Improving Sweet Potato Processing and Storage Performance through Slicing, Drying and Packaging

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Abstract

Sweet potato is an important food security crop in many parts of Tanzania. Despite this potential, research into its post-harvest handling for maximum utilisation has been low. The objective of this study was therefore, to assess slicing performance of a fabricated hand operated slicing machine against the traditional knife slicing by hand in the production of ***michembe****. It also assessed how slice thickness, the drying surfaces, and packaging of the slices influenced quality during storage. The slicing machine was set to produce slices of 4, 8, 12 and 16 mm thickness. Together with the traditionally obtained slices, the samples were dried on three surfaces (perforated surface, thatched roof and on the ground) for three days. Dry samples were then packaged in polypropylene bags, perforated polyethylene bags and sealed plastic containers and stored for nine months, with observation carried in three months' intervals. The investigations included moisture content, fungal count and mycotoxin detection, discolouration, and insect infestation as quality attributes. Results showed that the slicer throughput ranged between 16 and 46 kg/h of fresh peeled roots in the thickness range of 4-16 mm, against 17 kg/h for traditionally sliced (7.5 mm) sweet potatoes. During drying, weight of slices decreased exponentially with time. In terms of drying effectiveness, the three drying surfaces used displayed almost the same final mean moisture content in the lower slice thickness range (4-8 mm). With increased slice thickness to 12 and 16 mm, the perforated surface was the most effective (10.63-18.03%), followed by the ground floor (15.67-18.65%) and thatched roof the least (16.5-19.36%). Quality of dried michembe decreased with storage time and the best performance was obtained in polypropylene bags for the nine months storage. Packaging in sealed plastic containers produced the worst results. Quality was also influenced by the drying surfaces used, with ground floor resulting in poor product and perforated surface the best. Increasing the slice thickness affected the quality of the dry product except in the range of 4 to 8 mm. Slicing of the roots to 4-8 mm, drying on perforated surface, and packaging in polypropylene bags for room temperature storage of up to six months produced michembe of acceptable quality. Use of improved slicing machines, including mechanically powered machines requires further investigation. Studies on more drying surfaces, more packaging materials, and nutrition of michembe are also recommended.*

Keywords: Sweet potato, slicing, drying, *michembe*, packaging, storage

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Introduction

Sweet potato *(Ipomoea batatas)* is an important food security crop in many parts of Tanzania (Kapinga *et al.*, 1995). Despite this potential, research on its production and post-harvest handling for maximum utilisation has been minimum (Silayo *et al.*, 1998). The crop can improve the income of rural societies through small-scale processing (Wheatley *et al.*. 1996). It is an efficient producer of carbohydrate that is easy to convert into stable intermediate goods such as starch and flour for diversified food and feed industries. The starch component can further be processed into glucose and fructose (Kainuma, 1984; Martin and Deshpande, 1985; Truong *et al.*, 1986), which are high value sugars for domestic consumption, industrial and medicinal use. The roots can also be easily processed into starch at the household enterprise level (Marter and Timmins, 1992). High sugar content (sucrose, glucose and fructose) in some sweet potato cultivars makes the crop suitable for consumption during hard labour (Woolfe, 1992).

Availability of sweet potato roots is very seasonal mainly due to their high perishability. When stored in the fresh form they last for a period of less than 4 weeks under the tropical ambient conditions (Anon. 1991). One of the interventions to this problem has been processing into dry products, which is widely practiced in China, Japan, Indonesia, and the Phillipines (Woolfe, 1992). In Tanzania, this has been traditionally practiced in the regions of Tanzania, notably Shinyanga, Mwanza and Tabora (Anon, 1989; Hatibu and Mtenga, 1996; Silayo *et al.*. 1998; UNDP, 1994). The dry products produced are locally known as *michembe* and *matobolwa*, with the former having more potential for improvement (Silayo *et al.*, 1998; Silayo *et al.*, 1999). Production of both *michembe* and *matobolwa* involve peeling, slicing, and sun drying on thatched roofs, but for *matobolwa* the sweet potato roots are boiled prior to peeling (Silayo *et al.*, 1998). However, processing of sweet potatoes may lead to slight changes in physical and chemical constituents and microbiological quality (Data and Operario, 1992). Also, quality of processed products depends on hygiene of the processing techniques and handling procedures and later on the storage methods used.

