Utilization of Cassava Through Freezing

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ABSTRACT

Investigations were carried out to use cassava in frozen form to increase the consumption among people. Two popular varieties MU 51 and Kirikavadi were used for the study. Heat treatments of blanching and boiling together with packing materials of Low-density polyethylene (LDPE) and Low-density polyethylene and Nylon (LDPE+N) were tested in completely randomized design. Both varieties had a minimum percentage weight loss during storage. Microbiological study showed that all samples were safe for consumption up to 3 months at freezer storage. Cyanide levels were significantly reduced by boiling before freezing. Variety Kirikavadi had significantly lower cyanide levels than variety MU 51. Quick freezing using a modification in a normal freezer showed superior quality of frozen product compared to those of stored in a normal freezer. Both varieties of cassava after boiling for 15 minutes for softening, can quick freeze and then transfer to a normal freezer to maintain the frozen condition. This method can therefore commercially be recommended to utilize cassava for up to 3 months of storage life.

Keywords: Cassava, freezing, quality, storage life

INTRODUCTION

The tropical root crop cassava (*Manihot esculenta* Crants) is considered a low risk crop that adapts readily to a wide variety of agro ecological conditions. It is highly efficient in converting solar energy to starch (Dufour *et al*., 1996).

Importance of cassava in the socioeconomic development of rural areas has gained recognition during the last few years. It is also a source of income and is used as a raw material in manufacturing of processed food, animal feed and industrial products (Beléia *et al*, 2004). Wider utilization of cassava products can be a catalyst for rural industrial development and raise the income for producers, processors and traders. It can also contribute to the food security status of its producing and consuming households.

Cassava is one of the most perishable tuber crops with a high postharvest loss. In the case of urban markets, often distant from the producing regions, roots have to be handled within a short time period to reach the consumer before deterioration becomes visible. There is a substantial risk to the wholesalers and retailers that roots will deteriorate before they can be sold. Another problem of cassava is the presence of cyanide. Immediate processing of freshly harvested cassava helps to minimize the cyanide levels (Diasolua Ngudi *et al*., 2003).

Sri Lanka has a surplus production of cassava and it is an unexploited tuber crop while having high demand in both local and export markets. The present demand for cassava is mainly in the form of fresh roots for domestic consumption. The supply of fresh roots is seasonal in most areas of the country. Therefore, wholesale and the retail prices are low during the peak production period and high during the lean production period of the year. This price fluctuation cannot be overcome under rain fed growing situations unless off-season cultivation is done with irrigation. However, development of proper technology to increase the shelf life of processed cassava will help to increase its potential utilization. Therefore, it is essential to identify new uses for cassava and improve the market demand to minimize the postharvest loss of the crop. Establishing new markets for cassava and its products would enhance the cassava cultivation and establish important links between small-scale agriculture and expanding markets.

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If cassava is processed and sold at the primary level, the prospects for cassava as a source of income are limited. Cassava producers and processors will need to respond to the growing urban demand for foods that are more convenient. Diversification of cassava into value added products seems to be a way to increase the demand and this market can be exploited. The export potential for cassava is considerable and market for ready to eat cassava can be increased to meet the demand. Method used should be simple to carry out with less capital costs because most of the growers and processors are small to medium-scale with limited access to capital investment.

Freezing is a quick, convenient, and popular way to preserve foods. Freezing retards the growth of bacteria, molds, and yeasts by reducing the available water for the microorganisms. It has been a major factor in bringing convenience foods to the housewife, restaurant and institutional feeding establishments (Poter, 1978). Shelf life of the frozen foods will be affected by freshness of the raw materials selected, method of preparation, method of freezing and method of packaging of the final product (Raab, 1999). If freezing is done properly, it preserves foods without causing major changes to its size, shape, texture, colour, flavour and nutrients.

This study was carried out to identify the best method of freezing cassava and to increase the shelf life through better packaging.

