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DURATION OF FREEZING INFLUENCES SENSORY ATTRIBUTES OF CASSAVA (*Manihot esculenta Crantz*) AND PLANTAIN (*Musa paradisiaca AAB*)

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ABSTRACT

In order to reduce post-harvest losses, this work was designed to evaluate the impact of freezing time on the organoleptic and nutritional properties of cassava and green plantain. Peeled fresh cassava (C), fresh plantain without peeling (PWP) and fresh plantain with peeling (PP) were cut into pieces of regular sizes, weighed, bagged in plastic packages and placed in a freezer at -18 °C. Over a period of 30 days, samples were removed from the freezer for sensory and nutritional analysis. Sensory analysis revealed that there was a significant difference ($P \leq 0.05$) between samples frozen at different time for different sensory attributes. The score for taste decreased from 3.56 to 2.9 for the cassava and 4.55 to 2.60 for the plantain with the increase in the time of freezing. As far as the overall acceptability is concerned, all the cassava samples were rated approximately the same, while for the plantain, there is significant difference between non-frozen and 30 days frozen. In fact, the score for the overall acceptability of non-frozen plantain was the highest (4.00) followed by 3 and 7 days frozen plantain and from 14 days of freezing, the samples had the least mean value (1.85) because they started getting brown and their taste has changed. Regarding the nutritional properties, there is no significant differences both for the cassava and plantain. Freezing time has no significant impact on the cassava while the taste and color of plantain change from the seventh day. Freezing time decrease the organoleptic properties of cassava and plantain but does not affect their nutritional quality.

Contribution/Originality: This study is one of very few studies which have investigated the influence of freezing duration on physic-chemical and proximate analyses of cassava roots and plantain fruits.

1. INTRODUCTION

Starchy foods are important staple crops that contribute to the calories and subsistence economies in Africa. They are good sources of carbohydrate (Marriott *et al.*, 1980) excellent source of energy and nutrients (Mg, K, Ca, P) and contribute significantly to food security in sub-Saharan Africa (INIBAP, 2002). Among these starches, we have cereals, vegetables and legumes, tubers and fruits. Cassava (*Manihot esculenta* Crantz) and plantain (*Musa paradisiaca* AAB) are among the last two groups of starchy foods mentioned above. Indeed, according to the world ranking by the FAO (2009a;2009b) they occupy the 2nd and 5th rank respectively of the food productions.

In Cameroon, total production of bananas and plantains was estimated at 1,400,000 metric tons in 2009 with dessert banana accounting for 35% whereas plantains and other cooking bananas accounted for 65% (FAO (Food and Agriculture Organisation), 2011). Nutritionally, *Musa* spp. constitute a rich energy source, with carbohydrates accounting for 22 and 32% of fruit weight for banana and plantain, respectively, and rich in vitamins A, B6, C, minerals and dietary fiber (Chandler, 1995; Honfo *et al.*, 2007a;2007b). The dense caloric content coupled with nutritional quality makes *Musa* spp. one of the most important and regularly consumed staple food in Cameroon and Nigeria (Ajayi and Aneke 2002; Lusty *et al.*, 2006).

Cassava (*Manihot esculenta Crantz*) is the staple food of about 800 million of peoples worldwide (FAO, 2000; Lebot, 2009). It is consumed for its leaves and roots (Gnonlonfin *et al.*, 2011; Famurewa *et al.*, 2013; Koko *et al.*, 2014; Mouafor *et al.*, 2016). According to the FAO, Cameroon has produced 4 287 177 tons of cassava (tubers) in 2013 (FAO, 2015). It provides a lot of energy for more than 500 million people in tropical and sub-tropical Africa (El-Sharkawy, 2004) due to the large amount of carbohydrates accumulated in its roots (Awah and Tumanteh, 2001; Beeching *et al.*, 2002; Nweke *et al.*, 2002).

They are often eaten boiled or roasted and accompanied by sauce. They are also used to make various traditional Cameroonian dishes. Among these dishes, the most important are the *mitoumba* (Fonji *et al.*, 2017) and the *malaxé* that use cassava as raw material and *condré*, *malaxé*, and *pilé* using the green plantain. For these different dishes, the main ingredient must be fresh. Findings have been reported in banana and other plantain varieties (Marriott and Lancaster, 1983; Baiyeri and Unadike 2001) suggesting that maximum dietary benefit of these minerals could be obtained when plantain fruits are consumed at the unripe stage. Unfortunately, like all foods, they are highly perishable and therefore the problem of fresh preservation remains a constraint that must be lifted to promote the production and use of these foodstuff such a way that they play their role in the food security.

