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Variability in traditional processing of gari: a major food security product from cassava

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Abstract: *Cassava is a major crop for food security in Nigeria and its principal processed form is gari. Gari processing practices were observed in the south-west (Oyo State) and south-east (Benue State) of Nigeria using two complementary approaches: 1) semi-quantitative surveys with processors (n = 123); and 2) actual detailed measurements at processing units (n = 7). Size of processing operations and types of practices differed significantly between the two states. There were also intra-state differences, influenced by ethnicity and customs. Variability of processing practices should be considered while seeking to improve processing productivity and introducing nutritious varieties of cassava to feed the fast-growing Nigerian population.*

Keywords: traditional practices, cassava, gari processing, survey, direct measurement

CASSAVA (*MANIHOT ESCULENTA*), A TROPICAL root crop, rank fourth in world production after rice, maize, and wheat. Its annual production is 277 million metric tonnes and more than 500 million people depend on it as a staple (Adebayo, 2009; FAOStat, 2018). Cassava is mainly grown by poor farmers, particularly in sub-Saharan Africa, and often on marginal land. Hence the crop has great importance for food security and income generation. Processing cassava is important for two reasons: firstly, the crop deteriorates rapidly after harvest and therefore needs to be preserved for future consumption (Westby, 2002); and secondly, cassava may contain cyanogenic compounds, which makes the chronic consumption of inadequately processed cassava products a serious risk to human health (Oluwole, 2008).

Nigeria is the most densely populated country in Africa with an approximate 200 million inhabitants in 2018. By 2050, the population of Nigeria is expected to reach 0.5 billion and exceed that of the USA. Nigeria is also the largest global cassava producer with an annual volume of 57 million tonnes in fresh weight (FAOStat, 2018). Currently gari, a dry granulated product with a slight acidic taste (Westby, 2002; Adeoti et al., 2009), is the predominant form of cassava consumption across the different regions of Nigeria. Gari accounts for 70 per cent of cassava produced

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(Sanni et al., 1999; Phillips et al., 2004; Ohimain et al., 2013). The volume of gari produced to feed the Nigerian population is substantial, nonetheless most of the production relies on traditional know-how (Escobar et al., 2018): processing is conducted at a small scale using semi-mechanized, rudimentary techniques of processing, and in particular little is known about the variability in the process and its impact on finished productivity (e.g. the ratio of Gari to fresh roots). Gari processing involves several operations: peeling, grating, fermenting, pressing, sifting, and roasting of the root. Previous studies have looked at the processing scale of gari (Ekwe et al., 2009; Ohimain et al., 2013; Adekanye et al., 2013; Matanmi et al., 2017) and recording of processing parameters (Nago, 1995; Okorji et al., 2003; Amoah et al., 2010; Ukenye et al., 2013). Fermentation at ambient temperatures is known to vary in terms of duration between different locations (Westby, 2002). Roasting conditions may also be variable because of the different equipment used by different processors (Westby, 2002). Other variations in processing may also exist in different locations, but overall these differences have been poorly documented.

There are efforts through international organizations such as HarvestPlus to promote biofortified varieties of cassava that are rich in provitamin A, an essential micronutrient for health and often deficient in sub-Saharan African diets. A constraint is that, due to their unsaturated chemical structure, provitamin A molecules (carotenoids) can be degraded during processing, when exposed to high temperature and oxygen from the air (Bechoff et al., 2010, 2018). Understanding how people traditionally prepare gari can help determine the critical steps that could affect provitamin A carotenoids and consequently decrease nutritional value.

This can provide an important knowledge baseline to help better target biofortification campaigns and give advice to populations on the best way of processing those more nutritious cassava varieties. In addition, a better understanding of the traditional processing could provide insights for scaling up the production in a way that will not cause harm to current social and cultural practices.

The purpose of our study was to examine the variability that exists in gari processing in two different geographical regions of Nigeria. The fast-growing Nigerian population, with its increasing number of mouths to feed, requires improvement in food systems and food delivery. Detailed information about existing food technologies is useful for possible policy and technological interventions. First, those that seek to mechanize gari equipment and increase efficiency of processing with a view to improving food security (Oparinde et al., 2016), and second, those that promote improved varieties of cassava such as biofortified (high provitamin A) yellow cassava with a focus on provitamin A retention during processing (Oparinde et al., 2017; Bechoff et al., 2015, 2018) for a more nutritious product.

Materials and methods

Study area

The study was conducted in two Nigerian states. Oyo State is located in the southwest of Nigeria and covers an area of approximately 28,454 km^2. Ibadan is its capital and the population is mostly Yoruba-speaking. Benue State is located in the south-east and covers an area of 34,059 km^2 with Makurdi as its capital. It is mainly inhabited by the Tiv, Idoma, and Igede people. The population is believed to have doubled in the last 10 years in those states, and was about 15 million and 8 million inhabitants in Oyo and Benue states, respectively, in 2018. In the south-west, the main staple is cassava, and gari the major form of cassava consumption followed by *lafun* (dried and fermented flour) and *fufu* (fermented and sieved dough), while in the south-east, gari is still the main form of consumption but is closely followed by *fufu* (Phillips et al., 2004).

In order to accurately capture the traditional practices of gari processors in the south-west and south-east of Nigeria, our approach consisted of observation and documentation of the traditional processes of gari production using complementary approaches:

- indirect data collection through a semi-quantitative survey with individual processors (Approach 1);
- direct data collection through detailed recording of gari processing conditions (Approach 2).

