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

Running title: Variability in gari processing practices

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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 southwest (Oyo State) and southeast (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 type 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 whilst seeking to improve processing productivity and introducing nutritious varieties of cassava to feed fast-growing Nigerian population.

Key-words: traditional practices; cassava; gari processing; survey; direct measurement

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INTRODUCTION

Cassava (Manihot esculenta) - a tropical root crop - ranks fourth in the world production after rice, maize, and wheat. Its annual production is 277 million metric tonnes and more that 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 non-adequately 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% of cassava produced (Sanni et al., 1998, Phillips et al., 2004, Ohimain et al., 2013). The volume of gari produced to feed the Nigerian population is very substantial, nonetheless most of the production relies on traditional know-how (Escobar et al., 2018): processing is conducted at a small scale using semi-mechanised 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 (Ohimain et al., 2013, Adekanye et al., 2013, Ekwe et al., 2009, Matanmi et al., 2017) and recording of processing parameters (Amoah et al., 2010, Nago, 1995, Okorji et al., 2003, 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 organisations 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 temperature, and oxygen from the air (Bechoff et al., 2010, Bechoff et al., 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 on 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 i.e. those that seek to mechanise gari equipment and increase efficiency of processing with a view of improving food security (Oparinde et al., 2016); 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 approximately an area of 28,454 km2. Ibadan is its capital and the population is mostly Yoruba speaking. Benue State is located in the southeast and covers an area of 34,059 km2 and has 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 would be around 15 million and 8 million inhabitants in Oyo and Benue States, respectively, in 2018. In the southwest, 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) whilst in the southeast, gari is still the main form of consumption but closely followed by 'fufu' (Phillips et al., 2004).

In order to accurately capture the traditional practices of gari processors in South West and East of Nigeria, our approach consisted of an 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 Programmes (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 3 different areas in each of the 2 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); 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 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 50kg 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: 50.0 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 (10.0g) was weighed using an electronic balance (CS5000, Ohaus, I Parsippany, NJ, USA – maximal weight 5kg. precision 2g) and transferred into a clean and dry container. Twenty (20.0) grams of distilled water was added and the sample stirred. The electrode of the pH meter was cleaned before the pH value was recorded. An infra-red 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 (3 roots per processor) and processed samples at each processing step (about 400-500g 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 (International Institute for Tropical Agriculture (IITA), 1990) . In brief, a 100g 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 72h. 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 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 (Wards 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 a Chi-square (for counts) or an ANOVA (for averages) statistical tests at $p<0.05$.

RESULTS AND DISCUSSION

General information about processors

Table 1 summarises 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 compared to Benue ($p<0.05$), which indicates that the processing of gari was on a larger scale in Oyo compared to Benue. This may be explained by the proximity of Oyo to large urban centres and the capital whilst Benue is a much rural and less densely populated area. Overall, there were more illiterate processors in Oyo and less 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 State 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 88% (=108/123) 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 were a higher proportion of male employees in the Benue State sample compared to Oyo State sample (up to 50%). 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 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 middlemen whilst in Benue roots were sold equally to traders and 'directly on the market'. Gari was mostly stored at the shop in Oyo whilst 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 gari product had equivalent storage conditions and similar quality although 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 (Wards 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, processed the largest quantity of roots, the roots were transported for longer distances between the field and processing place, used more mechanised equipment, processed ‘white gari’ and had a longer fermentation period (~4 days). These were the most business-oriented gari enterprises compared to the two other clusters. We called C2 processors the ‘large scale mechanised processors’. Processors in Cluster 3 (C3) were the smallest enterprises, employed the least number of employees, 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 Cluster 2 and 3. These enterprises were intermediate in size and number of people employed, and quantities of cassava processed were more than in C3 but less 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), processing duration (i.e. peeling and roasting) were not as high as for C2 processors but were more than for C3 processors. At some of C1 processors’, sifting was mechanised and a few of them processed red palm oil-gari. We named C1 processors ‘intermediate-scale processors’.

‘Intermediate-scale’ and ‘large-scale mechanised’ processors (C1 and C2) comprised exclusively of 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 State) as well as intra-State variations: i.e. 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 West and East parts of Southern Nigeria agrees with those studies. Whilst those previous studies tended to be localised in one region of Nigeria, in addition we draw observations on variation between gari practices across regions in Nigeria.