Under ambient temperature (about 30 °C), these foodstuffs deteriorate from 2 to 4 days after harvest for the cassava roots (Guillemot, 1976a; Lépengué, 1999) and plantain matures between 5 and 9 days. This is due to the high water content, rich store of carbohydrates, presence of degradation enzymes in the tissues (Beeching *et al.*, 2002; Osei *et al.*, 2013) followed by microbial deterioration 3-5 days thereafter (Karim *et al.*, 2009).

Concerning conservation, numerous studies have made proposition on appropriate solutions. To overcome the problem of high perishability of cassava roots, several based products are being processed from these roots. The major operations involved in these processing steps include peeling, washing, boiling, chipping, soaking, grating, dewatering, fermenting and drying. Several combinations of these steps improve shelf-life, palatability and reduction in cyanide content (Arisa *et al.*, 2011). However, some consumers may not prefer fermented product, but rather fresh roots. As far as the plantain is concern, studies done by Dick and Yao (1997) to evaluate the effect of polyethylene packaging on the conservation of plantain at 4 °C, 12 °C and 25 °C, showed that they can keep the plantain green for 20 days at 12 and 25 °C; but conservation beyond that time is detrimental to the quality of the fruit. This study also indicated that the packaging of plantain in polyethylene and its storage at 4 °C does not have a favorable conservation effect.

In addition with modernization and the professionalization of women, there is more tendency to store food stuff. Fresh cassava roots and plantain fruits are then stored in the freezer to be used later run. The question is that, do these foods conserve their nutritional and sensory properties? The aim of this study is to assess the impact of freezing on nutritional and sensory properties of cassava roots and plantain fruits.

2. MATERIALS AND METHODS

2.1. Study Site

The study was carried out at the Food Technology Laboratory of the Institute of Agricultural Research for Development (IRAD) in Nkolbisson-Yaounde.

2.2. Material

Cassava roots and plantain of popular local varieties called "Makumba" and "Ebanga" varieties respectively were used. These varieties are largely consumed fresh and green after boiling. The cassava roots of twenty four (24) months old were sampled from the experimental farm of IRAD at Nkolbisson and used for this experiment. Mature green plantain were harvested in one farm in Yaounde town neighborhood.

2.3. Freezing Process

Cassava roots and plantain fruits freshly harvested were seriously washed to eliminate all impurities using tap water. After peeling, the cassava roots (C) were cut into pieces of regular size of 5 cm of length, weighed and packaged in plastic bags. Plantain fruits were divided into two parts, one part was peeled (PWP) and the other one not (PP). Like the cassava roots, they were cut into pieces of regular size of 5 cm of length, weighed and packaged in plastic bags. The packages of 500 g were then introduced into a freezer at -18 °C for conservation. Both were sampled at 0, 3, 7, 14 and 30 days for sensory and nutritional analysis.

2.4. Cooking process

For each cassava roots and plantain fruits sampled at different time from the freezer, 500 g were boiled in 750 ml of water and for about 25 minutes. The samples were put to boil immediately after removing from the freezer. While the PP was peeled before cooking.

2.5. Sensory Analysis

A descriptive test was done on frozen cassava and plantain, in order to determine differences between the tested products to be evaluated which are fresh and frozen roots and fruits. A trained panel of 12 testers did the evaluation at the food technology laboratory of IRAD Nkolbisson. Parameters taking into consideration were taste, color, texture, aroma and overall acceptability. Parameters were scored using a scale from 0 (absence) to 5 (very pronounced) for taste, color, texture, aroma, and for the overall acceptability from 0 (very disagreeable) to 5 (very pleasant) (Table 1). All data were collected with three replications.

Table-1. Scores and descriptors for sensory attributes

Scores	Sensory attributes of cassava roots	
	taste, color, texture, aroma	**overall acceptability**
0	Absent	Very disagreeable
1	Very weak	Unpleasant
2	low	Rather unpleasant
3	Net	Rather pleasant
4	Pronounced	Pleasant
5	Very pronounced	Very pleasant

2.6. Physical and Chemical Characterization

The following physical and chemical characteristics were measured: color, dry matter content (DM), crude protein, total lipids, total carbohydrates, crude fiber and ash.