MATERIALS AND METHODS

Two different varieties of cassava were selected for the experiment. The selected varieties were 'MU 51' and 'Kirikavadi'. Variety 'MU 51' was harvested from the field at Doluwa, Gampola area and variety 'Kirikavadi' was harvested from the field at Horticultural Crop Research and Development Institute (HORDI), Gannoruwa. Both varieties were carefully transported to the laboratory at Food Research Unit, Gannoruwa using shallow, rigid, ventilated plastic crates.

Determination of Blanching Time

Effective blanching time for cassava pieces was determined before starting the experiment. The effective blanching time was determined by peroxidase test using 0.08%(w/v) hydrogen peroxide, 50%(w/v) ethanol and 0.5%(w/v) guiacol (Ranganna, 1986).

Preparation of Samples

Samples were prepared using freshly harvested cassava on the same day. Cassava roots were cleaned to remove mud and other dirt. Peel of cassava roots was removed using a sharp stainless steel knife. Peeled cassava was washed using clean water prior to cutting them into 5 cm pieces horizontally. Then each piece was cut twice longitudinally to get four pieces.

Half of the pieces were blanched in boiling water for 4 minutes taking results of the peroxidase test into consideration. Half of the blanched cassava was packed in 300 gauge low-density polyethylene (LDPE) bags and other half was packed in nylon mixed low-density polyethylene (LDPE+N) bags.

The remaining half of cassava was boiled for 15 minutes prior to pack. Boiled cassava was separated into two halves and one half was packed in 300 gauge (76.2 micron) low-density polyethylene while the other half was packed in nylon mixed low-density polyethylene bags.

Each package contained approximately 400 g. of cassava pieces.

Freezing of Samples

Freezing was done using two different methods, Normal Slow Freezing (NSF) and Modified Slow Freezing (MSF). Normal freezing was done by using domestic ordinary freezer for 5 hours (-20°C). Slow frozen samples were kept in the same freezer to maintain the same freezing temperature. Another domestic freezer was modified using an electric fan having 1600 rpm for modified slow freezing. A chamber (45cm x 42cm) was fabricated to create an airflow over the commodity. The fan was installed at one end of the freezing chamber. Samples were inserted into the chamber and continuous airflow was maintained over the produce for 3 hours for quick freezing. Quick frozen samples were then transferred into a normal freezer to maintain the same freezing temperature.

Samples were stored for 3 months to evaluate the quality characteristics of both normal slow frozen and modified slow frozen cassava. Percentage weight loss, microbiological analysis, cyanide content and sensory properties were recorded as the quality characteristics for frozen samples. Percentage weight loss was calculated based on weight difference during the storage. Total plate counts were determined during storage using the method distributed by SLS, 1991. Cyanide content of fresh, blanched, boiled and frozen roots were determined using steam distillation method (AOAC, 1995). Sensory evaluation of frozen cassava, colour, appearance, taste, texture and overall acceptability were carried out using 1-7 hedonic scale.

Completely randomized design with 9 replicates was used for the experiment. Parametric data were statistically analyzed using ANOVA and mean separation was done using DMRT 5%. Non-parametric data were analyzed using Kruscal Wallis test in Minitab statistical package.

RESULTS AND DISCUSSION

Percentage Weight Loss

Percentage weight losses of frozen cassava variety “MU 51” were shown significant differences with the treatments (Table 1). Significantly higher weight loss in LDPE/Boil samples was observed throughout the storage. The percentage values were higher in modified slow freezing used for pre-cooling. Similarly boiled samples in combine packages (LDPE+N) showed a significantly higher weight loss than that of blanched and stored under same packaging. However, modified slow freezing showed lesser percentage weight loss compared to those of normal slow freezing. In addition, the table shows that the percentage weight loss was not increased with the storage duration. The value recorded at 1 month after storage was maintained for 3 months. Further, all the values recorded even at 3 months of storage was less than 1% indicating that moisture loss was efficiently controlled. During blanching there was not much softening of the cassava pieces due to less time exposure to boiling water. But, during boiling the pieces became softened significantly due to break down of cell wall polymers (Harrison and Andress, 1992). Then break down of cell structures may facilitate moisture loss significantly. Similar results were obtained for frozen cassava variety “Kirikavadi” (Table 2). Although the moisture loss values were significantly different, the difference was negligible as far as commercial scale is concerned.