Storage of plain *michembe* is in traditional cribs where they suffer from contamination by cockroaches, reptile droppings, roof debris and pest attack including that of rodents. In this form, shelf life of *michembe* is not more than 6 months (Silayo *et al.*, 1998). Whereas attack by rodents may require different interventions, contamination may be minimised by making use of appropriate and hygienic processing, handling and packaging. The current work aims at solving some of these problems. Therefore, the main objective of this study was to investigate the effect of slicing to different levels of slice thickness and drying surfaces on drying with respect to shelf life and quality of stored *michembe* in different packaging materials stored in a traditional house at ambient conditions in Shinyanga.

Materials and methods

Materials

Fresh and sound local varieties of sweet potato roots were purchased from the market in Shinyanga town in Tanzania in the morning of each day of experimentation. They were white skinned with white flesh. After purchasing they were packed in bags and transported to the experimental site, ready for immediate use.

Methods

Slicing and drying: Sweet potato roots were peeled by hand and sliced into chips by using a manually operated slicer developed by Silayo *et al.*, (1999) at the calibrated thickness of 4, 8, 12 and 16 mm, using male and female operators. The chips were then open-air dried (day sun drying and night convection drying and cooling) in a single layer for three days on three drying surfaces. These surfaces were grass-thatched roof, perforated surface (coffee wire mesh of 3 mm x 3 mm) raised 30 cm from ground, and ground lined with polypropylene bag. The experiment was replicated three times.

Packaging experiments: Drying experiments were followed by packaging trials whereby about 1 kg of each of the dry sample was packed in three different packages namely polypropylene bags, perforated polyethylene bags and sealed plastic containers of approximately the same volume. The packages were then stored at room temperature (27± 3°C) in a living house in a village in Shinyanga district.

Measurement of response variables: During drying, weights of the samples were taken after 0, 3, 20, 27, 44, 51, 68, and 72 hours, that means on day times only. The weights were then used to determine the mean weight loss and corresponding moisture content as reported by Silayo (1995). The stored samples were analysed in a laboratory at three months' intervals for a period of 9 months. The parameters measured included moisture content, physical appearance (colour and visual fungal growth), insect damage and fungi count. Moisture content of the stored samples was determined by oven drying at 105°C overnight (AOAC, 1995). Enumeration of fungi was done after growing these organisms on potato dextrose agar (PDA) (pH 7.0, 33°C), respectively as detailed by Harrigan and McCance (1976). In addition to fungal growth, mycotoxin examination was also done, using ultraviolet light, model UVGL-25 mineral light lamp, multiband UV-254/366 nm, for Ultra-violet Prod. Inc., San Gabriel, California, U.S.A. This enabled separation of the samples into two categories: those that gave fluorescence (positive results) and those that did not fluoresce (negative results). Discolouration and insect infestation in the dry samples were assessed visually.

Data analysis

The results were compiled using Turbo-Pascal programming language and SAS statistical package. Comparison of the means was made using analysis of variance and results confirmed using the Least Significant Difference (LSD) method (Chatfield, 1983).

Results and discussion

Slicing performance

Slicing of peeled sweet potatoes using the machine developed by Silayo *et al.* (1999) with the knife set to produce slices of 4, 8, 12 and 16 mm thickness resulted in actual thickness of 5, 9, 13 and 17 mm, respectively, corresponding to throughputs of about 16, 22, 32 and 46 kg/h. The traditional hand slicing by knife produced slices of about 7.5 mm thickness and throughput of about 17 kg/h. This implied that, the slices produced by the traditional hand slicing method were in the size range of slices produced at 4 and 8 mm knife settings. Although the slicing machine was observed to reduce the slicing drudgery, the advantage of high throughput was achieved only when the slicer was set to produce slices thicker than 8 mm. However, a similar slicer produced in the Philippines (Anon, 1993) recorded a throughput of 21-23 kg/h although the size of the slices produced was not mentioned. This figure is closely within the range of 16 and 22 kg/h for 4 and 8 mm knife settings of the slicer used in this study.

