Implication of 7 Per Cent Moisture Content (NIS 81: 2004) for Garion Fresh Cassava Tubers

Olusegun Adeoti, Aderoju Funmilayo Ogunnaike, Yetunde Mayowa Adeosun*

Department of Agricultural and Bio-Environmental Engineering, The Federal Polytechnic, Ado Ekiti, Ekiti State, Nigeria
**Corresponding author*

Abstract:- **This study used data from Nigeria to show that complying with the 7 per cent moisture content for gari (Nigerian Industrial Standards (NIS) 81: 2004) has an implication on fresh cassava tubers. The result showed that roasting cassava grits to 7 per cent moisture content (wet basis) could result into fresh tuber loss amounting to 1.2 and 1.9 tonnes/hectare when batched same volume as gari produced at 12 per cent (CODEX STAN 151 -1995) and 16 per cent (retail markets) moisture contents, respectively. The study has important implications for improving standards for gari in Nigeria and other gari producing economies.**

Keywords: **Gari; NIS 81: 2004; CODEX STAN 151 -1995; Moisture content; Implication; Cassava tuber; Nigeria**

I. INTRODUCTION

Moisture content (MC) is crucial to the quality, acceptability and storage stability of gari. Of all cassava products in Nigeria and other West African countries, gari is the most traded[1]. In Nigeria, about 75 per cent of harvested cassava tubers are processed into gari [2]. Gari, a granular food product, is obtained from cassava tubers after several processing steps involving: peeling, washing, grating, dewatering and fermenting, sieving, and roasting [3]. Because of its convenience and numerous uses, the Nigerian Industrial Standards (NIS) 81: 2004 has stipulated that the moisture content (MC) of gari produced in Nigeria should not exceed 7.0 per cent m/m (wet basis) (wb). Compared with an international standard, the CODEX STAN 151 -1995 standard for gari has stipulated a maximum 12.0 per cent m/m (wb). Standards are set to regulate the quality and safety of produce/products in the markets and to protect the health of consumers.

In Nigeria, the MC of gari being sold in the markets varies. A review of the literature revealed that gari produced in Nigeria had moisture contents (wb) that varied between 9.6 and 17.7 per cent [4], or between 10.0 and 18.7 per cent [1], or between 15.1 and 22.3 per cent [5], or between 10.3 and 12.4 per cent [6], or ranged from 13 to 16 per cent [7]. As elsewhere, gari is still being produced by numerous smallholder processors and measured for sale by volume in Nigeria. However, it remains unclear what the implication of producing gari at 7.0 per cent m/m maximum (wb) will be on fresh cassava tubers. Although the Government of Nigeria is yet to enforce any of these standards, this study investigates the implication of complying with the 7.0 per cent m/m maximum moisture level on fresh cassava tubers. The result is useful to gari processors and state actors responsible for setting and enforcing standards for gari in Nigeria and elsewhere. To the best of authors' understanding, this is the first reported study to examine the implication of complying with NIS 81: 2004 on fresh cassava tubers. In 2017, Nigeria is the largest cassava (*Manihot esculenta* Crantz) producer, accounting for 20.4and 60.9per cent of world and Africa production, respectively[8]. As a stable food, cassava is consumed around the world by an estimated population of 800 million people [9].

II. MATERIALS AND METHODS

This study followed a two-stage approach to realise its aim.

Stage one determines the relationship between MC (wb) and batched mass of roasted cassava grits. Sieved cassava mash or grits were purchased from a gari processor at the Gari Processing Centre of the Department of Agricultural and Bio-Environmental Engineering, the Federal Polytechnic, Ado Ekiti, Ekiti State, Nigeria. The Centre, which became operational in 2011, had a 9 year history in small-scale cassava-gari processing. Two experiments were carried out to realise the objective of this subsection. The first experiment was conducted on 23 July 2019 with 2.35 kg sample of cassava grits, while the second experiment was conducted on 25 July 2019 with another 2.15 kg sample of cassava grits. The cassava variety was *Manihot utilissima* (Oko iyawo in Yoruba Language), harvested about 12months after planting in July 2018. The grits were roasted in a cast iron pan heated by fuel wood for 4 hours each, and samples were taken every 30 – 30 minutes for (i) MC determination (wb) using the gravimetric method with oven drying, and (ii) batched mass determination. ISO 712 was adopted for the MC determination. To obtain the batched mass (defined as the mass of roasted cassava grits to occupy same volume), the following procedure was followed:

a. a 24ml(13.6 mm internal diameter x 160 mm)glass tube was filled to the brim with the roasted grits, and tapped 20 times. Tapping helped eliminate the air spaces.
b. the resulting empty space above the settled grits was re-filled to the brim and the glass tapped for another 15 times
c. the resulting empty space was re-filled, and the glass tapped another 15 times.
d. the surface was filled, and the excess roasted grits scrapped off.

e. the batched sample was poured into a can and weighed using Alpha CRS-130 electronic compact scale

The essence of this approach was to be able to use the data obtained to predict the MC of roasted grits, given the batched mass.

In the case of the MC of fresh tubers, to avoid moisture loss during size reduction peeled samples were put in nylon bags and kept in a deep freezer for 36 hours. The frozen samples were removed from the freezer and some quantities were quickly grated manually. Samples weighing 5 g each were taken for MC determination (wb), dried at 120 ^oC until constant weight.

Stage two determines the mass of the resulting gari during roasting. A 20-heaps plot of cassava, *TSM 30555* variety, was purchased from a cassava farmer and gari processor at the Processing Centre. Cassava tubers, weighing 15.16 kg after cleaning, were harvested on Wednesday, 18 December 2019 roughly17 months after planting in July 2018, and processed same day after harvest following the procedure illustrated by James et al. (2012). The weights of the fresh cassava tubers and the resulting products were obtained using the TCS-150-JE62ZB electronic weighing machine. After 30 minutes of roasting, the resulting gari was scooped from the roasting pan into a desiccator, allowed to cool, and weighed. Samples were taken for batching, and returned. This operation was repeated seven times, which translated to a roasting duration of 4 hours. The purpose of this stage was to use the values obtained to predict gari's MC (wb) from the result of the data obtained from stage one. Roasting and other cassava processing activities were carried out at the Gari Processing Centre of the Department of Agricultural and Bio-Environmental Engineering, while batching and MC determination were carried out at the Postharvest Laboratory of the Department of Agricultural and Bio-Environmental Engineering.

The product yield, which measures the percentage of the resulting product at a certain processing step, was calculated using equation 1:

$$\text{Product yield (\%)} = \frac{\textit{Weight of the resulting product (kg)}}{\textit{Weight of the original product (kg)}} \; x\ 100 \qquad (1)$$

III. RESULTS AND DISCUSSION

3.1 The relationship between MC (wb) and batched mass of roasted grits

Roasting entails the simultaneous process of cooking and drying. In practice, the grit is first cooked with the moisture in it and then dehydrated[10]. Holding roasting (or heating) temperature constant, as the roasting duration increases, this further cooks and dehydrates the resulting product. Although fresh cassava tubers contain 25-40 per cent starch [11], some starch granules leachout during the dewatering process. The remaining starch granules in the grits gelatinises during cooking. This occurs at a temperature between 60 and 65 ^oC [12]. As the starch granules gelatinise*, dehydration also occurs (- a simultaneous process of heat and mass transfer), while most of the developed small lumps are broken by constant pressing and turning to avoid caking and to ensure near-uniform exposure of grits to the pan heat.

*Gelatinisation is a process during which astarch granule absorbs moisture, swells and undergoes irreversible structural change under the influence of heat. In this study the bulk of starch gelatinisation may have been completed before the end of the first 30 minutes of roasting.