Microbiological Analysis

Total plate counts were gradually decreased in both cassava varieties during the storage (Table 3 and 4). Initial counts of both varieties were higher than the final counts; but those were not in hazardous range. According to the results modified slow freezing was more effective than normal slow freezing against the microorganisms. Cell injury and death of microorganisms caused by freezing depends on the freezing rates (Garbutt, 1997). Despite a general increase in microbiological outbreaks in processed foods, frozen foods have demonstrated a good food safety record (Gustavo *et al.,* 2005). The confidence in frozen foods largely depends on the microbiological quality of the raw materials prior to usage and the efficiency of processing. For all practical purposes foods held at –10°C will not allow the growth of microorganisms. Therefore, freezing is an extremely effective method of preserving foods (Garbutt, 1997). Frozen foods are normally cooked or heated by the consumer or eaten soon after defrosting. Then as long as thawing instructions are followed, spoilage is not a problem. In this experiment blanching and boiling was done prior to freezing. These heat treatments have also helped to reduce the initial microbial levels in the safe range. Furthermore, boiling was more effective than blanching when considering destroying microorganisms. This can clearly be seen in both varieties used for the experiment. No significant difference in microbial counts between the two varieties of cassava has been observed.

Cyanide Analysis

Variety "MU 51" had high amount of cyanide when compared to variety "Kirikavadi" (fig.1). The total cyanide content of cassava parenchyma is dependent on the cultivar, the environment and various other factors (Balagopalan, 2002). However, both the varieties contained very low cyanine contents according to the WHO standards. Those amounts further can be decreased by processing. Because of the high level of cyanogens in the bitter varieties, the processing techniques used are important in producing a safe product (Zvauya *et al.*, 2002). As a defense mechanism against attack by predators, cassava produces two cyanogenic glucosides; linamarin and a small amount of lotaustralin (methyl linamarin). These cyanogens are distributed widely throughout the plant, with large amounts in the leaves and the root cortex (skin layer), and generally smaller amounts in the root parenchyma (Cardoso *et al.*, 2005).

Both blanching and boiling drastically reduced the initial cyanide levels in both varieties (Fig.1). Losses of cyanide on steaming, baking or frying are much smaller than on boiling, because of the stability of linamarin in neutral or weak acid conditions to temperatures of 100 °C (Bradbury *et al.*, 1991 and Nambisan and Sundaresan, 1985). Furthermore, boiling reduces more cyanide than blanching, because prolonged boiling facilitate the elimination of volatile hydrogen cyanide. However, the nature of liberation of cyanide from linamarine by plant tissues has proved to be somewhat complex (Jansz, *et al.*, 1974). Cassava contains cyanogenic glucosides in the form of linamarin and a small amount of lotaustralin, which are broken down during processing firstly to acetone cyanohydrin and methyl ethyl ketone, respectively, and secondly to volatile hydrogen cyanide (Sopade, 2000). There was no significant change in cyanide levels during the storage up to 3 months in both varieties of frozen cassava (Fig. 2). This indicated that there was no cyanide development any further. Cyanide levels of both varieties of cassava showed no increase during storage up to 3 months. Boiled and frozen cassava showed significantly lower level of cyanide compared to that of blanched cassava in both varieties.

In general, the cyanogenic potential was higher in freshly harvested cassava roots. But, it can be reduced by immediate processing. The present investigation was also an attempt to relate the cyanide levels to increasing postharvest life of cassava. These results demonstrated that frozen cassava is safe for human consumption and therefore their production and consumption could be encouraged.

