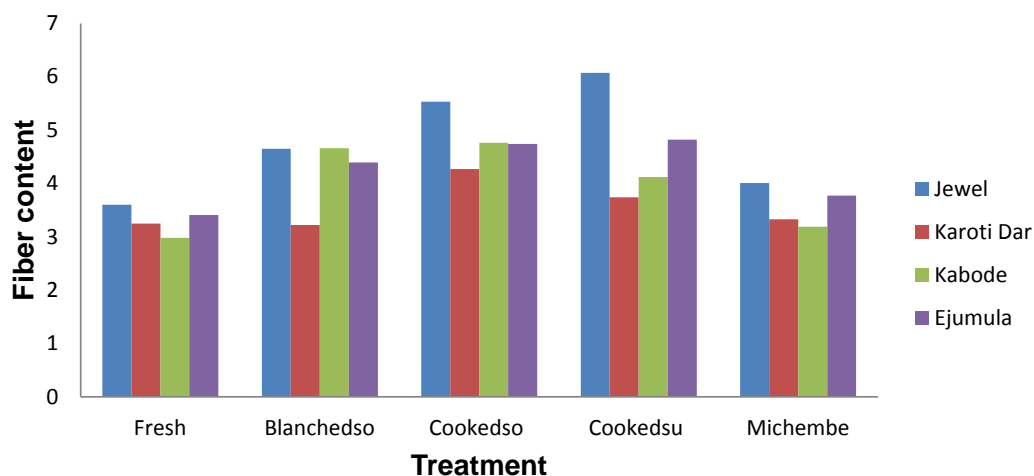


Figure 5. The graph of fibre content of orange fleshed sweet potato varieties (Blanchedso = blanched then solar dried, cookedso =cooked then solar dried, cookedsu= cooked then sundried and Michembe = Dried raw without boiling).

samples ranged 0.56 ± 0.01 to 1.93 ± 0.07 g/100g on dry matter basis. For *Jewel* variety, *Michembe* showed highest value. In *Kabode* variety, it was observed that there was no significant difference in all dried samples although solar dried samples had higher value than sundried sample. In *Ejumula* variety, there was also no significant difference between fresh and dried samples, the fresh samples having the lowest value compared to dried samples. The fat contents of fresh and dried sweet potato varieties are as indicated in Figure 4.

Fibre content

Fiber content of sweet potato varieties used in this study ranged between 3 ± 0.05 and 3.6 ± 0.08 % on dry matter basis for fresh samples with *Jewel* having the highest

value and *Kabode* the lowest. The crude fibre of dried samples ranged between 3.2 ± 0.18 and 6.1 ± 0.20 g/100g dry matter basis, having higher value compared to fresh samples. Three varieties *Jewel*, *Karoti dar* and *Ejumula* indicated that *Matobolwa* have significant highest value compared to *Michembe* and for *Kabode*, solar dried samples showed significantly higher value compared to sun dried samples The fibre content of fresh and dried sweet potato varieties are indicated in Figure 5.

Ash content

The ash content of fresh sweet potato varieties ranged between $2.8 \pm 0.01\%$ to $4.2 \pm 0.07\%$ on dry matter basis with *Ejumula* having low value and *Jewel* higher value.

