

Original article

End-user preferences for plantain food products in Nigeria and implications for genetic improvementDelphine Amah,^{1*}  Esmé Stuart,¹ Djana Mignouna,²  Rony Swennen^{3,4}  & Béla Teeken¹ 

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Summary Plantain is an important food security crop for farming households in Nigeria. This study investigates the relative importance of plantain food products and their quality descriptors from the perspective of farmers in Southern-Nigeria, to inform end-user oriented and socially inclusive breeding strategies that drive hybrid adoption. Surveys were conducted in twelve rural communities in three states in the plantain belt of Nigeria, consisting of key informant interviews, sex-disaggregated focused group discussions and individual interviews. Dodo (fried plantains), boli (roasted plantains), boiled plantain, plantain with beans and porridge were the most common food products identified in the study areas. Fruit size, pulp texture (firmness/softness), colour, maturity stage and taste were identified as the most critical characteristics, with impact on quality of processed food products. There were significant differences between states regarding the importance of plantain food products, but little interstate and gender differences for fresh fruit and food product quality characteristics.

Keywords Breeding, consumer preference, food quality characteristics, *Musa* spp., plantain hybrid.

Introduction

The need to feed the earth's growing population in a sustainable way requires substantial improvements in crop breeding efforts to increase agricultural productivity and access to nutritious and preferred food products. Plantain (*Musa* spp. AAB) is a staple food for over three million households in West and Central Africa. Nigeria is the world's top plantain producer (Lescot, 2020) and plantain ranks third in production among starchy staples after cassava and yam (Akiyemi *et al.*, 2010). Plantains are mainly cultivated by smallholders for their starchy fruits which serve as a source of calories and can be processed for consumption across different stages of ripeness. Plantain ripening is categorized into nine stages based on peel colour: 1 (green), 2 (pale green), 3 (pale green with yellow tips), 4 (yellow-green), 5 (more yellow than green), 6 (completely yellow), 7 (yellow with black specks due to senescence), 8 (yellow-black) and 9 (more black than yellow; Adi *et al.*, 2019). Generally, unripe fruit

peels are predominantly green while ripe fruits peels are predominantly yellow and overripe fruit peels are predominantly black.

The principal food products consumed in Nigeria and other parts of West and Central Africa are derived from boiling/steaming, frying, roasting or drying of plantain fruits. Food products such as fried plantain, roasted plantain, boiled plantain, pounded plantain and plantain chips are common in Cameroon (Newilah *et al.*, 2005), Ghana (Dadzie & Wainwright, 1995), Nigeria (Ogazie, 1996; Akiyemi *et al.*, 2010), Ivory Coast (Kouamé *et al.*, 2015), Benin (Fainou *et al.*, 2018) and Democratic Republic of Congo (Ekesa *et al.*, 2012). However, names of food products and preparation preferences vary across locations. For example, fried ripe plantain is known as dodo in Nigeria and Cameroon, or as aloco in Ivory Coast and Benin or as red red and kelewele in Ghana, sometimes involving addition of other ingredients. Similarly pounded plantain comprises fufu in Ghana, Nigeria and Benin as well as futu in Ivory Coast. Diverse studies have demonstrated that plantain is an important source of carbohydrates, vitamins C and B6,

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potassium, antioxidants and provitamin A carotenoids (Tsamo *et al.*, 2015; Amah *et al.*, 2019; Bhuiyan *et al.*, 2020). The potential of plantain to grow in a wide range of environments and produce fruit all year round makes it an important food security and cash crop.

Over the years, breeders have developed and distributed high yielding disease-resistant plantain varieties, but adoption rates have been limited (Eriksson *et al.*, 2018; Tenkouano *et al.*, 2019). Similar to other bananas, plantain production is still dominated by farmer preferred local varieties, principally owing to their consumer-preferred attributes (taste, texture, colour and aroma; Ortiz & Swennen, 2014; Marimo *et al.*, 2020). Food uses of plantain in Nigeria include dodo (fried ripe pulp), boli (roasted unripe-ripe pulp), fufu (boiled and pounded unripe pulp), amala (unripe pulp milled into flour and reconstituted into a thick dough), moin-moin (unripe-ripe pulp milled and steamed), porridge/pottage (unripe pulp boiled with additional ingredients), chips (fried unripe pulp) and dodo Ikire (fried overripe pulp with additional ingredients; Ogazi, 1996). However, information on the importance of specific products, food quality descriptors/characteristics as well as varieties used for specific products is limited. Ogazi (1996) mentioned that dodo is commonly made from *ohun* (French type) or *agbagba* (False Horn type) while chips are commonly made from *agbagba erin* (elephant type) and amala is made from the *okinimah* type. Similarly, how region, socio-economic, culture and gender-specific factors are related to food product preferences and quality characteristics is not well-known. Recent studies on plantain food products in Nigeria have mostly focused on nutritional, compositional and organoleptic attributes of plantain chips and snacks from plantain flour blends (Adeyanju *et al.*, 2016; Badejo *et al.*, 2017).