Sensory Evaluation

There was a significant difference between fresh cassava and all the frozen cassava for colour and appearance in sensory analysis (Table 5 and 6). According to the results obtained fresh cassava had a higher rank than frozen cassava. When considering the two varieties there was a slight difference between them for colour and appearance. Colour of the frozen cassava variety "Kirikavadi was better than frozen cassava variety "MU 51". Mainly due to better colour appearance, the frozen cassava variety "Kirikavadi" was better than frozen cassava variety "MU 51". Furthermore, there was no significant difference between blanched or boiled samples. No significant differences for colour and appearance were observed with the packaging material. However, there was a significant difference in quality based on the method of freezing. Modified slow frozen cassava showed a better colour and appearance than normal slow frozen cassava in both varieties. In addition, both sensory characteristics were significantly affected by the time of storage. Colour and appearance of frozen cassava after 1 month of storage was better than the colour and appearance of frozen cassava after 3 months of storage in both varieties.

The first quality judgment made by a consumer when purchasing a food product is its visual appearance and colour (Dutta *et al.*, 2006). Excessive discolouration resulting from thermal processing lowers the market value of the food. Therefore, colour as a tool for sensory evaluation is important and interesting as well. Change in food colour can be associated with its previous heat treatments, packing material, method of storage and duration of storage. Various reactions such as pigments destruction, enzymatic browning and non-enzymatic browning (Millard reaction) can occur during processing and therefore, affect its colour and visual appearance (Cornwell and Wrolstad, 1981). However, retention of colour can be used as a quality indicator to evaluate sensory properties of the product.

Taste and texture are two of the most important sensory parameters when considering a food. Data shows that, fresh cassava has higher values for taste and texture than frozen cassava (Table 7 and 8). There was no significant difference of frozen cassava for taste and texture according to the packaging material used. But, there was a significant difference between blanched and boiled samples in both varieties of frozen cassava for above two parameters. Taste and texture of boiled cassava were preferred by panelists than blanched cassava. Cassava is a tuberous root that store mostly starch with low amounts of protein and lipids (Beleia *et al.*, 2004). As food, the fresh roots can be used after appropriate cooking or boiling. Cassava may have 35-40% total solids, taking longer to cook and having a characteristic texture. Therefore, blanching for 4 minutes prior to freezing and steaming for 5 minutes is not enough to get the favourable taste and texture for cassava. Boiling starchy tubers results in hydration, gelatinization, increase in cell volume, modification of cell wall and middle lamella carbohydrates, especially pectin solubilization through elimination and gradual tissue softening (McDougall *et al.*, 1996). Furthermore, cassava requires more cooking time than other tuber crops to soften before it becomes acceptable to consumers.

According to the results taste and texture of cassava variety “Kirikavadi” were preferred by panelists than variety “MU 51” for treated samples as well as fresh samples. Variety also has an influence on sensory properties and shelf life (Bramsnaes, 1981). Taste and texture were affected to some extent during the storage in all the samples. However, they were in the range of “like slightly” – “like moderately”. A large-scale cooperative investigation of green beans in the Netherlands and Germany unexpectedly showed that one of the varieties suffered a severe loss of texture and taste during storage (Steinbuch *et al*., 1977).

Fresh cassava had the highest overall acceptability when comparing to frozen cassava (Table 9). Variety “Kirikavadi” was preferred by panelists than variety “MU 51” according to the results obtained. There was no significant difference in overall acceptability of frozen cassava with the packaging material used. Overall acceptability of boiled cassava was significantly high in both varieties than the blanched cassava. Even though, the taste, texture and overall acceptability of all the frozen cassava samples was slightly reduced with the storage time. All the samples were in the acceptable range. Modified slow frozen cassava had high overall acceptability than normal frozen cassava. Figure 3 shows the overall acceptability of modified slow frozen cassava variety “MU 51” and “Kirikavadi” during the storage. It clearly indicates that variety “Kirikavadi” had high overall acceptability during all the 3 months of storage.

Table 1 Mean percentage weight loss of frozen cassava "MU 51" during storage for 3 months at –20°C.

Treatment	Storage time (months)					
	1		2		3	
	NSF	MSF	NSF	MSF	NSF	MSF
LDPE/Blanch	0.2[a]	0.0[a]	0.3[a]	0.1[a]	0.3[a]	0.1[a]
LDPE/Boil	0.4[b]	0.3[b]	0.5[b]	0.3[b]	0.5[b]	0.4[b]
LDPE+N/Blanch	0.3[a]	0.1[a]	0.3[a]	0.1[a]	0.3[a]	0.1[a]
LDPE+N/Boil	0.4[b]	0.3[b]	0.4[b]	0.3[b]	0.4[b]	0.3[b]

Treatment means in a column having common letter(s) are not significantly different by DMRT 5%.