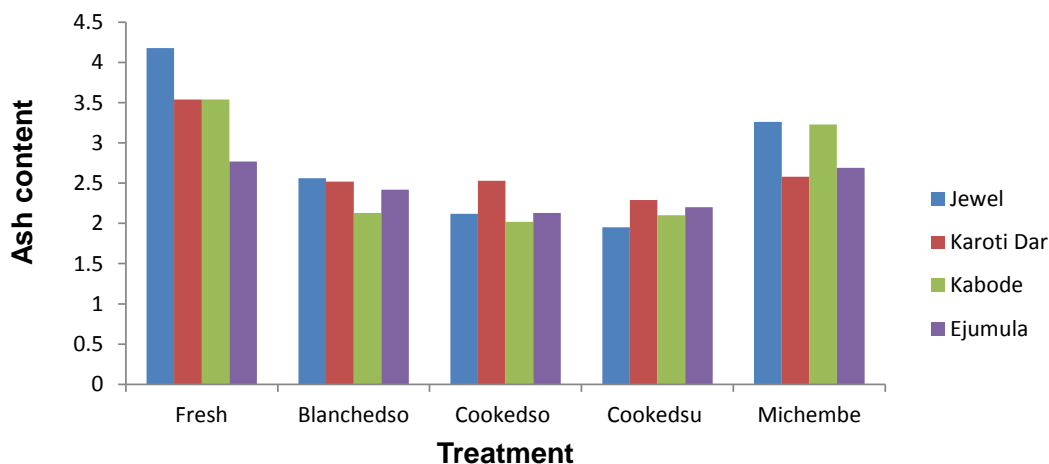


Figure 6. The graph of ash content of orange fleshed sweet potato varieties (Blanchedso = blanched then solar dried, cookedso =cooked then solar dried, cookedsu= cooked then sundried and Michembe = Dried raw without boiling).

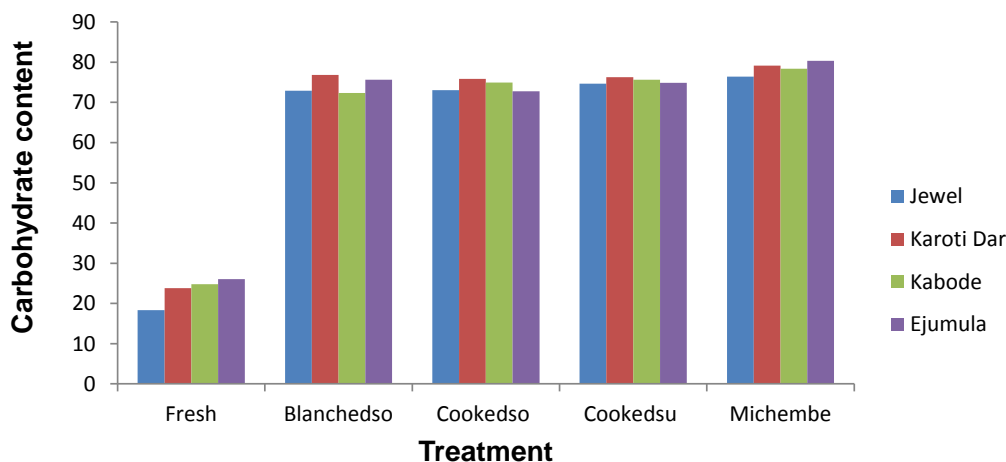


Figure 7. The graph of carbohydrate content of orange fleshed sweet potato varieties (Blanchedso = blanched then solar dried, cookedso =cooked then solar dried cookedsu= cooked then sundried and Michembe = Dried raw without boiling).

The ash content of dried samples ranged between 3.3 ± 0.22 and $2.0 \pm 0.07\%$ on dry matter basis. Among the dried samples of all varieties, *Michembe* had the highest value. The ash content of fresh and dried sweet potato varieties are as indicated in Figure 6.

Carbohydrate content

The carbohydrate content of fresh samples ranged between 18 ± 0.07 and $26.8 \pm 0.34\%$ on dry matter basis. Fresh samples have significant low value compared to dried samples. The variety observed with low carbohydrate content had high moisture content. Carbohydrate content of dried samples ranged between 72.36 ± 0.85 and $80.33 \pm 0.53\%$ on dry matter basis.

Michembe showed high significant values compared with other dried samples in all varieties studied. The carbohydrate content of fresh and dried sweet potato varieties are as indicated in Figure 7.