Processing yield of gari

From 50kg of unpeeled roots, the quantity of gari obtained was 12.5kg on average (min.10.5kg- max.16.1kg) (Table 3). Variations in conversion yield from unpeeled roots to gari in the quantities recorded hence were minimal (< 14%) between the 7 processors. It may be explained by a high root dry matter for all processors interviewed. The main varieties of cassava in Oyo and Benue State in the survey (Approach 1) were the same as those found in the field (Approach 2). On average, peeled roots, grated mash, pressed mash, gari and sieved gari weighed 37, 34, 30, 24, 14 and 12kg (73%, 69%, 60%, 48%, 28% and 25% 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%(Nago, 1995), up to 26% (Adeoti et al., 2009) and 23% (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% (Table 3). Studies with variety TMS 30572 have reported dry matter contents of 39.5% (Hongbété et al. 2011) and 42% (Ukenye et al., 2013). The high value of 48% 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% to 49%. Equally, (Da et al., 2010) working with varieties in Vietnam reported dry matter contents of up to 53%. In addition TMS 30572 also had the highest conversion yield from unpeeled roots to gari (16.1kg) 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% in the roots, the dry matter increased in the pressed mash (57%) to reach 90% on average in the finished 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% and 93.9% and was in accordance with previous work (Adeoti et al., 2009, Nago, 1995).

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 of 1 day in Ibadan (n=18) (Table 2). Recordings equally showed that in Ibadan the product was left only for 5h (counted as 1 day) to ferment before being pressed and roasted whilst in Iseyin, the fermentation was around 90h (4-5 days) (Table 3). The difference in fermentation time between the locations might be explained by the ethnical 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 to the Yoruba-speaking groups in Oyo State (Atiba and Iseyin). In Benue State, the fermentation time was variable with 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) whilst 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 one day (15h) (counted as 2 days) whilst those in Ihugh fermented it for 47h (3 days). Idoma-speakers in Otukpo (Benue State) also fermented the mash for about 47h (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 whilst 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 physicochemical properties of gari (Escobar et al., 2018). The decrease was related to the length of fermentation, for e.g. pH value was 4.9 in the Army Barracks after a short fermentation and, was 3.9 in Crown Centre, Iseyin after 93h of fermentation. However the decrease was not always directly proportional to the fermentation time. After 47h of fermentation in Otukpo and Ihugh, Benue State and 92h 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%) compared to Oyo State (25°C/84%) would have accelerated the fermentation process. In addition, there was a stabilisation of the pH value with time: a pH value of 4.2 was obtained after 45h and 90h of fermentation in the Ibukun Oluwa and Rose Centres respectively in Iseyin. Previous studies (Oguntoyinbo, 2008, Oyewole and Odunfa, 1991) have equally shown that pH during gari fermentation stabilised with time. Although it is generally accepted that fermentation of cassava is exothermic [It was first stated by (Akinrele, 1964)], globally temperature of the fermented mash did not increase compared to 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 South-South and South-East 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 in by gari processors at the Army Barracks, Ibadan, Oyo State (immigrants from the South-South parts of Nigeria), after fermentation by Tyo-Mu group, Makurdi processors, and during frying by the Koko Yuoth 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% for an average amount of red palm oil added of 310g per 50kg 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 2h 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 (1 out of 4) or manual press (3 out of 4); sifting using the grater (3 out of 4)) in comparison with the processors in Benue (e.g. manual press (1 out of 3) or traditional press (2 out of 3) with sticks and ropes; manual sieving (3 out of 3). Pressing with a traditional stick press could take up to 7 hours compared to 1 hour using a mechanical press. Benue processors and Ibadan immigrants from South-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 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 that to that of round pans rather than iron pans. The Army Barracks immigrants also practiced 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 mechanisation (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 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 State: 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 mechanised 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 (5 months on average) between the two States. Final gari to fresh root conversion yield was approximately 25% (the quantity of gari obtained from 50kg of fresh cassava roots was typically 12kg). The fermentation times (from 5h to 93h) and equipment differed between the different ethnic groups within the States. Three out of 7 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) whilst 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 deserves consideration because 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 commercialisation of gari processing in Nigeria, important factors are productivity and quality. In order to increase gari productivity, less mechanised 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 that the systems for transferring grated cassava into bags for fermentation is not optimised.

In conclusion, our study show 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.

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