This study, therefore, investigates the relative importance of plantain food products consumed in Southern-Nigeria and their quality characteristics/descriptors as elicited from farmer-processors in three states in Nigeria, that are well-known for their high plantain production and consumption. The focus was to identify predominant plantain products and preferred varieties for each product, preferred characteristics of fresh fruit and processed products, processing methods and specific preferences peculiar to various stakeholders. Specific attention was given to interstate and gender differences because of the strong gendered task division related to farming, processing, food preparation and marketing of food products. In terms of cultivation, women play a larger role in decision-making regarding manure application, recognition of mature fruits and removal of dry leaves that are close to the ground. (Ajayi & Baiyeri, 1999). Women across the Southern belt of Nigeria play a dominant role as

wholesalers, retailers, and traders (Adewole, 2017). Considering these different roles, plantain food products are hypothesised to possibly differ in importance for men and women. Equally, plantain and plantain food characteristics can have a different priority within the livelihoods of men and women. Information obtained underpins end-user-oriented and socially inclusive breeding strategies to prioritise breeding objectives and define traits for selection to meet cultivar needs for target production areas and will foster the potential adoption of new hybrids.

Materials and methods

Study area and sample selection

The study was conducted in Nigeria during July–August 2019 in line with the methods described in Forsythe *et al.* (2020) with some modifications. A multistage sampling procedure was employed to select the study area and population. The first stage involved a purposive selection of three states in the plantain growing belt of Nigeria, namely South-West and South-South based on plantain production potential, importance for processing, and/or marketing of plantain as well as prior introduction of improved hybrids. These states include Osun (representative of the South-West and characterised by forest/savanna transition agroecology), and Delta and Rivers (representative of the South-South, characterised by humid forest agroecology). The second stage involved the selection of four rural communities in each of the three selected states based on information from the government Agricultural Development Programme (ADP) officers regarding the importance of plantain cultivation, processing, consumption and marketing. The rural communities were Ago-Owu, Patara, Ogudu and Akola Alaerebere for Osun, Isele Uku, Ossissa, Agoloma and Umeh for Delta as well as Choba, Omoku, Abua and Etche for Rivers.

Survey tools and data collection

A structured questionnaire containing both closed- and open-ended questions and a set of qualitative interview questions for individual interviews (II), key informant interviews (KIIs) and focus group discussions (FGDs) were used for data collection as specified in Forsythe *et al.* (2020). Interviews were conducted in English, pidgin and local languages depending on the preference of the respondent. These involved structured sex-disaggregated questionnaires and a set of qualitative interview questions which focussed on (i) existing social segments and their farming-related activities with special attention to plantain and gender; (ii) household demographics; (iii) the different uses of

plantain; and (iv) agronomic and food product quality characteristics of plantain.

The field survey was conducted by an interdisciplinary team of trained enumerators selected based on their expertise in socio-economics, food technology and plant science as well as prior involvement with plantain research. In each community, one KII was first organised with community leaders with extensive knowledge of the communities, after which two sex-disaggregated FGDs were organised in each community with people who produce, process and consume the product. A total of 24 FGDs were conducted, each with an average of 5–6 people, summing up to 126 FGD participants. Based on this information, 10–12 IIs were then conducted in each community (a total of 125 IIs). Criteria for selection of the II respondents were that they were cultivating plantain and were also involved in the processing/preparation of plantain and that the local social groups identified during the KIIs and FGDs were represented. Participants were selected through snowball sampling starting with a representative of each of the identified social groups identified by the KIIs and/or FDG participants.

