

# Estimation of Material Losses and the Effects of Cassava at Different Maturity Stages on Garification Index

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## Abstract

*Gari*, a West African staple food was processed using fresh cassava tubers (TMS 30572 cultivar). Material losses and *garification* rate index as affected by the cassava ages of maturity, fermentation days and processing stages were determined. The material losses and yield of *gari* from 9, 12 and 15 months old cassava plants at different processing stages and fermentation days were evaluated. Results showed that the average peeling loss at different maturity ages ranged between 21 and 28.86% while percentage grating loss ranged from 3.71 to 5%. Likewise, estimated percentage dewatering/fermentation loss ranged from 25.55 to 30%, while sieving loss ranged from 4.24 to 5.14%. *Garification* losses ranged from 17.45 to 19.79% with an average *gari* yield between 19.86 and 23.68%. Cassava of 15 months maturity age generally produced higher yields of *gari* than those harvested early. The mean *garification* conversion rate achieved was 22% (0.22, wt/wt).

**Keywords:** Cassava; Material losses; Yield; *Gari*; *Garification* index

## Introduction

Cassava (*Manihot esculenta crantz*) is one of the major root tubers produced in the forest zones of Nigeria, with yields as high as 38 million metric tons per annum [1]. It is a major source of staple food in West Africa, providing basic diet to millions of its teeming population across the different socio-economic classes. Due to its relative high moisture and cyanide content, cassava needs to be converted into suitable forms with longer shelf life and lower cyanide levels [2,3]. Different forms in which the processed root exists includes cassava bread, wet chips, *elubo*, *lafun*, cassava starch, roasted/boiled cassava, *fufu* (*akpu*) and *gari* [4,5].

In Nigeria, similar to other West African countries, over 70% of the cassava yield is processed into *gari*, a staple and convenient food [6]. It is the major form in which cassava is consumed in West Africa. *Gari* is a fermented roasted granule prepared from peeled, grated and fermented cassava root through a series of processing steps [7]. The conventional method of producing this involves peeling and grating the fresh roots. The grated pulp is then fermented for one to five days. Subsequently, the pulp is compressed to reduce its moisture content, after which it is sieved and fried in heated pans. A dash of palm oil may during grating or at the point of *garifying* to prevent burning, producing a yellowish-*gari* is distinct from white-*gari* in which no oil is added. This is either consumed immediately or further processed into various forms that combine diversity, convenience and nutritional value [8,9].

The traditional method of processing *gari* is an arduous, intricate and tedious operation. This requires a good understanding of combination factors which affects the quality and yield of the *gari* produced [10]. The inability to control moisture content as related to particle size and the exposure of processors to heat and fumes have been major mitigating factors reducing the efficiency of the traditional processing methods.

With the current food crisis in most part of the world and the potential of *gari* to substantially address calorie inadequacy of millions of people in Africa [11], it is imperative to maximize the yield of *gari* processing systems. This will ensure a comprehensive process analysis, to pinpoint factors causing material losses, as a guide in re-designing the *garification* process to minimize losses. This is vital for

the development and assessment of new processing technologies [12]. Therefore, the purpose of this work was to establish a standard measure, to quantify the various losses and then determine the *garification* rate index associated with *gari* processing, using a locally fabricated electro-mechanical *garifier*.