The dry matter content (DM) was arbitrarily deduced from the moisture content. The moisture content was determined according to the AOAC (1990). The samples are weighed (M_0) using a precision balance. They are dried in an oven at 105 °C for 24 hours. At the outlet of the oven, the samples are cooled in a desiccator and weighed (M_1); the percentage of moisture was determined by calculation according to the formula:

$$\text{Moisture } \% = \frac{M_0 - M_1}{M_0} \quad \text{Hence,} \quad DM = 100 - \text{ Moisture } \%$$

Crude proteins: Protein assay was done according to the Kjeldahl method (BIPEA, 1976). Total nitrogen was converted to protein, using the factor 6.25, or 100/16. The total nitrogen and crude protein levels are obtained with the following formulas:

$$\text{Protein Rate} = \text{Nitrogen Rate} * 6.25$$

Determination of the ash rate: It was made according to the AOAC (1990) it consists of mineralizing a sample of 5 g (M_0) at 550 °C for 6 h in a muffle furnace until all the organic matter contained in the sample has been destroyed. The ash rate was determine according to the formula:

$$\% \text{Ash} = \frac{M_0 - M_1}{M_0}$$ Where M_1: sample mass after mineralization.

Determination of total lipid content: The determination was made according to the BIPEA (1976) consisting in extracting the fats with hexane, which is then evaporated and the residue dried and then weighed.

Determination of total carbohydrate content were assayed according to the method of Dubois *et al.* (1956) using sulfuric acid and phenol.

Determination of the crude fiber content was determined by the neutralization method (AOAC, 1990).

The color of the samples was measured using a Hunter's Lab color analyzer (Hunter lab scan XE, Reston VA, USA). In the Hunter colorimeter, the color of a sample is designated by the three dimensions, L *, a * and b *. The value L * gives a measurement of the brightness of the color of the product of 100 for the perfect white at 0 for the black, as the eye would evaluate it. Red to green and yellow to blue are indicated by the values a * and b *, respectively. The color of the samples was measured after placing the samples in front of the smallest opening (Navneet and Shitij, 2011). In order to obtain data reflecting the color of the cassava roots and plantain, three different points were taken into consideration for each sample. All data were collected with three replications.

2.7. Statistical Analysis

All the results were subjected to an ANOVA using the Excel, SPSS version 16 and SAS version 9.0 softwares with the generalized linear model procedure. The Duncan test for mean comparison was used to determine a significant difference between the various samples that was set at 5% ($P < 0.05$).

3. RESULTS AND DISCUSSIONS

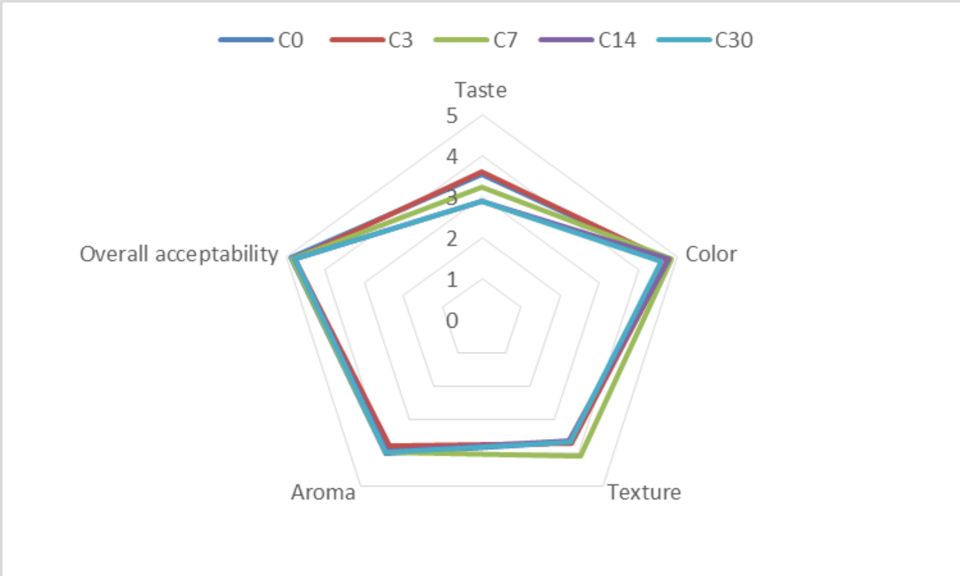
3.1. Sensory Characterization of Frozen Samples