LDPE - Low-density polyethylene
N - Nylon
NSF - Normal slow freezing
MSF - Modified slow freezing

Table 2 :Mean percentage weight loss of frozen cassava "Kirikavadi" during storage for 3 months at –20°C.

Treatment	Storage time (months)					
	1		2		3	
	NSF	MSF	NSF	MSF	NSF	MSF
LDPE/Blanch	0.2[a]	0.0[a]	0.2[a]	0.1[a]	0.2[a]	0.1[a]
LDPE/Boil	0.4[b]	0.2[b]	0.4[b]	0.3[b]	0.4[b]	0.3[b]
LDPE+N/Blanch	0.3[a]	0.1[a]	0.3[a]	0.1[a]	0.4[b]	0.1[a]
LDPE+N/Boil	0.5[b]	0.3[b]	0.5[b]	0.3[b]	0.5[b]	0.3[b]

Treatment means in a column having common letter(s) are not significantly different by DMRT 5%.

LDPE - Low-density polyethylene
N - Nylon
NSF - Normal slow freezing
MSF - Modified slow freezing

Table 3: Total plate counts as cfu/g of cassava "MU 51" during frozen storage for 3 months at –20°C.

Treatment	*Storage time (months)*					
	1		*2*		*3*	
	NSF	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*
LDPE/Blanch	0.45×10^{2} a	0.40×10^{2} a	0.40×10^{2} a	0.38×10^{2} a	0.10×10^{2} a	0.50×10^{2} a
LDPE/Boil	0.20×10^{2} b	0.10×10^{2} b	0.15×10^{2} b	0 b	0.50×10^{2} b	0 b
LDPE+N/Blanch	0.50×10^{2} a	0.30×10^{2} a	0.40×10^{2} a	0.25×10^{2} a	0.10×10^{2} a	0.10×10^{2} a
LDPE+N/Boil	0.25×10^{2} b	0.12×10^{2} b	0.12×10^{2} b	0.10×10^{2} b	0 b	0 b

Treatment means in a column having common letter(s) are not significantly different by DMRT 5%.

LDPE - Low-density polyethylene
N - Nylon
NSF - Normal slow freezing
MSF - Modified slow freezing

Table 4: Total plate counts as cfu/g of cassava "Kirikavadi" during frozen storage for 3 months at –20°C.

Treatment	*Storage time (months)*					
	1		*2*		*3*	
	NSF	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*
LDPE/Blanch	0.30×10^{2} a	0.21×10^{2} a	0.15×10^{2} a	0.15×10^{2} a	0.10×10^{2} a	0.10×10^{2} a
LDPE/Boil	0.14×10^{2} b	0 b	0.10×10^{2} b	0.10×10^{2} b	0 b	0 b
LDPE+N/Blanch	0.35×10^{2} a	0.20×10^{2} a	0.20×10^{2} a	0.20×10^{2} a	0.10×10^{2} a	0.15×10^{2} a
LDPE+N/Boil	0.30×10^{2} a	0.20×10^{2} a	0.10×10^{2} b	0 c	0 b	0 b

Treatment means in a column having common letter(s) are not significantly different by DMRT 5%.

LDPE - Low-density polyethylene
N - Nylon
NSF - Normal slow freezing
MSF - Modified slow freezing

Table 5 : Estimated median values for sensory characteristic colour of frozen cassava during storage for 3 months at –20°C.