## Materials and Methods

### Processing of cassava tubers into *gari*

The method described by Achinewhu, *et al.* [12] and Akingbala, *et al.* [13] was largely adopted. Fresh cassava tubers of the TMS 30572 cultivar were harvested at maturity ages of 9, 12 and 15 months. They were sorted according to size, weight and shape by visual assessment. 70 kg of between 300-400 pieces of each maturity age of fresh cassava tubers were selected. There were respectively peeled, washed, drained and grated in a mechanized commercial grater. The grated pulp (mash) was loaded into jute bags and tied with a string. The mash was left to naturally ferment for a period of 0, 1, 2, 3, 4, 5, and 6 days at ambient temperature before pressing out the juice with hydraulic press. The pressed out mash (cake) were manually crushed and sieved (1.50 mm mesh) to remove fibers. The starchy granules obtained were analyzed at different fermentation days and 1 kg from each of the samples was *garified* at a steady state in an electro-mechanical *gari* roaster developed locally with a capacity of 5 kg/h and functional efficiency of 80%. The machine (Figure 1) was operated at a constant stirring rate and allowed for gelatinization at 20 sec interval. This process is called *garification* as it dextrinizes the starch and dries the granules. The *gari* produced

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Figure 1: Electro-mechanical gari roaster

was air dried, cooled and packaged in polyethylene bags for further processing and analysis.

### Material losses

Material losses comprise of both heat and mass transfer, occurring at all the stages of processing. The losses at each processing stage were determined using the difference in the weight of material recovered before and after each stage [14]. This was then subsequently calculated as a percentage of the initial weight of the fresh cassava. Based on this, the individual percentage losses [Peeling ( $L_p$ ), Grating ( $L_G$ ), Dewatering/Fermentation ( $L_D$ ), Sifting ( $L_s$ ) and Garifying ( $L_R$ )] were calculated using Eq. (1)-(5).

$$L_p = (W_1 - W_2)/W_1 \times 100 \quad (1)$$

$$L_G = (W_2 - W_3)/W_1 \times 100 \quad (2)$$

$$L_D = (W_3 - W_4)/W_1 \times 100 \quad (3)$$

$$L_s = (W_4 - W_5)/W_1 \times 100 \quad (4)$$

$$L_R = (W_5 - W_6)/W_1 \times 100 \quad (5)$$

where  $W_1$  is the initial weight of fresh cassava tubers (kg),  $W_2$  is the weight of peeled tubers (kg),  $W_3$  is the weight of wet mash collected from the grater (kg),  $W_4$  is the weight of cassava cake after fermentation and dewatering (kg),  $W_5$  is the weight of sifted granule (kg) and  $W_6$  is the weight of the garified sample (kg).

### Determination of the percentage yield of garification

The total loss for each age of maturity at different fermentation periods were obtained by totaling the losses in Eq. (1)-(5). Hence, the total amount of gari obtained, expressed as a percentage of the fresh cassava roots is calculated as follows;

$$\% \text{ yield of gari} = \text{mass of gari}/\text{mass of cassava that produced the gari} \times 100 \quad (6)$$

Mean values of the losses were also calculated. Therefore, from the obtained results, a relationship between the initial weight of fresh tubers ( $W_1$ ) and gari yield was established thus:

$$W = W_1 K \quad (7)$$

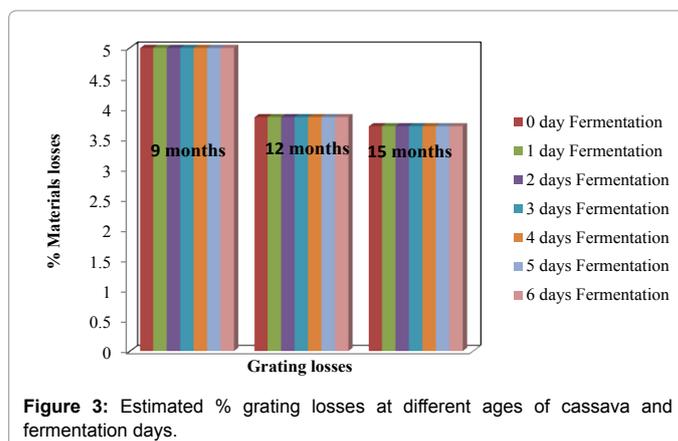
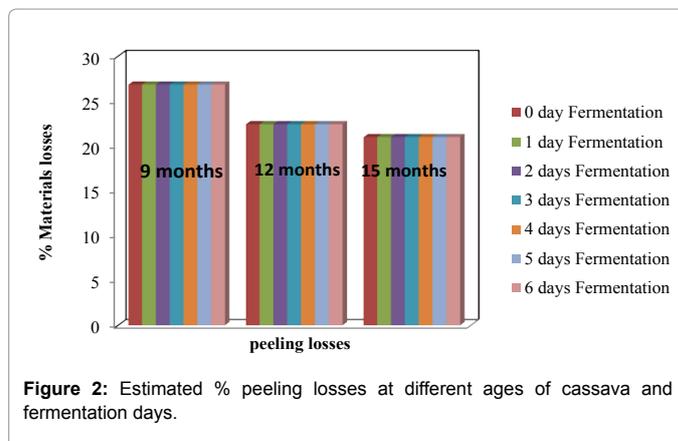
Where  $W$  is the weight of yield of gari (kg) and  $K$  is a constant [garification conversion rate (wt/wt)].