Taste is the primary factor which determines the acceptability of any product, which has the highest impact as far as market success of product is concerned. There was a light variability among different cassava samples frozen at different period (Fig 1) for the attribute taste, which scores varied between 2.90 and 3.56. However, panelists did not detect any difference in color, texture and aroma of cassava samples tested. Overall acceptability includes many implications, which is the important parameter in organoleptic estimation. All cassava samples received the same score for overall acceptability.

In the other hand, regarding plantain samples, there was variability among different samples frozen at different period (Fig 2) for all the sensory attributes. From a generally point of view, sensory quality decreased with duration of freezing. Between 0 and 7 days of freezing, the color, the aroma, the texture and the overall acceptability of tested plantains were rated the same, while from 7 to 30 days, these attributes decreased. For example, the taste decreased as from the fresh sample (4.55) up to sample frozen at 3 days (4.00) and from sample frozen at 7 days (2.58) to sample frozen at 30 days (2.58). Other attributes look the same as it is for the taste.

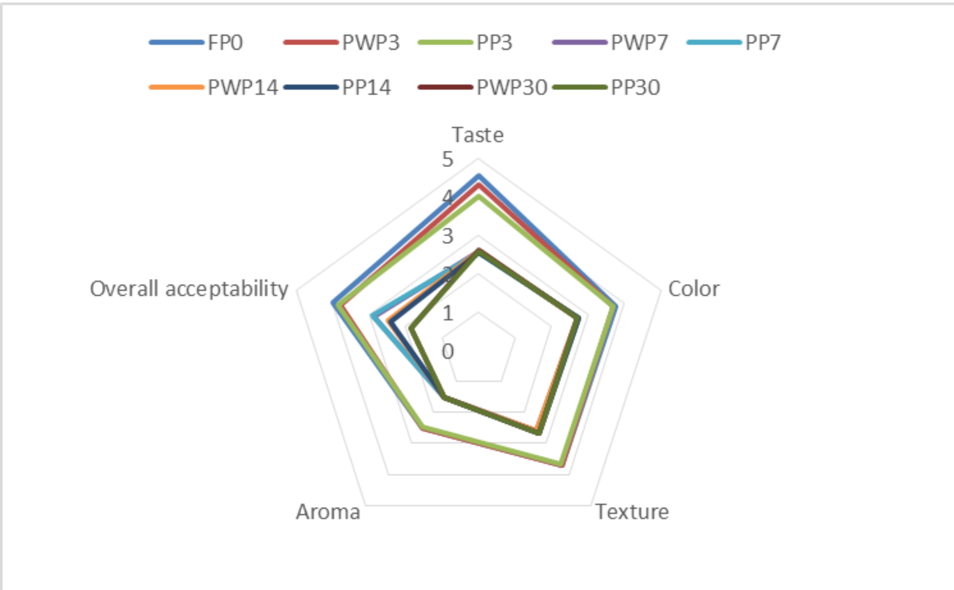
Concerning the effect of the peeling on the sensory quality of the frozen plantain, the figure 2 shows that for a given freezing time, there is no difference between unpeeled (PP) and peeled (PWP) plantain fruits. For example, at

7 days of freezing for the Overall acceptability, plantain without peeling (PWP) was rated 2.87 and 2.90 for the peeled plantain.



C_0, C_3, C_7, C_{14}, C_{30} are cassava roots samples frozen during 0, 3, 7, 14 and 30 days.

Figure-1. Sensory description of boiled plantains according to the freezing period.



FP: fresh green plantain, PP: frozen plantain with peeling, and PWP: frozen plantain without peeling; 0, 3, 7, 14 and 30 correspond to the freezing duration in days.