Data analysis

Qualitative and quantitative data analysis was done, according to Forsythe *et al.* (2020), with some modifications. All data collected were analysed in Excel and STATA using content analysis, percentages, frequencies and means. Responses from men and women in FGDs were summarised and clustered together into tables per subject/question and thereafter analysed qualitatively. Responses on plantain characteristics from all IIs were coded into more general characteristics based on the type and diversity of the descriptions provided, using a coding tree. Frequencies and their percentages of the number of times a coded characteristic was mentioned were calculated. The analysis was done by segregating data from the IIs according to gender and state and their intersections (disaggregation by sex within each state and by state within each sex), using Chi-square tests. In the cases where counts were less than five, a Fischer exact test was used.

The frequencies of mentioned products and characteristics from all IIs were considered as a quantitative measure of the importance of each product or characteristic, hence a modification from Forsythe *et al.* (2020). Additionally, for comparison with the quantitative measure, a qualitative ranking exercise was done with a subset of II respondents in each state regarding the importance of each plantain food product: thirteen in Osun (seven women, six men), nineteen in Delta (twelve women, seven men) and thirteen in Rivers (eight women and five men), who were able to provide a ranking of the relative importance. Other II

respondents were not able to rank the products in order of importance, mostly because they considered them equally important even if made less frequently. Respondents in the subset listed the top three food products in order of importance. For each respondent, each listed food product then got three, two or one point for the first, second and third ranked food product, respectively. Scores were then added up and used to rank the importance of the food products in each state. In this mixed method, most weight was given to the quantitative representation of the importance of the food products.

Results and discussion

Socio-demographic profile of the sampled farmers

The mean age of participants of both men and women FGDs was 47 years, with the youngest participant aged 27 and the oldest 75. The average number of participants in FGD was 5. Almost all participants (99 percent) reported being plantain producers, while 78% were also processors.

Characteristics of the sampled farmers are summarised by gender (female vs. male), age, marital status (need to cater for a household or not), main occupation (to ascertain the importance of farming within livelihoods) and involvement in production and processing to confirm the study site selection criteria (Table 1). About 33% of the individual respondents are from Osun, 31% from Delta and 36% from Rivers.

Results from the pooled sample show that the mean age of men and women in the study area is about 49 and 44 years, respectively. Half of the men sampled and 65% of the women in the sample are middle-aged (31–50 years old). Most of the respondents are married (94% for men and 88% of women) and likely to make jointly informed farming decisions (Table 1). A similar profile in age and marital status is observed in all sampled states.

As in most of the agricultural communities, both men and women are primarily engaged in farming: 75% and 58% of men and women, respectively, report farming as their main occupation. The farming sector is thus dominated by men except in Rivers. Farming is the core livelihood activity for all communities in the sample and study area, which was found suitable for growing a wide range of crops. Principal crops include plantain, cassava, yam, cacao and maize in order of importance.

All male respondents and 92% of women reported growing plantain (Table 1). Plantain production is vital in the surveyed area for both men and women with a slightly greater contribution from men. Plantain is important as a food crop that can provide food all

Table 1 Distribution of individual respondents according to their socio-demographic characteristics in Osun, Delta and Rivers states

Variable	Osun (n = 41)		Delta (n = 40)		Rivers (n = 44)		Pooled sample (n = 125)	
	Women (n = 18)	Men (n = 23)	Women (n = 24)	Men (n = 16)	Women (n = 22)	Men (n = 22)	Women (n = 64)	Men (n = 61)
Age								
Average age (years), SD	41.1 (9.6)	54.0 (15.2)	47.7 (12.9)	49.5 (11.2)	41.9 (9.2)	44.4 (11.3)	43.8 (11.1)	49.3 (13.3)
Youth (<30)	18.8	13.0	8.7	0.0	4.4	13.0	9.7	9.5
Middle-aged (31–50)	68.8	30.4	52.2	52.9	73.9	65.2	64.5	49.2
Older adults (51+)	12.5	56.5	39.1	47.1	21.7	21.7	25.8	41.3
Marital status								
Married	100.0	91.7	77.3	100.0	87.5	91.3	87.7	93.9
Single	0.0	4.2	13.6	0.0	4.2	8.7	6.2	4.6
Separated	0.0	4.2	0.0	0.0	0.0	0.0	0.0	1.5
Widowed	0.0	0.0	9.1	0.0	8.3	0.0	6.2	0.0
Main occupation								
Agro dealer/business/traders	31.6	0.0	25.0	5.6	13.0	4.6	22.6	3.2
Farming	52.6	95.7	65.0	83.3	56.5	45.5	58.1	74.6
Processing	15.8	0.0	10.0	0.0	8.7	0.0	11.3	0.0
Salary employment	0.0	0.0	0.0	0.0	17.4	9.1	6.5	3.2
Self-employment	0.0	0.0	0.0	0.0	4.4	4.6	1.6	1.6
Transporter	0.0	0.0	0.0	0.0	0.0	22.7	0.0	7.9
Others	0.0	4.4	0.0	11.1	0.0	13.6	0.0	9.5
Plantain growers (%)	94.4	100.0	90.9	100.0	90.9	100.0	91.9	100.0
Plantain processors (%)	100.0	100.0	100.0	83.3	84.2	64.7	95.1	84.5