### Data analysis

The statistical analysis of the data was conducted using MATLAB commercial software package [Version 7.10.0 (R2010a), Neural Works Professional II/Plus, Neural Ware, Pittsburg, USA]. All experimental data obtained were subjected to analysis of variance (ANOVA) using nonlinear regression model (NLR) procedure of Statistical Analysis System Institute (SAS, 2003). Means were compared at 5% significance level using Duncan's multiple range test, DMRT [15].

### Results and Discussion

The estimated material losses at different processing stages and the final yield of gari from cassava ages of maturity (9, 12 and 15 months) and days of fermentation (0-6 days) are shown in Figures 2-8. Likewise, the effects of processing variables on the moisture contents are presented in Figures 9-11. The average peeling losses for cassava of 9 months maturity age was 26.86%, the estimated percentage dewatering/fermentation loss ranged from 25.50 to 25.57%. The sieving loss ranged from 5.12 to 5.14%, while the value of garification losses ranged from 17.45 to 17.57%. The total loss was recorded to be between 79.93 and 80.14% with an average yield of gari ranging between 20.07 and 19.86%. The average peeling loss from 12 months cassava age of maturity was 22.43%. The percentage grating loss was 3.86%, while the percentage



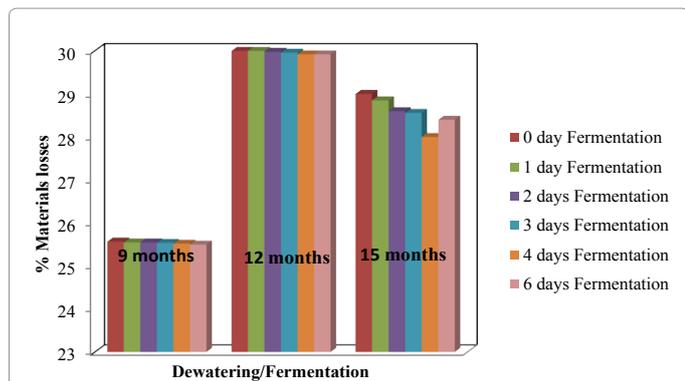


Figure 4: Estimated % dewatering/fermentation losses at different ages of cassava and fermentation days.

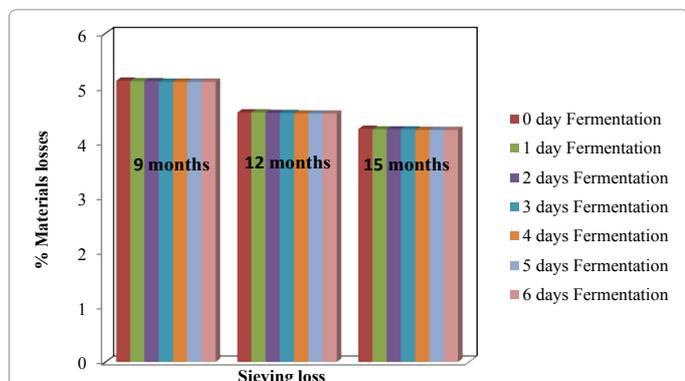


Figure 5: Estimated % sieving losses at different ages of cassava and fermentation days.