Drying performance

Weight loss during drying exhibited an exponential fall with . 1, 2 and 3), similar to the observations made by Tan *et al.* (2001). The exponential trend is similar to that of other biological materials (Husain *et al.*, 1973; Mulet *et al.*; 1993). The mean moisture content varied significantly ($P<0.05$) between the sizes (4-16 mm) on each of the three drying surfaces (Table 1), with lowest values on small size of chips and vice versa. This indicates progressive decrease of drying efficiency with increased slice thickness. Slices obtained from the traditional hand slicing by knife gave approximately same mean moisture values as the 4 mm slice thickness. Between the drying surfaces, the difference in mean moisture content at a particular time was not significant ($P>0.05$) on either 4 or 8 mm slice thickness. However, as thickness increased to 12 and 16 mm, there was a significant increase ($P<0.05$) in mean moisture content between the surfaces, with the perforated surface registering the lowest values, followed by ground floor and highest from thatched roof. Lowest values on the perforated surface implied high drying performance, a superiority that was observed only for higher thickness of slices. This was attributed to the additional convective heat and mass transfer through the perforations that enhances sun drying (Silayo, 1995). The reason for the difference between ground surface and thatched roof at higher slice thickness was attributed to high ability to conduct heat by soil compared with grass thatch (FAO, 1986).

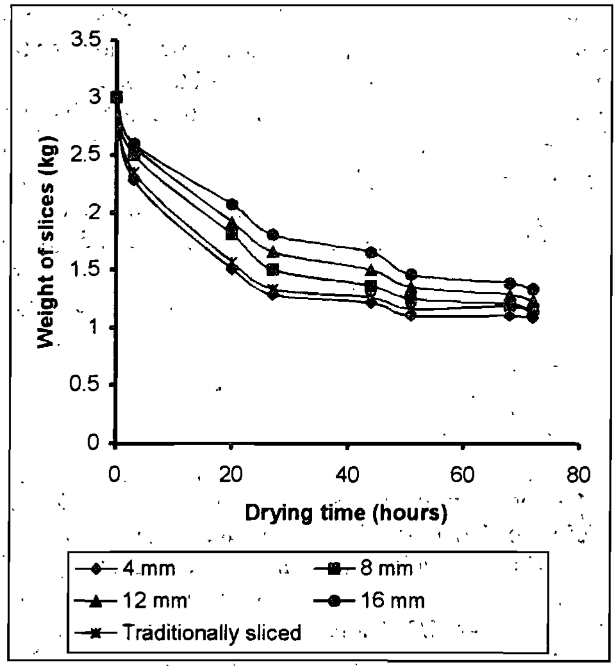

Figure 1: Effect of slice thickness on drying rate of *michembe* on thatched roof.