B-carotene content

The results (Table 2) indicated that beta carotene content of sweet potato varieties ranged between 24.2 ± 1.52 and 73.9 ± 5.84 mg per 100 g on dry matter basis for fresh samples. B-carotene content of dried samples ranged from 8.2 ± 0.52 to 59.8 ± 0.04 mg per 100 g on dry matter basis and was higher than that of fresh samples). Pretreatment conditions resulted in reduction in beta carotene content in all cases. Considering the fresh

Table 2. β -carotene content retention after six months storage.

Variety/ Treatment	Zero months (β -carotene)	Three months (β -carotene)	% retention	Six months (β -carotene)	% retention
Jewel					
Blanched	52.38 \pm 0.51 ^b	42.24 \pm 2.24 ^a	81	40.21 \pm 1.00 ^a	77
Cookedso	59.77 \pm 0.04 ^c	49.22 \pm 0.07 ^b	82	37.32 \pm 0.47 ^a	63
Cookedsu	59.60 \pm 0.05 ^c	46.91 \pm 0.05 ^b	79	31.75 \pm 0.26 ^a	53
Michembe	39.88 \pm 0.99 ^c	14.43 \pm 0.74 ^b	36	5.44 \pm 0.24 ^a	14
Karoti Dar					
Blanched	19.77 \pm 0.06 ^c	7.53 \pm 0.53 ^b	38	5.83 \pm 0.19 ^a	29
Cookedso	19.20 \pm 0.04 ^c	7.14 \pm 0.29 ^b	37	5.76 \pm 0.09 ^a	30
Cookedsu	23.09 \pm 0.64 ^c	20.72 \pm 0.26 ^b	90	7.59 \pm 0.20 ^a	33
Michembe	14.78 \pm 1.58 ^c	8.23 \pm 0.55 ^b	56	2.25 \pm 0.04 ^a	15
Kabode					
Blanched	22.37 \pm 0.01 ^c	15.80 \pm 0.37 ^b	71	12.94 \pm 0.05 ^a	58
Cookedso	28.03 \pm 0.68 ^c	21.68 \pm 0.30 ^b	77	9.98 \pm 0.41 ^a	36
Cookedsu	18.42 \pm 0.55 ^c	14.29 \pm 0.01 ^b	78	10.56 \pm 0.16 ^a	57
Michembe	8.21 \pm 0.52 ^c	4.19 \pm 0.27 ^b	51	2.18 \pm 0.04 ^a	27
Ejumula					
Blanched	21.02 \pm 0.08 ^c	16.41 \pm 0.06 ^b	78	10.50 \pm 0.41 ^a	50
Cookedso	31.51 \pm 0.47 ^c	25.32 \pm 0.49 ^b	80	18.65 \pm 0.09 ^a	59
Cookedsu	28.69 \pm 0.69 ^c	21.69 \pm 0.30 ^b	76	18.09 \pm 1.08 ^a	63
Michembe	18.07 \pm 0.75 ^c	3.13 \pm 0.18 ^b	17	1.02 \pm 0.08 ^a	7

The values are means \pm SD. For each variety, means in the same row bearing different superscripts are significantly different ($p < 0.05$).

samples, *Jewel* had the highest β -carotene content, 2-3 fold higher than any of the other varieties. Of all the samples, *Michembe* showed the lowest β -carotene content. For *Jewel* and *Karoti dar* varieties, *Matobolwa* results showed that there was no significant difference between solar and sun dried samples although solar dried samples showed relatively higher values than sun dried. *Kabode* and *Ejumula* indicated that solar dried *Matobolwa* had significantly higher values compared to sun dried *Matobolwa*.

Blanching resulted retention of β -carotene in *Kabode* (92%), *Jewel* (71%), *Ejumula* (67%) and *Karoti dar* (62). Retention of β -carotene in *Michembe* was different in OFSP variety; *Ejumula* (58%), *Jewel* (54%), *Karoti dar* (46%) and *Kabode* (34%) and solar dried *Matobolwa* were observed to retain more beta carotene compared to sun dried *Matobolwa* in all the varieties studied.