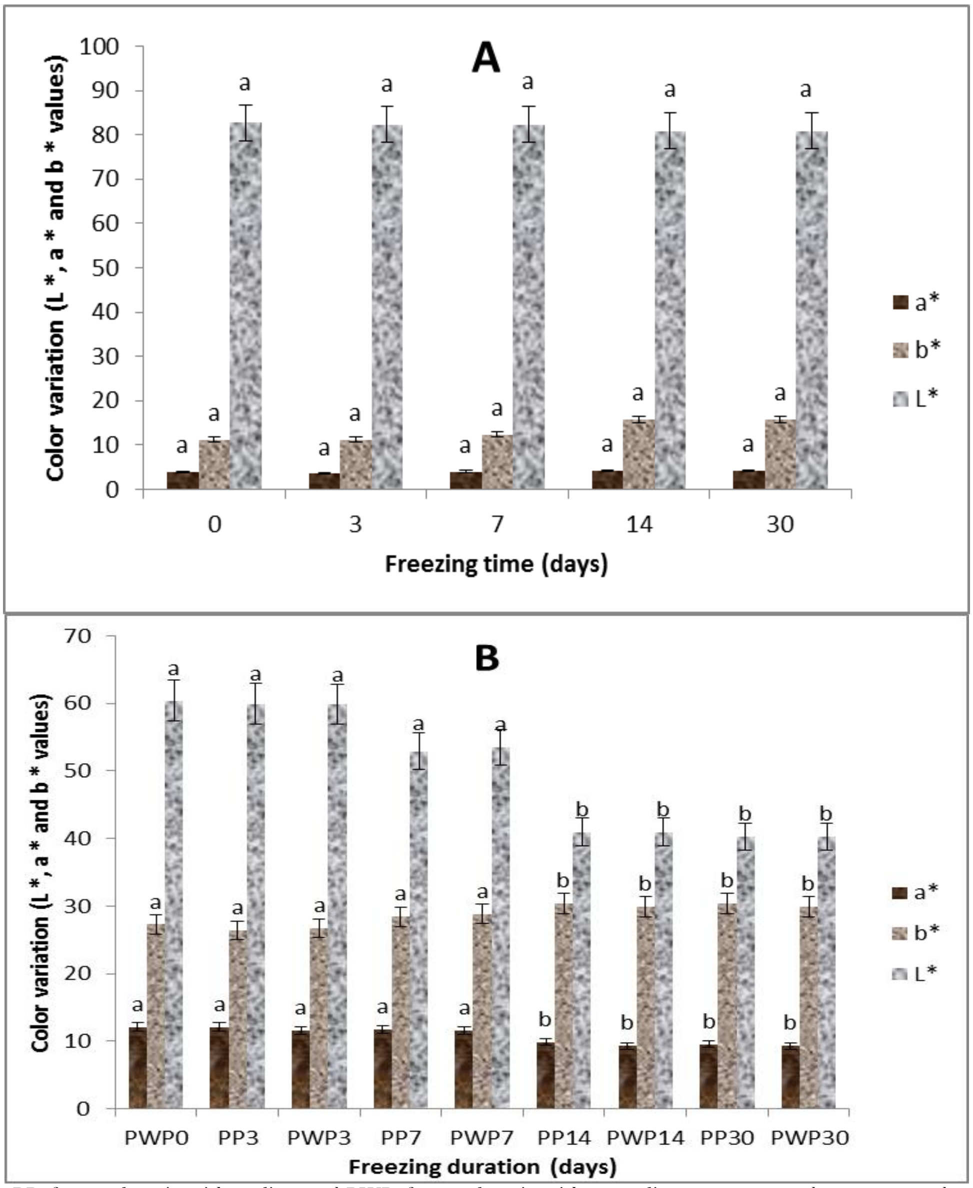
Figure-2. Description of boiled plantain according to the freezing period.

3.2. Variation of Color with Freezing Duration

Generally, there was no significant difference in the variation of color of the frozen cassava all along the freezing time (Figure 3A). These results confirmed the sensory analysis done by panelist previously. This means that cassava tubers don't change in color whatever the time they make in the freezer.

Plantain fruits decrease in color while the freezing time increase (Figure 3B). The decrease of the brightness (L) and redness (a*) appeared from the 7^{th} day of freezing, and from that day, they were almost constant till the 30^{th} day, while there is an increase for redness of frozen plantain. Since L* value was reducing, signifying that the color becomes darker as the freezing time was increased, which may be due to the enzymatic reaction. Freezing induces a decrease of available water for the enzymatic reactions leading to less activity of polyphenoloxidase (Lavelli and

Caronni, 2010). According to the Arrhenius law, a temperature decrease leads to a decrease of the rate of browning reactions (Mastrocola *et al.*, 1998).