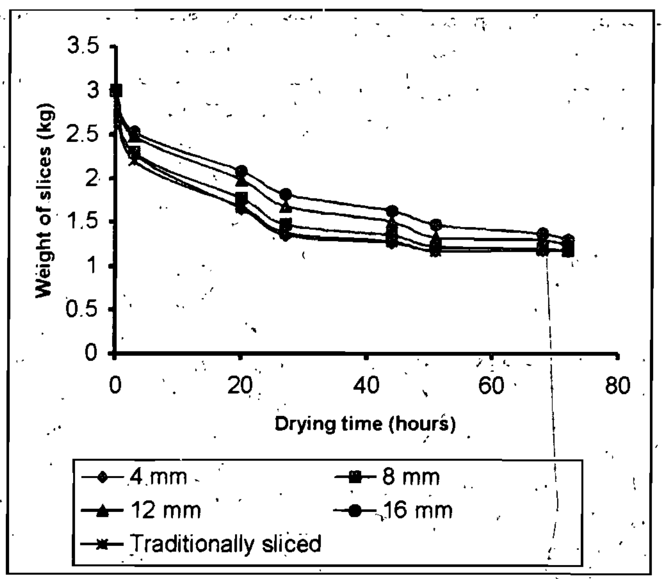

Figure 2: Effect of slice thickness on drying rate of *michembe* on ground floor

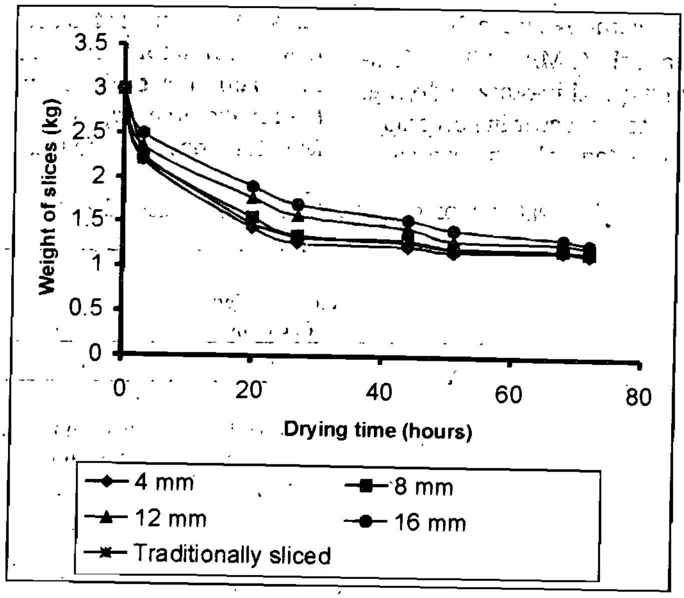

Figure 3: Effect of slice thickness on drying rate of *michembe* on perforated surface

Table 1: Mean moisture content (% d.b.) after 72 hours of open-air drying

Slice thickness (mm)	Drying surface		
	Thatched roof	**Elevated perforated surface**	**Ground floor**
4	7.54 ± 0.13[a]	7.80±0.08[a]	7.33±0.10[a]
8	10.56±0.15[b]	10.57±0.10[b]	10.08±0.12[b]
12	16.50±0.44[c]	10.63±0.25[e]	15.67±0.42[g]
16	19.36±0.53[d]	18.03±0.48[f]	18.65±0.30[h]
Traditionally knife-sliced	7.59±0.21[a]	7.38±0.11[a]	7.54±0.07[a]

Means with different superscripts within a row are significant different at 5% level

Effect of packaging material on storage performance

Moisture content: Packaging materials affected the condition and quality of stored *michembe* with respect to storage time (Table 2).

During the nine months storage: there was moisture decrease in the first three months, followed by an increase in the second three months and finally a decrease in the last three months in polypropylene bags and perforated polyethylene bags. The fluctuations in moisture contents were attributed to ambient low relative humidity and high relative humidity during the dry season (August-November) and the rainy season (November – February), respectively, although the exact data could not be obtained. This was reflected in the mean rainfall of about 21 mm (August – October) and the mean rainfall of about 66 mm (October –

February) (TMA, 1999). During the same period, the mean ambient temperatures were 30± 6 °C and 29 ± 5 °C, respectively (TMA, 1999). Moisture decrease, which implied in-storage drying, was in the first three months higher in polypropylene bags than in perforated polyethylene bags. This was probably attributed to sufficient in-pack aeration due to the material weaving characteristics compared with polyethylene with few localized vents. On the contrary, during the rest of the storage period, the corresponding moisture increases and decreases were higher in perforated polyethylene bags than in the polypropylene bags for reasons that could not be established. However, in sealed plastic containers there was a continuous increase in moisture up to six months storage and a slight decrease to the ninth month. This implies that the reported quality maintenance of dry sweet potatoes when packaged in airtight and moisture proof material (Woolfe, 1992) was not achieved. Reasons for this could also not be established but in-pack condensation due to high moisture content of the dry *michembe* could be held accountable. This would in turn lead to more activities of food-borne microorganisms than in the other types of packaging materials. Moisture losses in the last month could not be accounted for but the same microorganisms could for some reasons have used part of the water although this requires further investigation.