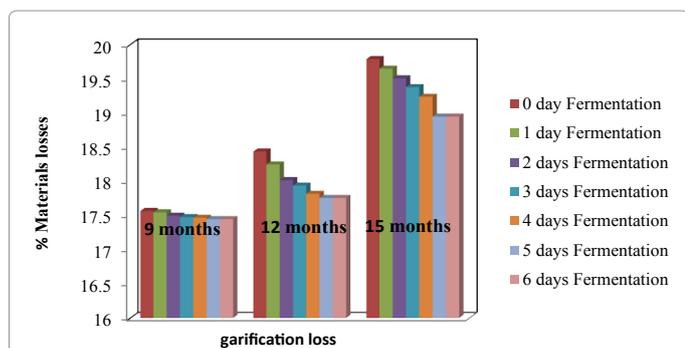


Figure 6: Estimated % garification losses at different ages of cassava and fermentation days.

dewatering/fermentation loss ranged from 29.92 to 30%. The sieving loss ranged from 4.54 to 4.56%, while the garification losses ranged from 17.76 to 18.44%. The total loss was estimated to be between 78.51 and 79.29% with an average yield of gari ranging between 21.49 and 20.71%. The average peeling loss from 15 months cassava maturity age was 21%. The grating loss was 3.71%, while the estimated percentage dewatering/fermentation loss ranged from 28.42 to 29%. The sieving loss ranged from 4.24 to 4.26%, while the garification losses ranged from 18.95 to 19.79%. The estimated total loss was between 76.32 and 77.76% with an average yield of gari ranging between 23.68 and 22.24%.

The results from this study revealed that greater losses were recorded during the peeling, dewatering/fermentation and garification stages of processing, while grating and sieving had the lowest losses. According to Amoah, *et al.* [14], peeling requires the removal of the outer root cortex which contains the toxic cyanide, rotten portions and stumps. Alongside this, some considerable dry matter is also lost. The amount and quantity of these materials lost, however largely depends on cultivar type, peeling efficiency and quality of the cassava tubers. These peels make up about 10 - 15% of the tuber, but 25 - 30% losses is associated with hand peeling Opara [3] while its about 8.6% with a mechanized peeling machine [16] Losses observed with the mechanical grater used in this study ranged between 2 and 5%, which can be attributed to mash spillage from the hopper due to vibrations during cassava grating.

Losses at the dewatering stage are caused by the removal of the cyanide dissolved water and starch from the mash. The amount of expressed water is relative to the moisture content of the cassava tuber, which is a function of maturity ages. At this stage, lesser losses tend to correspond to cassava age of lesser moisture content. Cassava roots of 15 months age of maturity with higher dry matter accumulation and lower moisture content had lower dewatering losses compared to those harvested early. This result showed consistently higher dewatering losses for cassava harvested at 12 months age of maturity than corresponding 15 months cassava age, while 9 months age of cassava has the least. This may be due to duration of planting and variations in seasons of harvest. As noted by Hahn [17] during the rainy season, the dry matter content

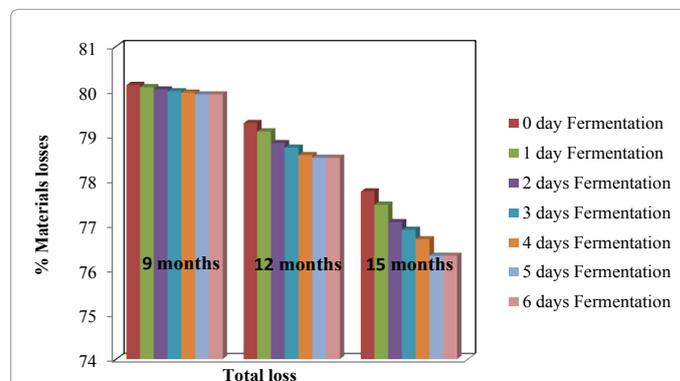


Figure 7: Estimated % total losses at different ages of cassava and fermentation days.