Approach 1: field surveys with gari processors

A survey for gari processors was developed in collaboration with the Agricultural Development Programme's (ADP) regional leaders during a planning meeting. The ADP leaders identified the best areas in each state to conduct research work. Selection of locations was based on maximal inter-processor variability (in order to capture various practices) and also willingness of the processors to participate in the study. Local ADP agents were designated to assist with the surveys by the ADP heads and by the Oyo State Agricultural Development Programme (OSADP) zonal manager. A semi-quantitative questionnaire was administered to processors from three different areas in each of the two states (Figure 1). In Oyo State, the areas were: Atiba area in Oyo town (n = 22) (7.8430° N, 3.9368° E); Iseyin town (n = 22) (7.9765° N, 3.5914° E); and Odogbo Army Barracks area in Ibadan town (n = 18) (7.3775° N, 3.9470° E). In Benue State, the areas were Ndere Mbawar Vandeikya area in Ihugh town (n = 20) (7.0157° N, 9.0289° E); Obagangya area in Otukpo town (n = 21) (7.1982° N, 8.1393° E); and Tyo Mu area in Makurdi town (n = 20) (7.7322° N, 8.5391° E). The total number of interviewees was n = 123. The survey included questions on gari processing, but also on marketing and storage to understand the supply chain from processors to consumers. The use of red palm oil was documented. Surveys were carried out orally in the main local languages: Yoruba in Oyo State, and Tiv and Idoma in Benue State, and written answers reported in English.

Approach 2: direct observations of gari processing

Data recording of gari processing. The processing centres for data recording were selected by the ADP leaders on the basis of having distinctive practices that were demonstrative of the variability of processes existing in the state. The processing of gari was observed and documented in processing groups (n = 7) located in the same

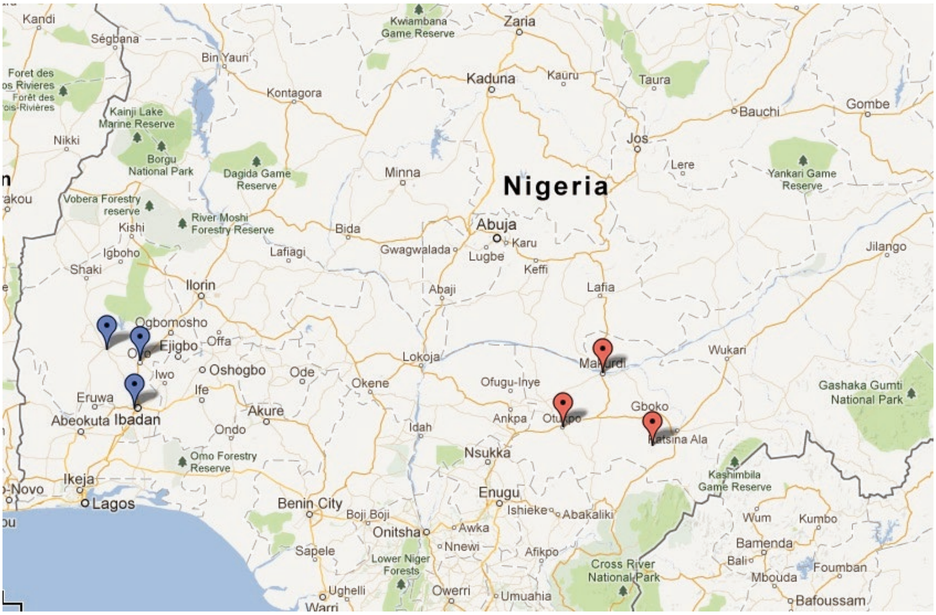

Figure 1 Location of the areas surveyed: South-west Nigeria – Oyo State (left-side): Iseyin, Atiba (Yoruba speakers), and Ibadan (immigrants from south of Nigeria) (mainly Igbo speakers); South-east Nigeria – Benue State (right-side): Makurdi (Tiv speakers), Ihugh (Tiv speakers), and Otukpo (Idoma speakers)

areas as for the survey. In Oyo State, the groups were located in Iseyin town (n = 3), and in the Odogbo Army Barracks area in Ibadan town (n = 1). In Benue State, the areas were Ndere Mbawar Vandeikya area in Ihugh town (n = 1), Obagangya area in Otukpo town (n = 1), and Tyo Mu area in Makurdi town (n = 1).

Processing was followed in real time. The study consisted of a step-by-step observation and recording of the quantities of material (total mass balance, from an initial 50 kg roots), and of ambient temperature/humidity, length of time, pH values and temperature of the mash, and roasting temperature. All this information was combined to understand the characteristics of each step in the traditional process. Samples were weighed during processing using a digital scale (EHF-203 Series Digital Hanging Scales, Scales of the World, Milton Keynes, UK; maximal load: 50 kg). The pH value was measured before and after fermentation using a waterproof pH meter with dual LCD (Hannah Instruments, Leighton Buzzard, UK). For pH, a sample (10 g) was weighed using an electronic balance (CS5000, Ohaus, I Parsippany, NJ, USA; maximal weight 5 kg, precision 2 g) and transferred into a clean and dry container. Then, 20 g of distilled water was added and the sample stirred. The electrode of the pH meter was cleaned before the pH value was recorded. An infrared thermometer (RayTemp® 3, ETI, Worthing, UK) was used to measure product temperature before and after fermentation and during roasting. Ambient temperature and humidity were recorded throughout processing using a Tinytalk Ultra 2 device (RS Components Ltd, Northants, UK).