Treatment	*Storage time (months)*											
	1				*2*				*3*			
	MU 51		*Kirikavadi*		*MU 51*		*Kirikavadi*		*MU 51*		*Kirikavadi*	
	NSF	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*
LDPE/ Blanch	5.2	6.0	5.0	6.0	5.0	5.7	5.0	5.8	4.5	5.0	4.7	5.8
LDPE/ Boil	5.3	6.0	5.4	6.1	5.0	5.6	5.2	6.0	4.4	5.4	4.9	5.9
LDPE+N/ Blanch	5.0	5.8	5.0	6.2	4.7	5.0	4.8	6.1	4.2	4.8	4.7	6.0
LDPE+N/ Boil	5.3	6.1	5.8	6.0	5.0	5.8	5.6	6.0	4.8	5.6	5.0	6.0
P< 0.05								NS				NS
Fresh	6.5		6.7		7.0		6.5		6.8		7.0	

7=Like very much, 6=Like moderately, 5=Like slightly, 4=Neither like nor dislike, 3=Dislike slightly, 2=Dislike moderately and 1=Dislike very much

LDPE - Low-density polyethylene
N - Nylon
NSF - Normal slow freezing
MSF - Modified slow freezing

Table 6: Estimated median values for sensory characteristic appearance of frozen cassava during storage for 3 months at –20°C.

Treatment	*Storage time (months)*											
	1				*2*				*3*			
	MU 51		*Kirikavadi*		*MU 51*		*Kirikavadi*		*MU 51*		*Kirikavadi*	
	NSF	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*
LDPE/ Blanch	6.0	6.4	6.3	6.8	5.8	6.0	6.0	6.8	5.4	5.7	5.5	6.3
LDPE/ Boil	6.2	6.5	6.4	6.9	6.0	6.1	6.0	6.7	5.5	5.7	5.7	6.3
LDPE+N/ Blanch	6.3	6.2	6.1	6.5	6.0	5.9	5.8	6.4	5.2	5.5	5.0	6.2
LDPE+N/ Boil	6.0	6.3	6.4	6.7	5.7	6.0	6.1	6.2	5.1	5.4	5.2	6.0
P< 0.05												NS
Fresh	7.0		7.0		7.0		7.0		7.0		7.0	

7=Like very much, 6=Like moderately, 5=Like slightly, 4=Neither like nor dislike, 3=Dislike slightly, 2=Dislike moderately and 1=Dislike very much

LDPE - Low-density polyethylene
N - Nylon
NSF - Normal slow freezing
MSF - Modified slow freezing

Table 7: Estimated median values for sensory characteristic taste of frozen cassava during storage for 3 months at –20°C.

Treatment	*Storage time (months)*											
	1				*2*				*3*			
	MU 51		*Kirikavadi*		*MU 51*		*Kirikavadi*		*MU 51*		*Kirikavadi*	
	NSF	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*
LDPE/ Blanch	5.8	5.9	6.2	6.5	5.5	5.6	5.9	6.2	4.8	5.2	5.4	6.0
LDPE/ Boil	6.0	6.5	6.4	7.0	5.9	6.2	6.0	6.8	5.0	5.8	5.6	6.3
LDPE+N/ Blanch	5.6	5.7	6.0	6.3	5.0	5.5	5.7	6.0	4.5	5.0	5.2	5.9
LDPE+N/ Boil	6.1	6.0	6.1	7.0	5.9	5.9	5.8	6.7	5.0	5.6	5.5	6.1
P< 0.05	NS	NS	NS	NS	NS	NS	NS	NS				
Fresh	6.8		7.0		6.9		7.0		6.8		7.0	

7=Like very much, 6=Like moderately, 5=Like slightly, 4=Neither like nor dislike, 3=Dislike slightly, 2=Dislike moderately and 1=Dislike very much

LDPE - Low-density polyethylene
N - Nylon
NSF - Normal slow freezing
MSF - Modified slow freezing

Table 8: Estimated median values for sensory characteristic texture of frozen cassava during storage for 3 months at –20°C.