Table 2: Effect of packing material on storage shelf life of *michembe*

Parameter /type of packaging material		Storage period (months)			
		0	3	6	9
Moisture content (%):					
	PB	10.8 ± 0.11^a	5.9 ± 0.06^b	10.9 ± 0.13^a	7.0 ± 0.10^d
	PPB	10.8 ± 0.12^a	6.4 ± 0.08^e	12.5 ± 0.14^f	6.6 ± 0.08^e
	SPC	10.8 ± 0.10^a	13.1 ± 0.13^g	21.5 ± 0.30^h	18.8 ± 0.24^i
Fungal count ($x10^{-5}$):					
	PB	Trace	1961 ± 170^a	2161 ± 94^b	7153 ± 107^c
	PPB	Trace	2460 ± 0.89^d	4184 ± 218^e	9727 ± 269^f
	SPC	Trace	63 ± 4^g	3490 ± 167^h	16450 ± 485^i
Mycotoxin presence:					
	PB	-Ve	-Ve	-Ve	-Ve
	PPB	-Ve	-Ve	-Ve	+Ve
	SPC	-Ve	-Ve	-Ve	+Ve
Discolouration (%):					
	PB	0	0	0	6.7^a
	PPB	0	13.4 ± 0.22^b	26.7 ± 0.67^c	40 ± 2.42^d
	SPC	0	40 ± 2.79^d	60 ± 3.60^e	66.7 ± 3.54^f
Insect infestation (%):					
	PB	0	Trace	Trace	Trace
	PPB	0	40 ± 2.60^a	53.3 ± 3.10^b	53.3 ± 2.40^b
	SPC	0	20 ± 0.75^c	20 ± 1.14^c	20 ± 1.10^c

Mean of a parameter with different superscripts in a row are significantly different at 5% level

Fungal count: Fungal count (Table 2) increased with storage time with significant variation ($P<0.05$) between the three packaging materials, with high acceleration in sealed plastic containers that had relatively higher moisture content. This concurs with the observation by Noorlidah *et al.*: (2000) that susceptibility of foodstuffs to fungal growth is mostly dependent on water activity and length of storage. Associated with fungal growth was the presence of mycotoxins in perforated polyethylene bags and sealed plastic containers after six months and

Table 3: Effect of drying surface on michembe packaged in polypropylene bags

	Drying surface		
	Thatched roof	Ground flour	Elevated perforated surface
Moisture content (% w.b)	8.2 ±0.19^{a}	8.7 ±0.20^{b}	8.1^{a}
Fungal count (x10-5)	1446± 63^{c}	941 ±292^{d}	411^{e}
Mycotoxin presence	-Ve	-Ve	-Ve
Discolouration (%)	0	5±0.15^{f}	0
Insect ifestation (%)	20±1.20^{g}	5± 0.16^{h}	0

Means with different superscripts in a row are significantly different at 5% level

none in polypropylene bags in the entire nine months of storage. Due to relatively low fungal count there was no presence of mycotoxins detected after three months of storage in all the packaging materials and the entire nine months in polypropylene bags.

Colour: Observations made on colour (Table 2) of the product show an overall increase in discoloration with time, especially in polyethylene bags and sealed plastic containers with the later being more affected. This corresponded to high moisture content and the rapid growth of mould.

propylene bags only traces of insects were observed in the entire nine months of storage. Together with other results, use of propylene bags for storage of *michembe* was the most superior among the three packaging materials. Therefore, this type of packaging material was singled out for evaluation of the effects of interaction of drying surface used and the size of chips.