Collection of samples during field visit and dry matter content. Fresh samples (three roots per processor) and processed samples at each processing step (about 400–500 g per processor) were collected and immediately placed in a cool box packed with frozen gel. Total mass balance was adjusted to take into account the weight of collected samples.

On return to the laboratory each day, samples were analysed for dry matter content. Analysis for dry matter content followed the method developed by the International Institute of Tropical Agriculture (IITA, 1990). In brief, 100 g of sample (chipped root or processed sample) was weighed in a paper bag (in triplicate) (W_0) and dried in an oven at 70°C for 72 hours. Samples were removed from the oven and left to cool down at ambient temperature and weighed (W). Percentage dry matter (DM) was calculated using the following formula: DM (%) = $(W - T)/(W_0 - T)$, where W = final weight (in g); W_0 = initial weight (in g); T = tare (in g).

Ethics

This study was assessed and approved by the University of Greenwich Research Ethics Committee. Participants were informed about the study and it was explained that their participation was entirely voluntary, that they could withdraw at any time, and that the responses would be anonymous.

Statistical analysis

Analysis of variance (ANOVA) (mixed effect model), Chi-squared analysis (non-parametric test for counts), and hierarchical cluster analysis (Ward's method) were carried out using SPSS (V 20.0) or XLSTAT (V 5.2, Addinsoft). Differences between Oyo and Benue states were analysed using either Chi-square (for counts) or ANOVA (for averages) statistical tests at $p < 0.05$.

Results and discussion

General information about processors

Table 1 summarizes the general characteristics of the gari processors interviewed (n = 123). Data showed that there were differences between the processors in the two states. The owners of processing units were significantly older in Oyo than in Benue. The total number of employees was five times higher in Oyo than in Benue ($p < 0.05$), which indicates that the processing of gari was on a larger scale in Oyo compared with Benue. This may be explained by the proximity of Oyo to large urban centres and the capital, while Benue is a much more rural and less densely populated area. Overall, there were more illiterate processors in Oyo and fewer who had reached primary school. Nevertheless, the number of processors who had attended secondary and university education did not significantly differ in the two states (14 and 18 people in Oyo and Benue states, respectively). Therefore, we cannot conclude that there were differences in terms of education level. Gari processing was mostly a woman's activity, with women representing

Table 1 General information about the gari processors (n = 123) interviewed and about practices regarding cassava roots and storage of gari (Approach 1)

			State			*Significant difference*
			Oyo	*Benue*	*Total*	
General information	Processor (owner) (*count*[1])	Total	62	61	123	
		Male	5	10	15	0.128
		Female	57	51	108	
	Status (*count*[1])	Married	62	53	115	0.036 *
	Family (*average*[2])	Number of children	5	5	5	0.502
	Level of education (*count*[1])	Illiterate	28	10	38	<0.001 *
		Primary school	19	32	51	
		Secondary school	12	15	27	
		University	2	3	5	
		Other	1	1	2	
	Employees (*count*[1])	Total per processor	30	6		<0.001 *
		Males per processor	4	3		
		Females per processor	26	3		
	Age of owner (years) (*average*[2] *min. – max.*)		47 (25–69)	37 (20–55)	42 (23–62)	<0.001*
Cassava roots	Variety (*count*[1])	Odongbo	21	0	21	<0.001*
		Oko-Iyawo (IITA 3303)	41	0	41	
		Ege Dudu (IITA 3055)	42	0	42	
		Local variety Uwono	0	34	34	
		Banarda (TMS 30572)	0	39	39	
	Age of cassava roots at harvest (*average*) (years)		1.5	1.2	1.3	0.001*
Gari storage	Who would you sell to? (*count*[1])	Broker	45	25	70	<0.001*
		Directly on the market	11	25	36	
		Wholesaler	6	0	6	
		Broker and directly on the market	0	10	10	

(Continued)

Table 1 (Continued)

		State			Significant difference
		Oyo	Benue	Total	
Storage place (*count*[1])	Home	0	22	22	<0.001*
	Factory place/store	44	37	81	
	Front of the shop	7	0	7	
	No storage, straight to market	1	0	1	
	Open place	10	0	10	
Shelf life of gari (*average*[2]) (months)		6	5	5	0.155

Notes: [1] Counts were analysed using a Chi-square test; and [2] averages were analysed using an ANOVA test. Significant differences at $p < 0.05$ (Tukey test) are indicated with *.

88 per cent (108 of 123) of the owners on average, and this finding is similar to other published work (Okorji et al., 2003). It was observed that the proportion of women processor owners and their number of children did not differ between the two states. However, there was a higher proportion of male employees in the Benue State sample compared with the Oyo State sample (up to 50 per cent). The greater involvement of men in gari processing in Benue may be due to the fact that gari units were mostly household-level family businesses and this means that male and female relatives were involved.