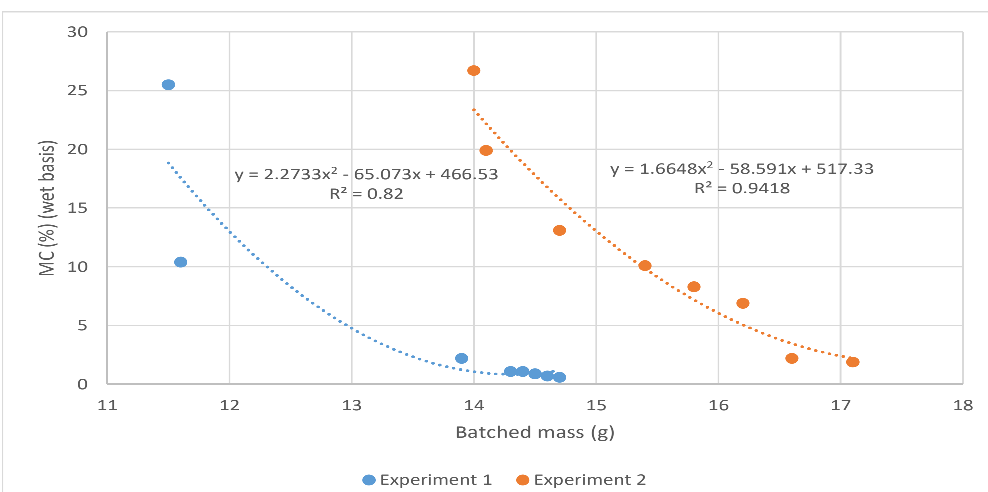

Fig. 1: The relationship between MC and mass of roasted grits batched at same volume
[from cassava grits roasted on23 July 2019 (Experiment 1) and on 25 July 2019 (Experiment 2)].
Mean values, number of samples (n) = 3

As shown in Figure 1, as the MC of the grits decreased, the batched mass of the roasted grits increased. A possible explanation is that as the roasting duration increased, the size of the grits shrunk as they lose moisture, thereby enabling more roasted grits to occupy same volume. Grit dryness is a property linked to swelling index and water absorption capacity. While both swelling index and water absorption capacity are related, the literature [3, 13, 14] has reported a gari swelling index of up to 4. This indirectly implies that a cassava grit could shrink to four times of its original size. Although not measured, gari particle size could vary from 0.6 to1.1 mm [2]. Gari's particle size is affected by grating efficiency as well as the duration of roasting, holding heating temperature constant. It could therefore be deduced from Figure 1 that:

- roasting had effects on moisture loss and grit size shrinkage. Increasing the duration of roasting led to more moisture loss and further shrinkage in grit size.
- as MC and grit size decreased, more grits occupied same batched volume, which translated to an increase in weight per same volume
- there was a positive relationship between MC (%) (wb) and batched mass of roasted grits, and the relationship was better explained by a quadratic polynomial model. The R-squared of both experiments was higher than the goodness of fit for other models, such as, exponential, linear, logarithmic, or power. Sobowale et al. [15] also found that the relationships between heat and mass transfer during the roasting process were best described by quadratic polynomial models.

From the data presented in Figure 1, for grits roasted to 7 per cent MC (wb) (NIS 81: 2004) compared with grits roasted to 12 per cent (CODEX STAN 151 -1995), the predicted batched masses (from Experiment 2 in Figure 1) were 15.9 and 15.1 g, respectively. This revealed that more grits were needed from grits roasted to 7 per cent MC to occupy same volume than from grits roasted to 12 per cent. This initial result affirms that roasting gari to 7 per cent MC (wb) (NIS 81: 2004) has some implication on fresh cassava tubers.