Effect of drying surfaces on quality of stored *Michembe*

Table 4: Effect of slice thickness for michembe packaged in polypropylene Bags

	Slice thickness (mm)				
	4	8	12	16	THS
Moisture content (%) w.b	8.0 ± 0.12^{a}	7.4 ±0.13^{b}	8.4 ± 0.17^{c}	9.7 ±0.20^{d}	8.1 ± 0.11^{a}
Fungal count (x10-5)	1162 ±70^{e}	1576 ± 68^{f}	2646 ± 93^{g}	9914 ±310^{h}	3494 ± 298^{i}
Mycotoxin presence	-Ve	-Ve	-Ve	-Ve	-Ve
Discolouration (%)	0	0	8.3 ± 0.40^{j}	0	0
Insect infestation (%)	8.3 ± 0.58^{k}	8.3 ± 0.45^{k}	16.7 ±1.15^{l}	0	0

Means with different superscripts in a row are significantly different at 5% level

THS - Traditional Hand Sliced

No obvious discoloration was observed in polypropylene bags except in very few (6.7%) packages after nine months storage.

Insect infestation: The onset of infestation by insects (Table 2) was observed early, resulting in more than 50% losses in perforated polyethylene bags and 20% in sealed plastic containers after six months of storage. However, no identification of the types of insects involved could be made. In comparison, almost total losses of plain *michembe* were reported after 2-3 months storage in the traditional cribs in Shinyanga (Silayo *et al.*, 1998). In

Based on packaging in polypropylene bags, quality of stored *michembe* varied with the drying surfaces used (Table 3). *Michembe* dried on the ground floor had moisture content, fungal count, discolouration, and insect infestations that were significantly higher (P<0.05) than those dried on the thatched roof and the raised perforated surface. The least values were on *michembe* dried on the raised perforated surface. These results imply that apart from giving fast drying as opposed to the ground floor and other solid bases (Silayo, 1995), use of perforated surface also resulted in biologically and microbiologically better *michembe*.

Effect of slice/chip thickness on stored *Michembe*

Based on packaging in polypropylene bags, quality of stored *michembe* was affected by the size of chips (Table 4). The results indicated further that there was an overall increase in fungal count, corresponding to increase of moisture content although this was not very clear. Noticeable discolouration (8.3%) occurred for the 12 mm thick chips; with insect infestation that was two-fold that of 4 and 8 mm chips. For reasons that could not be established, no discolouration or infestation by insects were detected on 16 mm chips. These results confirm good drying performance of chips in the range of 4-8 mm thickness as attributed to fast drying to low moisture content, hence less effect on quality. Fast drying is due to increased surface area per unit weight by the small size chips as observed by Tan *et al.*, *(2001)*.

Conclusion

Use of the slicing machine reduced the slicing drudgery but the advantage of high throughput was only pronounced on producing thick slices. Among the three drying surfaces used to dry *michembe*, the elevated perforated surface was the most suitable in terms of drying performance. Quality of dried *michembe* decreased with increasing storage period and was affected by the type of packaging material used. Use of polypropylene bags maintained the quality of dry *michembe* at reasonable levels and is therefore recommended amongst the three packaging materials studied. The type of drying surface used affected quality of stored *michembe*, with the perforated surface being the best. Drying on the ground resulted in high fungal count. Drying of thin slices produced a dry product with better organoleptic qualities. Slicing of sweet potatoes into the size range of 4-8 mm, followed by sun drying on a raised perforated surface until equilibrium moisture is attained, and packaging in polypropylene bags for storage up to six months are suitable and recommended in Shinyanga district. Investigation on use of more drying surfaces, more packaging materials, and storage in different environments in the prevailing local structures is required.

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References

Anon (1989). Diagnostic survey of Maswa and Meatu District (Phase 1: Informal Survey). Tanzania-Netherlands Farming Systems Research Project. Lake zone. Working Paper No.4. pp 10-12.

Anon (1991). *Root Criop Processing*. The United Nations Development Fund for Women. Food Cycle Technology Sourcebook No.5, p 7.

Anon (1993). *Root Crop Processing*. Food Cycle Technology Science Books. Intermediate Technology Publications in association with United Nations Development Fund for Women (UNIFEM). London, pp 54.

AOAC (1995). Official Methods of Analysis. Association of Official Analytical Chemists. Washington D.C.

Chatfield, C. (1983). *Statistics for Technology*. 3rd edition, Chapman and Hall. London p 380.