Treatment	*Storage time (months)*											
	1				*2*				*3*			
	MU 51		*Kirikavadi*		*MU 51*		*Kirikavadi*		*MU 51*		*Kirikavadi*	
	NSF	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*	*NSF*	*MSF*
LDPE/ Blanch	5.5	5.7	5.6	5.8	5.0	5.4	5.3	5.6	4.7	5.0	5.0	5.1
LDPE/ Boil	5.6	6.0	6.2	6.4	5.1	5.9	6.0	6.2	4.9	5.7	5.6	5.9
LDPE+N/ Blanch	5.4	5.7	5.7	5.9	5.0	5.5	5.5	5.6	4.6	4.9	5.0	5.0
LDPE+N/ Boil	5.5	6.2	6.1	6.6	5.0	6.0	5.8	6.5	4.8	5.8	5.5	6.0
P< 0.05												
Fresh	6.9		7.0		6.8		7.0		6.8		7.0	

7=Like very much, 6=Like moderately, 5=Like slightly, 4=Neither like nor dislike, 3=Dislike slightly, 2=Dislike moderately and 1=Dislike very much

LDPE - Low-density polyethylene
N - Nylon
NSF - Normal slow freezing
MSF - Modified slow freezing

Table 9: Estimated median values for sensory characteristic overall acceptability of frozen cassava during storage for 3 months at –20°C.

Treatment	***Storage time (months)***											
	1				***2***				***3***			
	MU 51		***Kirikavadi***		***MU 51***		***Kirikavadi***		***MU 51***		***Kirikavadi***	
	NSF	***MSF***	***NSF***	***MSF***	***NSF***	***MSF***	***NSF***	***MSF***	***NSF***	***MSF***	***NSF***	***MSF***
LDPE/ Blanch	5.8	6.0	5.8	6.0	5.2	5.5	5.5	5.9	4.8	5.0	5.0	5.2
LDPE/ Boil	5.9	6.0	5.9	6.4	5.6	5.8	5.8	6.2	5.0	5.5	5.3	6.0
LDPE+N/ Blanch	5.7	5.9	5.6	6.1	5.1	5.6	5.5	5.8	4.6	4.9	4.9	5.2
LDPE+N/ Boil	6.0	6.0	5.7	6.5	5.7	5.7	5.6	6.3	5.4	5.6	5.4	6.1
P< 0.05	NS	NS					NS	NS		NS	NS	NS
Fresh	6.7		6.8		6.7		6.9		6.6		6.9	

7=Like very much, 6=Like moderately, 5=Like slightly, 4=Neither like nor dislike, 3=Dislike slightly, 2=Dislike moderately and 1=Dislike very much

LDPE - Low-density polyethylene
N - Nylon
NSF - Normal slow freezing
MSF - Modified slow freezing

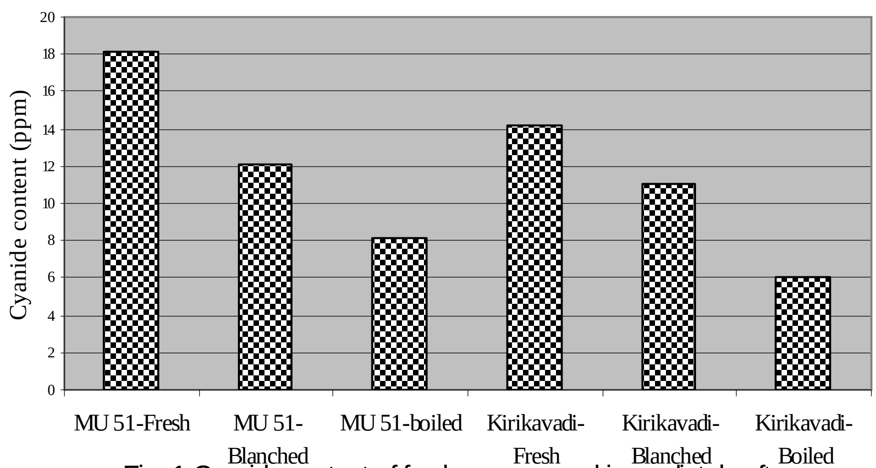

Fig. 1 Cyanide content of fresh cassava and immediately after blanching and boiling