PP: frozen plantain with peeling, and PWP: frozen plantain without peeling; 0, 3, 7, 14 and 30 correspond to the freezing duration in days. Means with similar letters in a column are not significantly (P<0.05) different.
Figure-3. Color variation (L *, a * and b * values) with the freezing time of the cassava (A) and plantain (B) samples.

From results of nutritional analysis, we noticed that freezing has no significant neither on cassava tubers nor on plantain fruits (Tables 3 and 4). This was expected since during freezing process, vitamins minerals and macro-elements content remains substantially the same as in the fresh state. Proteins in the diet helps primarily to build and maintain body cells, while fat supplies essential fatty acids. Crude fiber plays an important role in the prevention of many diseases of the digestive tract. It has been reported that intake of more fiber results in increasing faecal bulk and lowering of plasma cholesterol (Lisa *et al.*, 1999).

Table-2. Dry matter (DM), total lipid (TL), crude protein (CP), crude fiber (CF), total carbohydrate (TCH) and total ash (TA) content of frozen cassava.

Freezing time (Days)	DM (%)	TL (%DM)	CP (%DM)	CF (%DM)	TA (%DM)	TCH (%DM)
0	41 ± 0,12	0,19±0,01	1,94±0,08	1,41±0,08	1,97±0,01	89,00±0,40
3	43 ± 0,31	0,20±0,01	2,10±0,02	1,41±0,09	1,99±0,06	92,00±0,70
7	41 ± 0,17	0,20±0,02	2,17±0,04	1,44±0,05	1,88±0,02	91,00±0,40
14	42 ± 0,22	0,25±0,02	1,95±0,01	1,40±0,01	1,93±0,02	91,00±0,04
30	42 ± 0,27	0,23±0,04	1,97±0,01	1,41±0,01	1,89±0,03	91,00±0,03

Table-3. Dry matter (DM), total lipid (TL), crude protein (CP), crude fiber (CF), total carbohydrate (TCH) and total ash (TA) content of frozen green plantain.

Samples	Freezing Time (Days)	DM (%)	TL (%DM)	CP (%DM)	CF (%DM)	TA (%DM)	TCH (%DM)
FP	0	42 ± 0,12	1,13±0,01	2,26±0,08	0,01±0,00	1,02±0,01	91,00±0,40
PWP	3	43 ± 0,31	1,13±0,01	2,64±0,02	1,13±0,04	2,06±0,01	89,00±0,70
PP	3	42 ± 0,19	1,13±0,02	2,40±0,01	1,53±0,04	1,89±0,05	89,00±0,20
PWP	7	42 ± 0,06	1,12±0,01	2,31±0,02	2,13±0,05	1,76±0,14	89,00±0,20
PP	7	42 ± 0,17	1,11 ±0,02	2,12±0,04	1,30±0,01	1,76±0,01	90,00±0,40
PWP	14	43 ± 0,06	1,10 ±0,02	2,30±0,08	2,49±0,01	1,19±0,01	91,00±0,10
PP	14	42 ± 0,22	1,11±0,02	2,06±0,01	2,79±0,02	1,69±0,13	90,00±0,30
PP	30	42 ± 0,21	1,08 ± 0,02	2,30±0,01	2,50±0,02	1,65±0,13	89,00±0,30
PWP	30	43 ± 0,06	1,10 ±0,02	2,30±0,08	2,49±0,1	1,19±0,01	91, 00±0,10

PP: frozen plantain with peeling, and PWP: frozen plantain without peeling; 0, 3, 7, 14 and 30 correspond to the freezing duration in days.

4. CONCLUSION

The present research was conducted to evaluate the impact of freezing time on the organoleptic and nutritional properties of cassava tubers and plantain fruits. This study demonstrate that freezing can be used to increase product shelf-life. The finding of this research showed that freezing time decrease the organoleptic properties of cassava and plantain but does not affect their nutritional quality. Therefore, they could be stored by freezing for at least 30 days without any changes on its nutritional value. More studies should be conducted to investigate the effect of freezing on the nutritional and sensory quality of cassava and plantain on a long term.

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