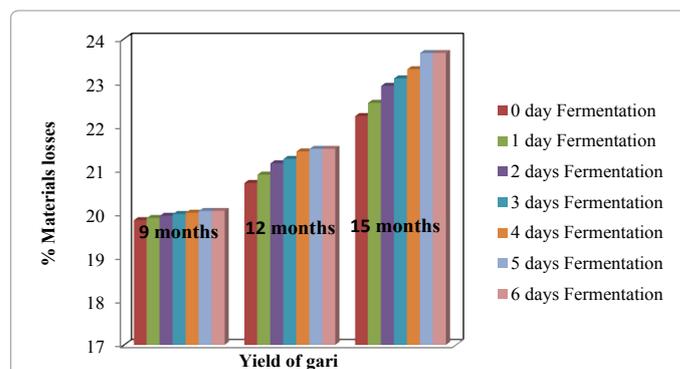


Figure 8: Estimated % yield of gari at different ages of cassava and fermentation days.

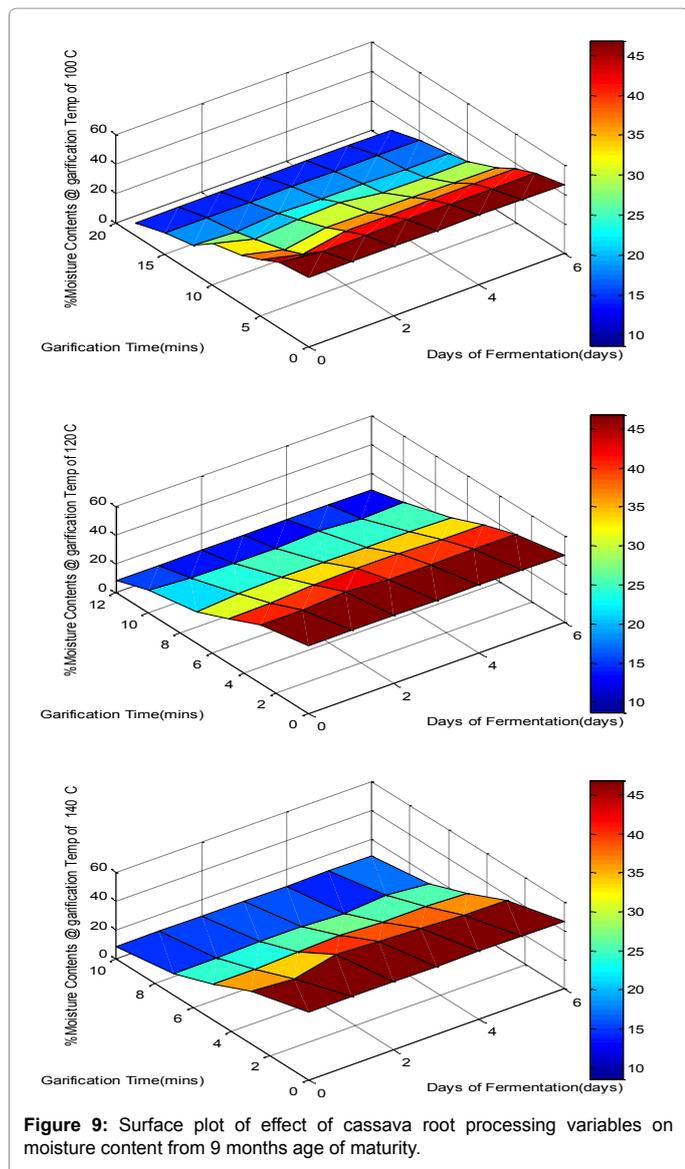


Figure 9: Surface plot of effect of cassava root processing variables on moisture content from 9 months age of maturity.