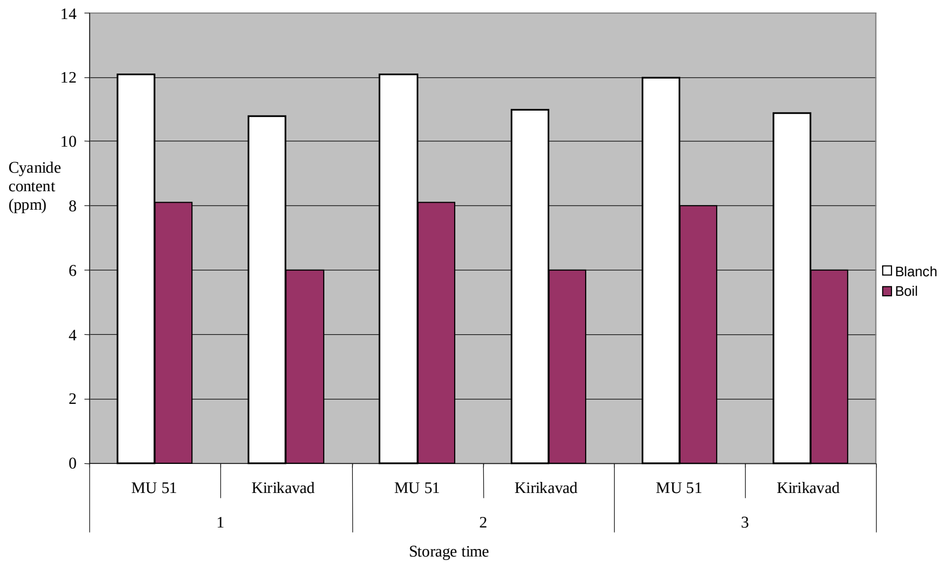

Fig.2 Cyanide content of frozen cassava during storage

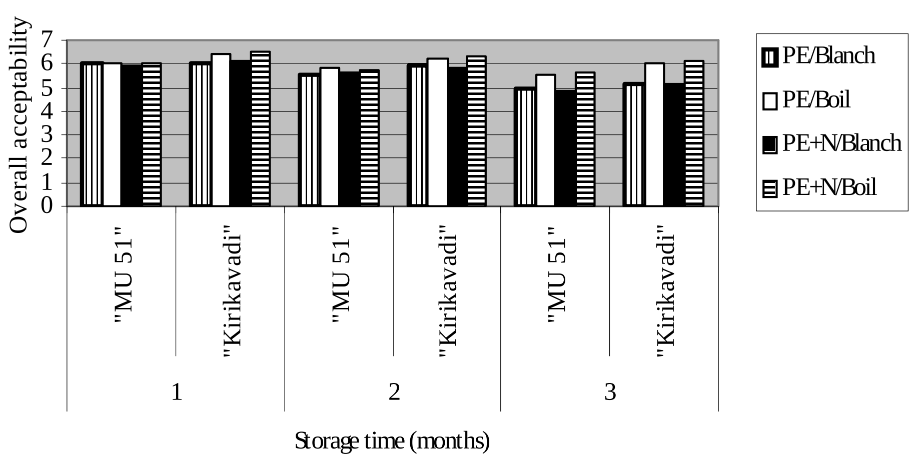

Fig. 3: Overall acceptability of modified slow frozen cassava during storage for 3 months at – 20^{0}c.

CONCLUSION

Cleaned and peeled cassava roots after boiling for 15 minutes for softening and to reduce the initial cyanide levels before freezing can be used for frozen storage. The prepared cassava pieces can be packed in 300 gauge low density polyethylene (LDPE) bags and freeze quickly using modified slow freezing (MSF) method. Modified slow freezing showed better quality than normal slow frozen cassava. Since there was a significant retention of quality in modified slow frozen method, the method can easily be adopted by modifying a normal freezer. The cyanide level of the frozen cassava was lower than the accepted minimum, it can be recommended for safe consumption. Available cyanide level also further reduced when it was heated before consumption. Therefore, cassava varieties

"MU51" and "Kirikavadi" can both be stored for 2-3 months under frozen storage conditions. However, deterioration of colour and appearance of frozen cassava during frozen storage need to be further investigated. Frozen storage of cassava can therefore be recommended to reduce postharvest loss of highly perishable root during marketing. Cassava consumption can also be improved by adopting this technology.

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