Cassava varieties and gari storage

In addition to differences between processors, there were also differences in the varieties of cassava and the practices of product storage (Table 1). The varieties of cassava differed across the two states. There were three important varieties for the processors in Oyo State: Odongbo, Oko-Iyawo (IITA 3303), and Ege Dudu (IITA 3055). In Benue State, the two most common varieties were Uwono (a local variety) and Banarda (an improved variety developed by International Institute of Tropical Agriculture (IITA) and also called TMS 30572). There was also a difference in the root age at harvest. Roots were significantly older in Oyo than in Benue (1.5 and 1.2 years, respectively). The root age might vary between varieties but may also be a result of the different agronomic practices in the two states. In Oyo State, processors more commonly sold the roots to cassava traders or brokers, while in Benue roots were sold equally to traders and 'directly on the market'. Gari was mostly stored at the shop in Oyo, while in Benue it was also stored at home, and this further indicated that gari processing was more of a household activity in Benue. However, the reported shelf life for gari (i.e. white gari (non-fortified with red palm oil)) was not significantly different in the two states, which may be because the gari product had equivalent storage conditions and similar quality even though it had been made from different varieties of cassava.

Differences in gari processing practices

The differences in processing practices were explored using hierarchical cluster analysis (Ward's method) and the processors (n = 123) were segmented into three different clusters according to their processing methods (Table 2). Segmentation is a useful method to understand differences between entities that have various practices or diverse characteristics. Clusters significantly differ between them in all the processing characteristics (ANOVA or Chi-square analysis at $p < 0.05$). Processors in Cluster 2 (C2) were larger enterprises, employing the most people; they processed the largest quantity of roots, the roots were transported for longer distances between the field and processing place, they used more mechanized equipment, processed 'white gari', and had a longer fermentation period (~ 4 days). These were the most business-oriented gari enterprises compared with the two other clusters. We called C2 processors the 'large-scale mechanized processors'. Processors in Cluster 3 (C3) were the smallest enterprises; they employed the smallest number of people, processed the smallest quantity of roots, and were more likely to own a farm and be situated in rural locations. Hence, C3 processors conducted processing without delay (on the day of harvest) and the roots only travelled short distances from the field. Peeling and roasting, however, were less time-efficient (the operations took longer), and sifting was mostly carried out by hand. In addition, C3 processors processed 'yellow gari' (with red palm oil – added to the mash mostly before fermentation). We called C3 processors (n = 70) 'household/small-scale rural processors'. Processors in Cluster 1 had intermediate practices to those of Clusters 2 and 3. These enterprises were intermediate in size and number of people employed, and quantities of cassava processed were higher than in C3 but lower than in C2. The distance between the field and processing place was also intermediate between that of the other clusters. The productivity (quantity of roots processed per hour) and processing duration (i.e. peeling and roasting) were not as high as for C2 processors but were higher than for C3 processors. At some C1 processors, sifting was mechanized and a few of them processed red palm oil gari. We named C1 processors 'intermediate-scale processors'.

'Intermediate-scale' and 'large-scale mechanized' processors (C1 and C2) comprised exclusively processors interviewed in Oyo State: C1 included most of the processors from the three locations in Oyo State (n = 40) and C2 included processors from Atiba and Iseyin (n = 13). 'Household rural processors' (C3), which includes the small-scale processors, was the largest cluster with n = 70 processors. It encompassed all the Benue gari processors interviewed (n = 61) and a few from Oyo State (n = 9). Cluster analysis showed that there were inter-state variations (between Oyo and Benue states) as well as intra-state variations: that is, processors from Oyo State were split between C1, C2, and C3. Ekwe et al. (2009) specifically analysed how socio-economic factors are linked to the fermentation time with gari processors from the south-east. Adebayo (2009) indicated that practices between cassava processors in the south-west region (Oyo, Ogun, Lagos, and Ondo) greatly differed according to the type of agrological zone. Our study across western and eastern parts of southern Nigeria agrees with those studies. While those previous studies tended to be localized in one region of Nigeria, in addition we draw observations on variation between gari practices across regions in Nigeria.

Table 2 Average characteristics of the three different sizes of processors (cluster analysis) (Approach 1)

	Cluster	*C1 (Intermediate-scale processors) (n = 40)*	*C2 (Large-scale mechanized processors) (n = 13)*	*C3 (Household/ small-scale rural processors) (n = 70)*	*Significant difference**
Number of employees (*average*[2])		29	39	8	<0.001*
Where do processors buy the roots? (*count*[1])	Farmers	33	9	22	<0.001*
	Brokers	2	1	2	
	Own farm & farmers	5	3	17	
	Own farm only	0	0	29	
Distance to the field (km) (*average*[2])		27.6	64.8	5.4	<0.001*
Date of harvest (*count*[1])	Day	6	1	52	<0.001*
	Day +1	15	5	13	
	Day +2	5	0	2	
	Day +3	1	5	0	
	≥ Day +4	10	2	3	
Estimated quantity of cassava roots processed per week (kg) (*average*[2])		11,750.0	26,153.8	1,372.6	<0.001*
Peeling duration (h) (*average*[2])		5.0	8.7	5.9	0.017*
Mechanical sifting using the grater? (*count*[1])	Yes	26	13	9	<0.001*
	No (hand sieving)	13	0	60	
Number of people to peel (*average*[2])		22.2	35.2	7.4	<0.001*
Fermentation duration (days[3]) (*average*[2])		2.9	4.2	2.6	<0.001*
Roasting duration (minutes) (*average*[2])		11.8	13.2	27.2	<0.001*
Sieving the gari after roasting? (*count*[1])	Yes	39	13	53	0.001*
	No	0	0	17	
Type of gari mostly processed? (*count*[1])	White	28	13	12	<0.001*
	With palm oil	1	0	31	
	Both	10	0	27	
Stage where oil is added to the product? (*count*[1])	Mash before fermentation	19	4	56	<0.001*
	Mash after fermentation	0	0	4	
Location of the processors (state, town, language) (*count*[1]) — Benue State	Ihugh (Tiv speakers)	0	0	20	<0.001*
Benue State	Otukpo (Idoma speakers)	0	0	21	
Benue State	Makurdi (Tiv speakers)	0	0	20	
Oyo State	Atiba, Oyo (Yoruba speakers)	15	7	0	