Effect of storage on β -carotene content of sweet potato varieties

Results indicated that orange fleshed sweet potato varieties varied significantly in their β -carotene content and retention capabilities on storage. All varieties studied indicated that there was a significant difference ($P < 0.05$) between zero, three and six months storage. The highest retention was observed in *Matobolwa* while the lowest was observed in *Michembe* (Table 2). After four months of storage through physical assessment, *Michembe* were infested by pest (Coleoptera family) (whereby small holes

were observed on the chips and powdery) although were nutritious when analysed. Beta carotene levels ranged between 1.02 \pm 0.08 to 7.59 \pm 0.20mg/100g on dry matter basis after six months storage at ambient temperature. The percentage retentions of dried sweet potato varieties after six months storage are as indicated in Figure 8.

Discussion

Moisture content

Results obtained in this study showed higher values of moisture content compared to those of the study conducted in Rwanda (Ingabire and Vasanthakaalam, 2011). The study of four sweet potato varieties in Uganda obtained the moisture content range of between 62.58 \pm 0.42% and 64.34 \pm 0.42%. Nafeesa et al. (2012) found moisture content ranging between 68.1 and 72.1% which was the same as the moisture content of *Jewel* in this study. The moisture content of the varieties studied showed positive relationship with the flesh colour. The higher the moisture content, the higher the β -carotene content (Jones, 1977; Vimala et al., 2011). Deviation could be attributed to the difference in the genetic composition, maturity, climate and also the agro-cultural practices gaps between harvesting time and analysis.

Protein content

The results of protein content were consistent with

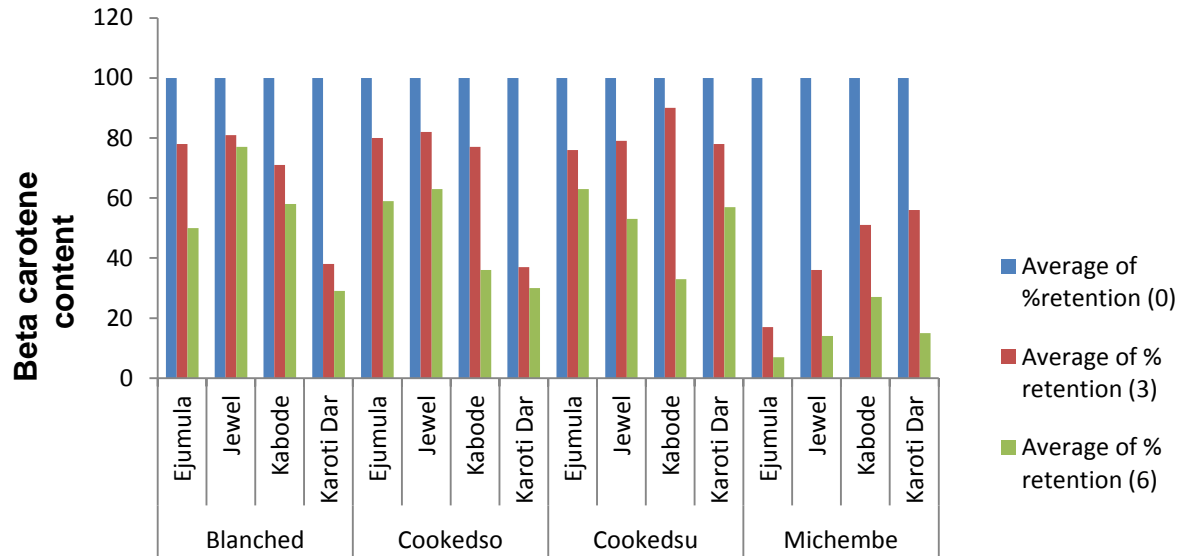


Figure 8. The graph showing percentage beta carotene content retention in dried sweet potato varieties after six months storage.