of roots is lower compared to the dry season. During growth season, both starch and roots production rapidly increases with moisture content to their maximum after which they decline afterwards [3]. The duration of fermentation showed slightly significant effect ( $p \leq 0.05$ ) on the moisture content at different processing stages of the *gari*. According to Achinewhu, *et al.* [12], fermentation could play a vital role in the processing of *gari* during which linamarin is hydrolyzed to hydrocyanic acid to a level that may become harmless after *garifying*.

Sifting losses are much more associated with the skill of the processor to ensure reduced spillage while *garification* losses are dependent on *garification* temperature and moisture content before *garifying*. Cassava roots of 15 months age of maturity produced higher yields of *gari* than other maturity ages harvested earlier. This may be accounted for as a result of vascular woodiness of the roots as observed from the higher dry matter and relatively lower moisture content in the older roots. The mean yield of *gari* associated with the *gari* processing system from the ages of cassava used in this study ranged from 19.86 to 23.68%, with average of about 21.77% of the initial weight of

fresh cassava tubers [17,18]. This translates into a mean *garification* conversion rate of 0.22 (wt/wt), which was achieved using a locally fabricated electro-mechanical *gari* roaster. A comparable *garification* rate index of 0.23 had been reported in the literature by Amoah, *et al.* [14]. Since, the cassava tubers harvested at different maturity ages were passed through the set of equipment and processing methods, it may be presumed that the effects of maturity ages of cassava tubers and fermentation periods on the *garification* conversion rate were neutralized by each other. Therefore, the average *garification* rate index of 0.22 can be posited to represent the efficacy of the processing system adopted in this study. This can be applied as a numerical index and bench mark for comparison of the efficacy of diverse *garification* processing systems for *gari* production. Hence, the higher the *garification* index of a system, the higher the potential yield of *gari*.

### Conclusions

Cassava tubers of 15 months maturity age generally produced higher yields of *gari* than those harvested earlier. The *garification* rate or index achieved was estimated to be averagely 0.22, which can be used as a numerical index and a bench mark for the determination of *garification* processing systems for *gari* production. The study also confirmed that the factors accounting for material losses are age of