Data, E.S. and Operario, J.J.A. (1992). Processing and storage characteristics of sweet potato chips for food. *In sweet Potato Technology for the 21st Century*. W.A. Hill, C.K. Bonsi and P.A Loretan (eds). Tuskegee University. Tuskegee. Alabama, p 407.

FAO (1986). *Farm structures in tropical climates*. L.P. Bengtsson and J.H. Whitaker (eds). FAO/SIDA Cooperative Programme. Rural Structures in East and South-East Africa. Food and Agriculture Organization of the United Nations. Rome, p 367.

Harrigan, W.F. and McCance, M.E. (1976). *Laboratory Methods in Food and Dairy Microbiology*. Academic Press. London p 452.

Hatibu, N. and Mtenga, N.A. (1996). Participatory baseline studies of smallholder technological constraints in Shinyanga district. FAO/AGROTEC.

Husain, A., Chen, C.S. and Clayton, J.T. (1973). Simultaneous heat and mass diffusion in biological materials. *J. Agric. Engng. Res.*.18, 343-354.

Kainuma, K. (1984). Uses of sweetpotato starch. *Farming Japan* 18(5): 36-40.

Kapinga, R.E., Ewell, P.T., Jeremiah, H.C. and Kileo. R. (1995). Sweet potato in Tanzania Farming and Food Systems: Implications for Research. International Potato Centre (CIP) and Ministry of Agriculture, Tanzania, p 47

Marter, A.D. and Timmins. W.H. (1992). Small scale processing of sweetpotato in Sichu province, People's Republic of China. *Trop. Sci.* 32: 241-250.

Martin, F.W. and Deshpande. S.N. (1985). Sugars and starches in a non-sweet sweetpotato compared to those of conventional cultivars. *J. Agric. Univ. Puerto Rico* 69(3): 401-406.

Mulet, A., Berna, A., Rossello, C. and Canellas, J. (1993). Analysis of open sun drying experiments. *Drying Technology*, 11(6), 1385-1400.

Noorlidah, A., Nawawi, A. and Othman, I. (2000). Fungal spoilage of starch-based foods in relation to its water activity (a_w). *J. Stor. Prod. Res.* 36(1): 56-61.

Silayo, V.C.K. (1995). *Sun Drying of Grains.* PhD thesis. University of Newcastle upon Tyne, Newcastle upon Tyne.

Silayo. V.C.K.. Laswai, H.S., Makungu, P.J. and Mbiha, E.R. (1998). Sweet Potato Processing into Dry Chips (*michembe*): Experiences form Shinyanga District. *PRA report* SUA-NORAD Frame Agreement, TAN 091 Project, p 37.

Silayo, V.C.K., Laswai, H.S., Makungu, P.J. and Mbiha, E.R. (1999). Mechanization of the slicing process for the production of sweet potato (*michembe*) in Shinyanga district. Paper presented at the 4th annual conference of the Faculty of Agriculture, 17-19 November 1999, Morogoro Tanzania.

Tan, D.L.S., Miyamoto, K., Ishibashi, K.. Matsuda. K. and Satow, T. (2001). Thin-layer drying of sweet potato chips and grates. *Transactions of the ASAE.* 44(3): 669-674.

TMA, 1999. Daily mean temperature data for Shinyanga from 1996-1998. Tanzania Metereological Agency, Dare es Salaam Tanzania.

Truong, V.D., Bierman, C.J. and Marlet, J.A. (1986). Simple sugars, oligosaccharides. and starch determination in raw and cooked sweetpotato. *J. Agric. Food Chem.* 34(3): 421-425.

UNDP (1994). Home garden irrigation and fish farming for women of Mwamalasa village. Pre-feasibility study. Final report. UNDP/URT/008.

Wheatley, C.C., Scott, G.J., Best, R. and Wiersema. S. (1996). Adding value to root and tuber crops. International Centre of Tropical Agriculture. Cali. Columbia p166.

Woolfe. J.A. (1992). Sweet potato: an untapped food resource. Cambridge University press. Cambridge p 586.