Because the result of Experiment 2 had a better distributed sampled values (Figure 1), this was used in the rest of the paper's analysis. The result of Experiment 1was affected by the relatively high roasting (or heating) temperature. Roasting with fuelwood is a bit complicated, and requires some level of experience. The relatively high pan/roasting temperature led to rapid moisture loss when compared with the result of Experiment 2. This indicates that the rate of moisture loss during roasting is sensitive to pan heating temperature. Although outside the scope of this study, the effect of different heating temperatures on the nutritional quality of gari is unknown. This may benefit from future study.To be moderate, however, the average roasting temperature (measured in the grits) could vary from 78 to 97°C, whilethe pan temperature should not be more than 108 ± 5°C. This will also help to prevent caking and the formation of lumps. However, according to processors, if the pan heat is not hot enough and sustained at the initial stage of roasting, the grits may not cook properly, with implications on the resulting gari quality.

3.2 Mass of the resulting gari during roasting

As shown in Figure 2, from unpeeled fresh cassava tubers of 15.16 kg, the resulting final gari amounted to 3.68 kg. This translated to a product yield of 24.3 per cent of unpeeled tubers. Therefore, from the original product to the resulting product, there were weight reductions. It was found that as the resulting mass of gari decreased with increase in roasting duration, the batched mass of gari also increased (Figure 2). This is in agreement with an earlier observation. The predicted MC of the grits (before roasting) obtained from Figure 1was 43.39 per cent(wb). According to Ikechukwu and Maduabum [16], the MC of cassava grits could range between 50 and 65 per cent (wb), while the values obtained by Ajayi et al. [12] were 41.2 and 38.6 per cent. This indicates that there was no fixed MC value for cassava grits. However, the MC of cassava grits could be influenced by period of harvest, age at harvest, method and duration of dewatering. Using the batched mass values (from Figure 2), the corresponding MC values of the resulting gari were obtained from Figure 1. These values (MC and mass of gari) were used to plot Figure 3, and the information from Figure 3 was used to predict the mass of the gari, given the MC. Therefore, from Figure 3, at 12 per cent MC (wb), the mass of gari amounted to 5.04 kg, while at 7 per cent MC (wb) this translated to 4.42 kg. As the MC of the cassava grits decreased with increase in roasting duration, the mass of the resulting gari decreased (Figure 3). As illustrated in Section 1, the moisture contents of gari being sold in the Nigerian markets vary. This study has used an average value of 16 per cent (wb). Therefore, the predicted mass of gari roasted to 16 per cent MC (wb) (from Figure 3) would amount to 5.50 kg.

In terms of product yield, for cassava grits roasted to 7 per cent MC (wb), the product yield amounted to 29.2 per cent of unpeeled fresh tubers, lower than that of grits roasted to 12 per cent MC (wb), 33.3 per cent, or grits roasted to 16 per cent MC (wb), 36.3 per cent. Roughly speaking, the predicted product yield of market gari obtained in this study was higher than 31.2 per cent obtained by Karim et al. [17], but comparable with 37.0 per cent obtained by Komolafe and Arawande [14] and 37.5 per cent obtained by Odigboh and Ahmed [7]. Variation in gari yield could be attributed to varietal differences, age at harvest, period (or time) of harvest, and processing methods [18 - 20].To be profitable when batched by volume, Karim et al. [17]revealed that gari yield should not be less than 25 per centof unpeeled fresh tubers. This suggests that cassava grits roasted to 7 per cent MC (wb) could be profitable.