(Continued)

Table 2 (Continued)

	Cluster	C1 (Intermediate-scale processors) (n = 40)	C2 (Large-scale mechanized processors) (n = 13)	C3 (Household/ small-scale rural processors) (n = 70)	Significant difference*
	Iseyin (Yoruba speakers)	12	6	4	
	Ibadan (mainly Igbo speakers)	13	0	5	

Notes: [1] Counts were analysed using a Chi-square test; and [2] averages were analysed using an ANOVA test. Significant differences at p < 0.05 (Tukey test) are indicated with *.
[3] Processors interviewed actually count 2 days for a 24 hour-long fermentation and 3 days for a 48 hour-long fermentation since it is perceived as being carried, respectively, over 2 or 3 days. Similar observations were made for 4, 5, or more days.

Processing yield of gari

From 50 kg of unpeeled roots, the quantity of gari obtained was 12.5 kg on average (min. 10.5 kg, max. 16.1 kg) (Table 3). Variations in conversion yield from unpeeled roots to gari in the quantities recorded hence were minimal (< 14 per cent) between the seven processors. It may be explained by a high root dry matter for all processors interviewed. The main varieties of cassava in Oyo and Benue states in the survey (Approach 1) were the same as those found in the field (Approach 2). On average, peeled roots, grated mash, fermented mash, pressed mash, gari, and sieved gari weighed 37, 34, 30, 24, 14, and 12 kg (73, 69, 60, 48, 28, and 25 per cent of initial weight), respectively. These processing yields are in accordance with previous studies on gari in Benin (Nago, 1995) and Nigeria that reported final gari/roots yields of 22 per cent (Nago, 1995), up to 26 per cent (Adeoti et al., 2009) and 23 per cent (Amoah et al., 2010) respectively.

Root dry matter and dry matter during processing

The initial root dry matter content was high, ranging between 38 and 48 per cent (Table 3). Studies with variety TMS 30572 have reported dry matter contents of 39.5 per cent (Hongbété et al., 2011) and 42 per cent (Ukenye et al., 2013). The high value of 48 per cent for TMS 30572 therefore seemed out of range; however, Kawuki et al. (2011) screened varieties of cassava in Africa and described a large variation in dry matter contents that ranged from 16 per cent to 49 per cent. Equally, Da et al. (2010), working with varieties in Vietnam, reported dry matter contents of up to 53 per cent. In addition, TMS 30572 also had the highest conversion yield from unpeeled roots to gari (16.1 kg) and this is in accordance with the variety's high dry matter (Table 3).

Moisture steadily decreased during the processing into gari. From an initial average dry matter content of 44 per cent in the roots, the dry matter increased in the pressed mash (57 per cent) to reach 90 per cent on average in the finished

Table 3 Direct recordings and measurements in the field for processors in Oyo State (n = 4) and in Benue State (n = 3) (Approach 2)

State		*Oyo*					*Benue*		
Town		*Iseyin*			*Ibadan*		*Makurdi*	*Otukpo*	*Ihugh*
Processing centre		*Crown Centre*	*Rose Centre*	*Ibukun Oluwa Centre*	*Odogbo Barracks*		*Tyo Mu Centre*	*Ada Elakpa Centre*	*Koko Youth Centre*
Variety		*Ege Dudu (IITA 3055)*	*Oko-Iyawo (IITA 3303)*	*Oko-Iyawo (IITA 3303)*	*Oko-Iyawo (IITA 3303)*		*Banarda (TMS 30572)*	*Local variety Uwono*	*Banarda (TMS 30572)*
Quantities (kg)[2]	Unpeeled (fresh) roots	50.0	50.0	50.0	50.0	50.0	50.5	50.1	49.8
	Peeled roots	38.0	33.6	36.8	35.12	33.9	39.9	36.6	38.3
	Grated mash			33.0	34.26	**32.6**[1]	37.1	32.5	37.3
	Fermented mash	30.1	29.3	28.7			34.9	26.0	
	Fermented mash with oil						**35.0**[1]		
	Pressed mash	23.7	23.8	22.1	21.7	23.0	29.8	21.8	24.7
	Sifted or sieved mash	22.9	22.8	21.1	21.0	21.8	26.2	19.2	23.0
	Roasted granule (gari)	12.9	12.3	12.2	13.6	14.7	17.7	11.9	**14.5**[1]
	Sun-dried & roasted granule						16.1		
	Sieved & roasted granule	11.7	10.5	11.1	12.7	14.0			14.2
	Palm oil	No	No	No		0.328	0.261		0.342
Dry matter content (%)	Roots	38.0	44.3	44.3	44.2	44.2	48.0	42.0	45.3
	Grated mash	40.0	43.2	40.7	38.9	41.5	47.5	42.1	40.6
	Fermented mash	47.3	45.7	45.4			50.0	48.4	
	Pressed mash	58.2	53.1	55.6	60.2	61.9	56.7	57.5	55.3
	Gari	94.5*	95.2	93.9*	86.7	86.4	91.5	88.7	86.2
pH value	Grated mash	6.3	6.4	6.8	6.6	6.7	6.4	6.5	6.6
	Fermented mash	3.9	4.2	4.2	4.9	4.9	4.7	4.1	4.2