previous studies. Villareal et al. (1979) indicated protein content of fresh sweet potato to be 2.8% and Senanayake et al. (2013) found it to range between 1.2 and 3.3% on dry weight basis in five sweet potato varieties studied. Some studies indicated sweet potato to have low content of protein of about 1.6% (FAO, 2001) and $1.10 \pm 0.03\text{g}/100\text{g}$ and $1.12 \pm 0.02\text{g}/100\text{g}$ was reported in Sri Lanka for *Ejumula* and *Kakamega* varieties (Tumuimbise et al., 2013). Deviation from literature results may be due to varieties or clones used in this study. The high values of protein content of dried samples (4.89 ± 0.49 to 9.29 ± 0.88) was due to the fact that during drying, food loses significant amount of moisture causing increase in nutrients in the remaining mass. For *Jewel*, *Kabode* and *Ejumula*, *Matobolwa* solar dried were observed to have higher protein content than *Matobolwa* sun dried. Sun dried samples were observed to have reduced crude protein content due to protein denaturation, leaching and prolonged drying.

Fat content

The results of fat content were higher than literature values. Paul and Southgate (1979) revealed that fat content in fresh sweet potato was 0.6% while Tumuimbise et al. (2013) reported $0.17\text{g}/100\text{g}$ and FAO (2001) 0.2%. The reason for deviation may be due to varieties used. Fat content of dried samples ranged between 0.6 ± 0.01 to $1.9 \pm 0.07\text{g}/100\text{g}$ on dry weight basis. The reason for deviation from the fresh value may be due to the fact that during drying, food loses significant amount of moisture causing increase in nutrients in the remaining mass.

Crude fibre content

The results of crude fibre obtained from this study are comparable to those obtained in Sri Lanka ranging between 2.1 and 13.6 % on dry matter basis (Senanayake et al., 2013), Oomen and Gruber (1978) obtained 3.9% and Huang et al. (1999) reported the total fibre content ranging between 2.01 and 3.87 g/100 g fresh weight of the 18 varieties of sweet potatoes in Hawaii. Other researchers have reported low values compared to this study. FAO (2001) reported 1.2g/100g and Ingabire and Vasanthakaalam (2011) 0.11-0.14% of the varieties studied in Rwanda. Pectin, cellulose and hemicelluloses together with lignin are classified as dietary fibre (Robinson and Lawler, 1980). Dietary fibre has recently gained much importance as it is said to reduce the incidences of colon cancer, diabetes, heart diseases and certain digestive diseases (Ingabire and Vasanthakaalam, 2011).

Ash content

The total ash obtained in this study is higher and may be contributed by different varieties used for the study because different varieties contain different mineral matters.

Goodbody (1984) reported total ash content in fresh sweet potato as 1.7% and Ingabire and Vasanthakaalam (2011) obtained ash content ranging between 0.40 ± 0.02 and $0.44 \pm 0.07\%$ in their study. The lowest value was observed in *Matobolwa* and blanching solar dried samples believed to be caused by leaching during blanching and cooking process.

Carbohydrate content

The results of this study were generally lower in carbohydrate content than literature values. Wenkam (1983) reported that fresh sweet potato contained 27% carbohydrates and FAO (2001) reported 28% for fresh samples. This was caused by factors like varieties and stages of maturity of the roots. The increase observed in dried samples was due to the fact that during drying, food loses the significant amount of moisture which resulted in increasing the nutrients in the remaining mass.