Therefore, considering the information in Figures 2 and 3 together, to produce 1 kg of gari at 16 per cent MC (wb), 2.76 kg of unpeeled fresh cassava tubers will be needed. To produce 1 kg of gari at 12 per cent MC (wb), 3.01 kg of unpeeled fresh cassava tubers will be needed, and to produce 1 kg of gari at 7 per cent MC (wb), 3.43 kg of unpeeled fresh cassava tubers will be needed. This shows that as the MC of gari decreases, the quantity of unpeeled fresh cassava tubers needed increases. Per hectare (ha), cassava yield in Nigeria averaged 9.36 tonnes (t) between 2010 and 2017 (Table 1). Fora smallholder gari farmer, roasting cassava grits to 16 per cent MC (wb) would on the average yield 3.40 t of gari per ha, to 12 per cent MC (wb) would amount to 3.12 t/ha, and to 7 per cent MC (wb) would translate to 2.72 t/ha. Therefore, roasting grits to 7 per cent MC (wb) would result to fresh cassava tuber loss amounting to 1.2 and1.9 t/ha when batched same volume as gari produced at 12 and 16 per cent moisture contents, respectively. Discussions with gari processors at the Processing Centre revealed that the on-farm price of fresh cassava tubers varied with season, cheaper during the raining season (because of the ease of harvesting and market glut) than during the dry season. Market sources revealed that one tonne on-farm could cost between 14000 and 21000 Naira (1US$ = 360.412 Nigerian Naira on 1 February 2020 [21]). Using an average of 17500 Naira/t, in monetary terms, the loss would amount to 21000 Naira (or US$58.27) or 33250 Naira (or US$92.26) per ha.