(Continued)

Table 3 (Continued)

State		*Oyo*					*Benue*		
Town		*Iseyin*			*Ibadan*		*Makurdi*	*Otukpo*	*Ihugh*
Processing centre		*Crown Centre*	*Rose Centre*	*Ibukun Oluwa Centre*	*Odogbo Barracks*		*Tyo Mu Centre*	*Ada Elakpa Centre*	*Koko Youth Centre*
Variety		*Ege Dudu (IITA 3055)*	*Oko-Iyawo (IITA 3303)*	*Oko-Iyawo (IITA 3303)*	*Oko-Iyawo (IITA 3303)*		*Banarda (TMS 30572)*	*Local variety Uwono*	*Banarda (TMS 30572)*
Temperature (T)	Ambient T (°C) (av. ± st dev)	24.9 ± 1.4	24.5 ± 1.5	24.7 ± 0.7	26.0 ± 1.7	26.0 ± 1.7	30.8 ± 1.5	30.9 ± 2.8	31.0 ± 1.4
	Humidity (%) (av. ± st dev)	83.5 ± 5.7	87.3 ± 7.4	85.4 ± 3.0	81.5 ± 8.2	81.5 ± 8.2	67.7 ± 5.1	69.2 ± 9.0	69.5 ± 4.4
	Grated mash T (°C)	25	23	25	25	25	28	27	26
	Fermented mash T (°C)	25	23	24	24	36	27	25	28
	Max. T of the roaster (°C)	197	208	162	133	135		117	126
	Max. product T in roasting (°C)	105	115	110	85	87	97	91	89
	Product T end of roasting (°C)	95	105	95	75	77	97	91	85
Duration of processing steps (h)	Peeling (1–5 persons)	0.52	0.48	0.32	0.73	0.58	0.35	0.52	0.23
	Washing (1–3 persons)	0.17	0.05	0.15	0.03	0.13	0.08	0.23	0.05
	Grating	0.03	0.02	0.03	0.03	0.05	0.07	0.05	0.05
	Mixing oil					0.18	0.28		
	Fermenting	93.43	91.88	45.98	5.28	5.28	15.30	47.38	47.63
	Pressing	1.62	0.88	0.87	1.25	1.25	6.72	0.65	6.00
	Sifting or sieving	0.03[a]	0.02[a]	0.02[a]	0.28[b]	0.20[b]	0.32[b]	0.12[b]	0.23[b]
	Roasting (after sieving/ sifting)	0.65	0.82	1.20	1.20	1.22	1.20	1.28	2.00
	Sieving (after roasting)			0.01	0.02	0.03			0.08
	Sun-drying						1.82		

(Continued)

Table 3 (Continued)

State		*Oyo*					*Benue*		
Town		*Iseyin*			*Ibadan*		*Makurdi*	*Otukpo*	*Ihugh*
Processing centre		*Crown Centre*	*Rose Centre*	*Ibukun Oluwa Centre*	*Odogbo Barracks*		*Tyo Mu Centre*	*Ada Elakpa Centre*	*Koko Youth Centre*
Variety		*Ege Dudu (IITA 3055)*	*Oko-Iyawo (IITA 3303)*	*Oko-Iyawo (IITA 3303)*	*Oko-Iyawo (IITA 3303)*		*Banarda (TMS 30572)*	*Local variety Uwono*	*Banarda (TMS 30572)*
Equipment	Grater	Diesel-powered rotating grating machine – locally fabricated	Diesel-powered rotating grating machine – locally fabricated	Diesel-powered rotating grating machine – locally fabricated	Electricity- or diesel-powered rotating grating machine	Portable diesel-powered grater	Lister type engine	Portable diesel-powered grater	
	Press	Manual press locally made screw jack type	Manual press locally made screw jack type	Manual press locally made screw jack type	Hydraulic jack press	Traditional press (sticks and ropes)	Manual press locally made screw jack type	Traditional press (sticks and ropes)	
	Roaster	Rectangular pan made from iron – fuel wood	Rectangular pan made from iron – fuel wood	Rectangular pan made from iron – fuel wood – stainless steel fryer and roaster with chimney	Two round pans made from iron	Round pan made from iron	Round pan made from iron	Round pan made from iron	
Roaster dimensions	(cm) Length × width × height	127 × 96 × 11	146 × 91 × 12	105 × 105 × 10	54 × 50 × 15	55 × 55 × 15	55 × 55 × 15	55 × 55 × 15	
Sieve particle size	(mm)	5	4	4	5	5	4	5	

Notes: [1] Addition of palm oil.
[2] The mass balance was adjusted to account for the quantities of sample collected at each step.

gari product. Hence, gari processing is essentially a process of moisture removal from the cassava roots by means of several processing methods: grating; fermenting; pressing; and roasting. The final dry matter content in gari varied between 86.4 per cent and 93.9 per cent and was in accordance with previous work (Nago, 1995; Adeoti et al., 2009).