Beta carotene content

These beta carotene results are similar to findings reported by other researchers. β -carotene content of sweet potato ranging between 0.01 and 26.6 mg/100g (fwb) have been reported (Takahata et al., 1993). β -carotene level of 11.8 mg/100 g in the variety Xushu 18 have been reported (Hagenimana et al., 1999). In deep orange coloured sweet potatoes, β -carotene content ranged between 4.29 and 18.55 mg/100g (Burgos et al., 2001), 0.009 and 20.525 mg/100g in orange variety in South Africa (Sunette, 2010) and 9.230 mg/100g for the main USA variety Beauregard (Teow et al., 2007) have been reported. Other researchers reported low values as compared to those obtained in this study. β -carotene content of 0.254 ± 3.84 and 0.181 ± 2.64 mg/100g for *Ejumula* and *Kakamega*, respectively have been reported (Tumuhimbise et al., 2013). Leighton (2007) reported that OFSP can provide up to 6.528 mg/100g and Ingabire and Vasanthakalam (2011) reported β -carotene of sweet potato varieties ranging between 1.68 and 1.85 mg/100g. The literature data led to the conclusion that, in the OFSP, there are high as well as low values of this nutrient, and are all determined by varieties.

Variation in β -carotene content may be due to differences in varieties, growing conditions, stages of maturity, harvesting and post-harvest handling, processing and storage of OFSP, air and soil temperature, radiation, location, soil moisture and fertilization (K'Osambo et al., 1998; Rodriguez-Amaya, 2000; Mbwaga et al., 2007; Ukom et al., 2009). Environmental conditions, genetic factors, crop age and cultivation management strategies can significantly influence the β -carotene content of varieties (K'Osambo et al., 1998). High irrigation levels were found to decrease β -carotene content (K'Osambo et al., 1998).

Cooking and processing have a degrading effect on β -carotene content. Sun drying was observed to retain 63 - 73%, oven drying 89 - 96%, boiling 84-90% and frying 72- 86% β -carotene in OFSP varieties studied (Vimala et al., 2011) and boiling retained 70-80% of the vitamins (Van Jaarsveld et al., 2006 ; Bengtsson et al., 2008). The influences of different processing procedures on the carotene content of orange-fleshed roots have been reported in sweet potato (Huang et al., 1999), carrots

(Debjani et al., 2005), and cassava (Chavez et al., 2007). In general, retention of beta-carotene content decreases with long processing time, high temperatures, cutting and maceration of food (Rodriguez-Amaya, 1997; Sunette, 2010).

Some of the sweet potato varieties indicates that cooking has an effect on β - carotene content. According to Rodriguez-Amaya (2001), carotenoids cannot be biosynthesized during cooking. Heat treatment inactivates enzymes responsible for carotenoid biosynthesis and stimulates isomerization and oxidative degradation of carotenoids (Rodriguez-Amaya, 2001). The increases in carotenoids may be due to appreciable leaching of soluble solids resulting in concentrating the carotenoids per unit weight of food (Rodriguez-Amaya, 2001). β -carotene is lost not only during processing but also afterwards, during storage of processed chips. Storage of sweet potato chips for 11 months reduced the total carotenoids from 70 to 59% (Hagenimana et al., 1999). Sun-dried chips of cassava stored for 4 weeks reduced β -carotene from 37.9 to 18.4% (Chavez et al., 2007). Storage, therefore, affects levels of the vitamins and the longer the period, the higher the losses.

Conclusion

Dried sweet potato chips have high levels of proximate composition values which can help to fight protein-energy malnutrition and its beta carotene content can also be used to reduce Vitamin A deficiency in Maswa and other districts of Tanzania. Among three products studied blanched solar dried chips, *Matobolwa* and *Michembe*; *Matobolwa* and blanched solar dried chips retained more β - carotene after drying. On storage, after four months, *Michembe* started getting infested while after six months storage, blanched solar dried chips and *Matobolwa* samples were not infested. Blanched solar dried should be adopted in place of *Michembe* because blanched solar dried chips retain more beta carotene, have longer shelf life and the technology is simple to be implemented by famers. More studies should be conducted to determine optimum blanching time and temperature for more vitamin retention and optimum microbial level of the dried chips.

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