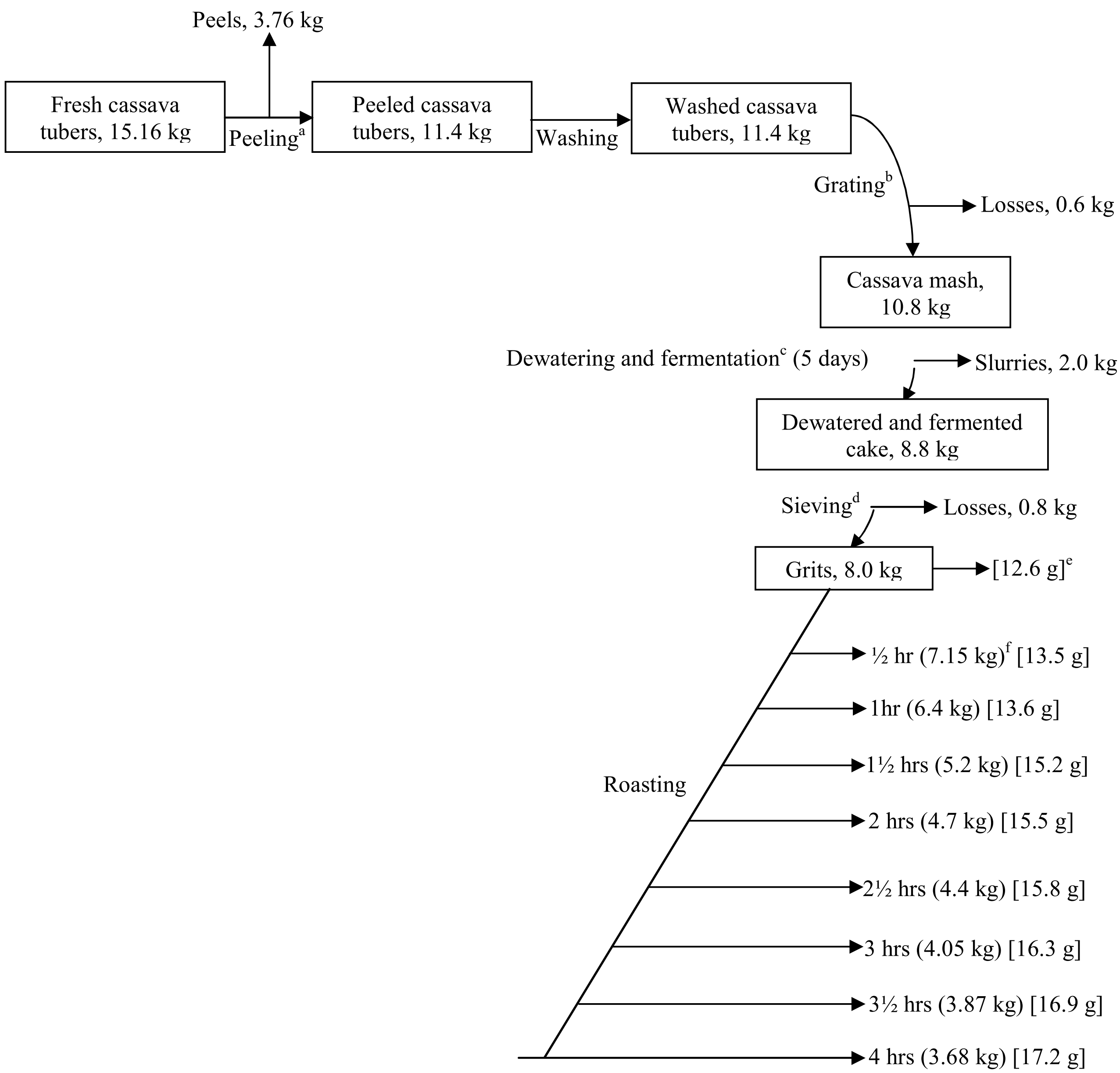

Fig. 2: The result of cassava processing to evaluate the amount of gari from unpeeled fresh cassava tubers at different roasting duration (from cassava tubers harvested on Wednesday, 17 December 2019 and roasted on Monday, 23 December 2019)

[a]Tubers were peeled manually. The MC of the fresh cassava tubers was 63± 5.2per cent (wb)

[b]Peeled tubers were mechanically grated using an electric-powered motor grater. Cassava starch granules are also released during grating

[c]At ambient temperature. Starch and other slurries leached out during the simultaneous processof dewatering and fermentation

[d]By breaking the wet cake into small pieces (grits) using the grater

[e]In square brackets were the batched values. The batched mass values were used to predict the corresponding values of the moisture contents from Figure 1 (experiment 2).

[f]In parentheses (or round brackets) were the values of the resulting mass of roasted grits

For grits and roasted grits samples: mean value, n = 3

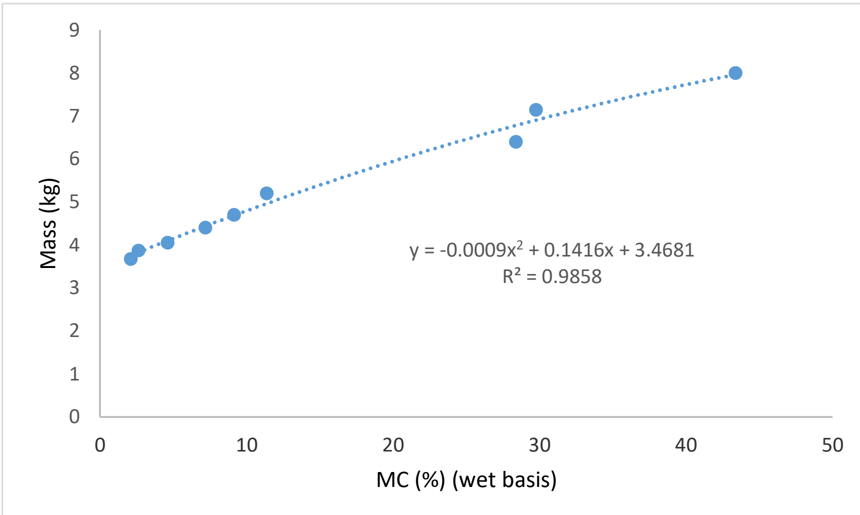

Fig. 3: Graph showing the relationship between MC and mass of the resulting grits (from cassava processed on Monday, 23 December 2019)

Table 1: Cassava yield in Nigeria (2010 – 2017)

Year	2010	2011	2012	2013	2014	2015	2016	2017	Mean ± SD
Yield (t/ha)	12.22	11.21	7.96	7.03	8.72	9.27	9.68	8.76	9.36 ± 1.69

SD indicates standard deviation

(Source: [8])