Duration of fermentation and pH values

Recordings (Approach 2) showed that the fermentation duration differed between the locations and between the ethnic groups, and this was in accordance with the surveys (Approach 1). The survey reported that the fermentation duration was 4 days in Atiba and Iseyin (n = 44) and 1 day in Ibadan (n = 18) (Table 2). Recordings equally showed that in Ibadan the product was left only for 5 hours (counted as 1 day) to ferment before being pressed and roasted, while in Iseyin the fermentation was around 90 hours (4–5 days) (Table 3). The difference in fermentation time between the locations might be explained by the ethnic origin of the processors linked to different culinary preferences: processors based at the Army Barracks, Ibadan were immigrants from the southern part of Nigeria (i.e. Igbo speakers from Delta State) and had different gari processing practices from those of the Yoruba-speaking groups in Oyo State (Atiba and Iseyin). In Benue State, the fermentation time was variable among different ethnic groups and within the same ethnic population located in a different place: on average, Tiv speakers in Makurdi fermented the mash for 2 days (n = 20) while those in Ihugh fermented it for almost 3 days (n = 20). Idoma speakers fermented cassava mash for 3 days (n = 20). Recorded measurements confirmed a similar pattern: Tiv-speaking people in Makurdi (Benue State) fermented cassava for 1 day (15 hours) (counted as 2 days), while those in Ihugh fermented it for 47 hours (3 days). Idoma speakers in Otukpo (Benue State) also fermented the mash for about 47 hours (3 days). It was unclear why the fermentation time varied between the Tiv processors: according to the Tiv processors we interviewed, gari buyers have various taste preferences that require variable fermentation time; some like unfermented gari while others prefer fermented gari.

The pH value of the mash decreased from an initial value of around 6.5 to 4.4 after fermentation (Table 3). Those values are in accordance with the recently published work that explored the physico-chemical properties of gari (Escobar et al., 2018). The decrease was related to the length of fermentation: for example, pH value was 4.9 in the Army Barracks after a short fermentation, and 3.9 in Crown Centre, Iseyin after 93 hours of fermentation. However, the decrease was not always directly proportional to the fermentation time. After 47 hours of fermentation in Otukpo and Ihugh, Benue State, and 92 hours of fermentation in Iseyin (Crown and Rose Centres), Oyo State, pH values were not different (4.1 on average). There may have been an influence of the ambient temperature: higher ambient temperatures in Benue State (30°C/69 per cent) than in Oyo State (25°C/84 per cent) would have accelerated the fermentation process. In addition, there was a stabilization of the pH value with time: a pH value of 4.2 was obtained after 45 hours and 90 hours of fermentation in the Ibukun Oluwa and Rose centres, respectively, in Iseyin.

Previous studies (Oyewole and Odunfa, 1991; Oguntoyinbo, 2008) have also shown that pH during gari fermentation stabilized with time. Although it is generally accepted that fermentation of cassava is exothermic (first stated by Akinrele, 1964), globally, temperature of the fermented mash did not increase compared with that of grated mash (25°C on average before and after fermentation).

Use of red palm oil

Crude palm oil is rich in provitamin A carotenoids and the practice of adding red palm oil is a way of improving the nutritional value and organoleptic characteristics of gari. Red palm oil gari is most common in southern and south-eastern parts of Nigeria. In our study, three out of seven processors used palm oil. The process step in which palm oil was added, however, varied: palm oil was added before fermentation by gari processors at the Army Barracks, Ibadan, Oyo State (immigrants from the southern parts of Nigeria), after fermentation by the Tyo Mu group, Makurdi processors, and during frying by the Koko Youth Centre processors, Benue State. According to our observations there was not a large variation in the quantity of red palm oil used by the three processors: a variation of 14 per cent for an average amount of red palm oil added 310 g per 50 kg of unpeeled cassava (Table 3). However, more recordings would have been required to confirm that the amount of red palm oil added was similar among processing groups.

Practice of sun-drying

Sun-drying following roasting was commonly observed in Benue State. In Makurdi, gari was left for 2 hours under the sun to remove moisture from the product (Table 3). This practice might be linked to the warmer and drier climate and reduces the fuel energy cost for roasting. According to some processors (data not shown), the practice of sun-drying also exists in Oyo State during the dry/hot season.

Type of processing equipment

The equipment used by the processors varied (Table 3). The interviewed processors in Oyo tended to use more advanced equipment (e.g. hydraulic (one out of four) or manual press (three out of four); sifting using the grater (three out of four)) than the processors in Benue (e.g. manual press (one out of three) or traditional press (two out of three) with sticks and ropes; manual sieving (three out of three)). Pressing with a traditional stick press could take up to 7 hours compared with 1 hour using a mechanical press. Benue processors and Ibadan immigrants from the south in the Army Barracks (mostly Igbo speakers) used round stainless steel pans for roasting. This type of pan generates lower temperatures than rectangular iron pans used by the Iseyin processors in Oyo State. Average product temperature on the rectangular iron pans and the round stainless steel pan were 113ºC and 90ºC, respectively. Maximal pan temperatures on the rectangular iron pans and the round stainless steel pans were 189°C and 128°C, respectively. Maximal pan temperatures of improved roasters used by research institutes in the literature were reported to be around 120°C and 140°C (Onadipe, 2011), and these temperature ranges were closer to that of the round pans rather than the iron pans. The Army Barracks immigrants also practised hand sieving after grating, similarly to the Benue processors. All processors used similar particle size sieves (4–5 mm) either metallic or mosquito net types. Although the main processing steps were similar in the different ethnic groups (Yoruba; Igbo; Tiv; Idoma), there was variability in equipment used (e.g. round or rectangular pan) and level of mechanization (i.e. press; sieving).