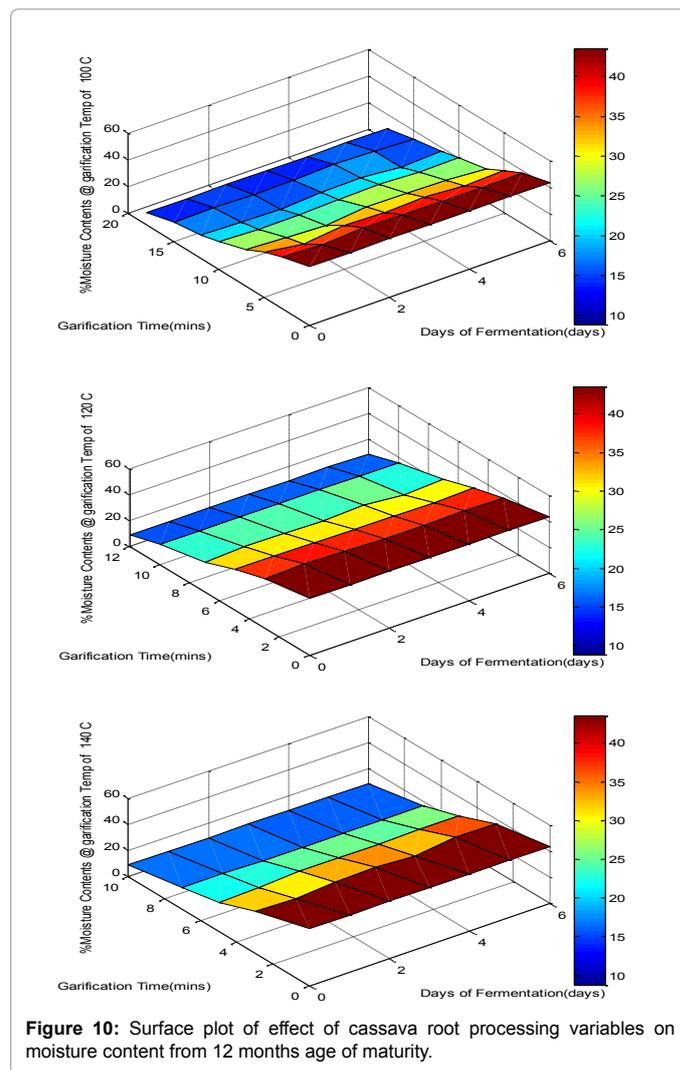
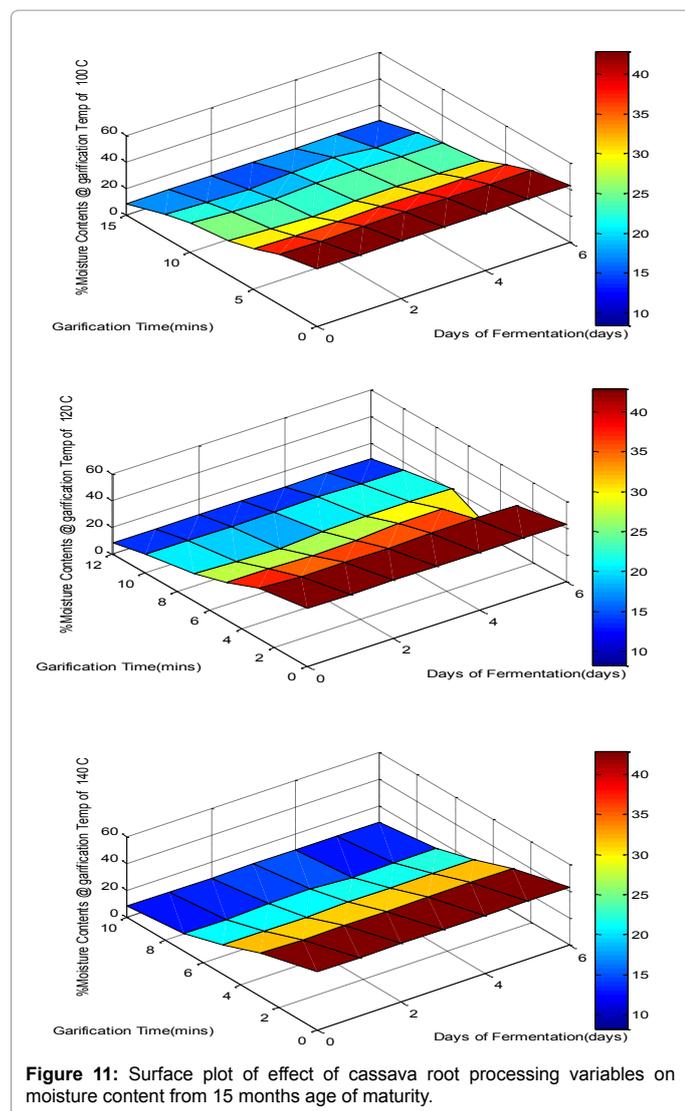


Figure 10: Surface plot of effect of cassava root processing variables on moisture content from 12 months age of maturity.



cassava at point of harvest and processing methods. The highest losses recorded were at the peeling, dewatering/fermentation and *garification* stages, while the least recorded losses were during the grating and sieving stages. Therefore, improved and increased *gari* yield should focus on the development and utilization of cassava tuber varieties with lesser peels and moisture content. These are important considerations to obtain an appreciable yield and quality *gari* for feasible commercial production.

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