IV. IMPLICATIONS FOR STANDARDS SETTING

The result of this study has important implications for improving standards relating to gari. In particular NIS 181: 2004 which has stipulated a maximum MC of 7.0 per cent m/m (wb) for gari produced in Nigeria. Although still at the draft level, the African Standard Gari - specification (CD-ARS 854:2014) has equally specified a maximum of 7 per cent MC m/m (wb), while the draft ECOWAS Code of Practice for Processing Cassava Products 2016 was silent on the maximum MC for gari. The result of this study has showed that when it comes to roasting cassava grits to 7 per cent MC in accordance with NIS 181: 2004, the losses to the farmers could be high more so that gari in the Nigerian markets is still being batched by volume. A key area of concern is that the majority of gari farmers in Nigeria and other African countries is still the smallholder farmers and processors, cultivating averagely 2 ha of land. In the case of Nigeria and other West African countries, cassava processors are mostly women [22, 23].

Given the relatively low income levels of these farmers, standards for gari need to strike a balance between quality, farmers' income, and environmental issues. For the developed economies, agricultural products in the retail markets are being batched by weight. Gari batched by weight may have limited financial implications for gari farmers in the producing countries. However, for the domestic economy where gari for sales is still being batched by volume, this has some important environmental and financial implications. For example, most gari processing centres in Nigeria and other parts of Africa still rely on fuelwood. Roasting to 7 per cent MC will entaila relatively longer roasting duration, and consequently, lead to an increase in fuelwood requirement. In most cases, the cost of this fuelwood (being obtained for free in most processing centres) as well as the environmental externalities of gari production (for example, the impact of waste flows from the processing sites on freshwater) and fuelwood use, hardly transferred to gari consumers, will be shouldered by the gari producing country. Although this study has not quantified the amount of fuelwood required to roast cassava grits to 7 per cent MC level (wb), drawing on the experiments carried out this can be substantial when totalled at the national level and will significantly impact the environment. Since MC is key to gari storability, regulators will need to stipulate a moisture level that guarantees reasonable income to farmers without jeopardising the environment and the long-term quality stability of the gari. According to Otutu et al. [1], gari with MC above 13 (wb), but less than 16 per cent (wb), could store for 2 to 7 months. However, Ojo et al. [24] noted that moisture levels above 14 per cent (wb) might promote microbial growth and reduce storage stability, thereby decreasing the storage life. This information offers regulators some important leeway. Considering the discussions made above and the data in Table 2 together, roasting cassava grits to 13 per cent MC (wb) may offer a right balance between quality, farmers' income, and environmental concerns. For cassava grits roasted to 13 per cent MC (wb), the product yield would amount to 34.02per cent, more profitable than gari roasted to 7 or 12 per cent moisture contents (wb).

Table 2: Gari yield from unpeeled fresh cassava tubers at different moisture contents

MC (%) (wb)	7	10	12	13	14	16
Gari yield (t/ha)	2.72	2.96	3.12	3.19	3.26	3.40

V. CONCLUSIONS AND POLICY RECOMMENDATIONS

This paper has investigated the implication of 7 per cent moisture content (NIS 181: 2004) for gari on unpeeled fresh cassava tubers. Using data from Nigeria, the paper has provided evidence in support of the argument that roasting cassava grits to 7 per cent MC (wb) would result into fresh tuber loss amounting to 1.2 and 1.9 t/ha when batched same volume as gari produced at 12 and 16 per cent moisture contents (wb), respectively. This has a direct impact on farmers' income and sustainability of gari business in Nigeria. However, considering the result and arguments presented in this study, and since it may be difficult to recommend batching by weight for gari meant for sales in the retail markets in Nigeria, roasting cassava grits to 13 per cent MC (wb) offers some right balance between quality, farmers' income, and environmental concerns. This is the initial recommendation that can be made from this study to inform policy decisions with respect to standards for gari in Nigeria and elsewhere. Future research areas include understanding the (a) effects of age at harvest, cassava variety, grating efficiency, and duration of dewatering on the implication of 7 per cent moisture content for gari on unpeeled fresh cassava tubers, and (b) implication of complying with NIS 81: 2004on physicochemical and nutritional properties of gari.

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