Conclusions

The individual semi-quantitative survey of processors (n = 123) and direct detailed observations of gari processing groups (n = 7) helped us to understand and document the traditional methods of gari processing. Both approaches – surveys and direct recordings – led to converging results. Practices differed between Oyo and Benue states: the processors interviewed in Oyo overall worked at a larger scale with more sophisticated equipment, while those interviewed in Benue tended to work with more rudimentary equipment at a smaller rural scale.

The processors in Oyo State tended to be more business-oriented and processed larger quantities of cassava, used more mechanized equipment, and employed more labour. The processors in Benue State tended to have smaller scale/household processing operations, harvest smaller quantities of roots from their own fields, used more rudimentary equipment, and added red palm oil. There were no differences between the reported storage duration of gari (five months on average) between the two states. Final gari to fresh root conversion yield was approximately 25 per cent (the quantity of gari obtained from 50 kg of fresh cassava roots was typically 12 kg). The fermentation times (from 5 hours to 93 hours) and equipment differed between the different ethnic groups within the states. Three out of seven processors added red palm oil to the gari product – either before or after fermentation, or during roasting. Different ethnic groups within the same state had variable fermentation time because some groups said they liked sour gari (lengthy fermentation) while other groups liked it sweet (short fermentation), and there were also differences in equipment used (rectangular or round shape of the roasting pan and other types of equipment such as the press).

From the results obtained, different approaches to a biofortification intervention deserve consideration because of the inter-state and intra-state diversity. In Oyo State, an approach that promotes the commercial benefits of biofortification to large-scale and commercially orientated farmers and gari processors would be more appropriate. In Benue State, in contrast, an intervention that focuses on the nutritional benefits at the household level, as well as reducing costs by avoiding using red palm oil, may have more impact. In terms of the further commercialization of gari processing in Nigeria, important factors are productivity and quality. In order to increase gari productivity, less mechanized operations in Benue State would benefit from more advanced equipment available in Oyo State. In both states, there is a need to improve the safety of gari operations for operators (i.e. exposure to potentially toxic fumes and smoke during roasting operations). In addition, improving the flow of operations in factories – to limit losses and reduce contamination at the different steps of processing – would be beneficial. One example of this is to optimize the systems for transferring grated cassava into bags for fermentation.

In conclusion, our study shows that the diverse processing practices within states and in-between states should be considered when seeking to improve productivity and gari production for food security, as well as introducing more nutritious new varieties such as biofortified cassava varieties.

Supplementary material

Photos and videos of cassava operations are available at https://www.developmentbookshelf.com/loi/fc.

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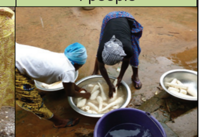
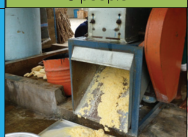
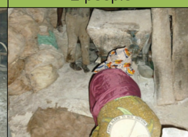
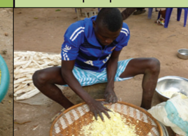
Date	25-26 Jul	27-31 Jul	27-31 Jul	1-3 Aug	7-8 Aug	7-8 Aug	23-24 Aug	23-25 Aug	24-27 Aug
State				Oyo				Benue	
City	Ibadan		Iseyin		Ibadan		Makurdi	Otukpo	Ihugh
Processor	IITA Plant (pre-trial)	Crown Centre	Rose Centre	Ibukun Oluwa Centre	Army Barracks		Tyo-Mu Centre	Ada Elakpa Centre	Koko Yuoth Centre
Variety									
	Mixed yellow	IITA 3055	IITA 3303				IITA TMS 3572	Local variety Uwono	IITA TMS 3572
Addition of Palm oil	no	no	no	no	no	yes	yes	no	yes
Peeling									
	2 people	2 people	4 people	3 people	1 person		5 people	3 people	4 people
Washing									
	3 people	1 person	2 people	3 people	1 person		1 person	1 person	2 people
Grating									
	2 people	2 people	2 people	2 people	2 people		3 people	2 people	3 people
Mixing oil									
					Addition of oil after grating		Addition of oil during frying		Addition of oil during frying
					1 person		2 people		2 people

Fermenting							No picture		No picture
Pressing									No picture
	1 person	1 person	1 person	1 person	1 person		4 people	1 person	
Sifting or hand sieving									
	Sifting using the grater	Sifting using the same grater as above	Sifting using the same grater as above	Sifting using the same grater as above	Hand sieving		Hand sieving	Hand sieving	Hand sieving
	2 people	2 people	2 people	2 people	1 person		2 people	1 person	3 people
Roasting									
	2 people	1 person	1 person	1 person	1 person	1 person	2 people	1 person	2 people (one outside – one inside)
Sieving (after roasting)								No picture (same as after pressing)	No picture (same as after pressing)
	1 person	1 person	1 person	1 person	White gari 2 people	Red gari 2 people	1 person		
Sun-drying