SD, standard deviation.

year round and as a cash crop for income generation especially during the years before cocoa or other tree crops starts to produce. Moreover, it is considered a high-value crop (Ojo & Ayanwale, 2019) with a relatively high market price compared to other staples like maize and cassava. Both women and men process plantain for home consumption with a larger contribution reported from women (95% and 84% of women and men, respectively).

These socio-demographic characteristics and especially gender can be important to understand the end-user preferences for future breeding programmes on plantain and other crops (Bechoff *et al.*, 2018; Weltzien *et al.*, 2019), and may have implications on poverty reduction consequent to the adoption of technology options (Teeken *et al.*, 2018; Mignouna *et al.*, 2020).

Relative importance of plantain products

A total of twenty six plantain food products were identified in this study amongst which dodo, boli, boiled, plantain with beans and porridge were most important across the study area (Table 2; Fig. 1). Other food products of substantial importance include chips, raw (ripe fruits consumed as a fruit or snack), flour, pepper soup, pounded (unripe fruits boiled and pounded in a wooden mortar with pestle), pounded

with yam/cocoyam/gari, pudding and amala. Notably, flour is an intermediary product that is used to make the edible product amala as well as other products like pudding. Plantain food products in Nigeria have previously been described by Ogazi (1996). Plantain with beans, an important food product not previously described by Ogazi (1996), is made from small pieces of unripe or ripe plantain boiled together with beans (*Phaseolus* spp. or *Vigna* spp.) and seasoned with other ingredients. Except for raw and dodo utilising ripe-overripe fruits, as well as chips, amala and pounded made mainly from unripe fruits, all other important products are made from fruits across several stages of ripeness. Several food products from plantains across different ripening stages sometimes involving additional ingredients were also described in Ghana (Dadzie & Wainwright, 1995) and Cameroon (Newilah *et al.*, 2005) supporting the observed diversity in food uses of plantains across producing regions.

Significant differences were observed regarding the importance of food products for men and women together across the different states. Porridge is more important in the South-South where it is the most preferred food product, than in the South-West (Delta; $P < 0.001$ and Rivers; $P < 0.001$, compared to Osun; Table 2). Similarly, pepper soup is predominant in the South-South (Delta; $P < 0.001$ and Rivers; $P < 0.001$, compared to Osun) and even more important in Rivers

Table 2 Importance of plantain food products based on the frequencies as mentioned by plantain farmer-processors in Osun, Delta and Rivers states

Food product/sex*	Frequencies %				P-values			Qualitative ranking exercise		
	Total	Osun	Delta	Rivers	Osun/Delta	Osun/Rivers	Delta/Rivers	Osun	Delta	Rivers
Women and men										
Dodo	74	80	80	64	n.s.	0.085	n.s.	1	3	2
Boli	66	59	83	59	0.018	n.s.	0.019	7	4	3
Boiled	54	63	60	41	n.s.	0.038	0.081	4	2	5
Plantain with beans	50	44	60	45	n.s.	n.s.	n.s.	5	6	4
Porridge	49	10	70	66	<0.001	<0.001	n.s.		1	1
Chips	48	49	58	39	n.s.	n.s.	0.084	6	5	
Raw	34	22	40	41	0.079	0.061	n.s.	6	9	
Flour	30	59	25	9	0.002	<0.001	0.051			
Pepper soup	30	0	28	59	<0.001	<0.001	0.004		4	2
Pounded	17	5	10	34	n.s.	0.006	0.010			6
Pounded with yam/cocoyam/gari	22	44	13	9	0.003	0.001	n.s.	2	8	
Pudding	14	0	45	0	<0.001		<0.001		6	
Amala	10	7	13	9	n.s.	n.s.	n.s.	3	7	
Women										
Dodo	73	83	75	64	n.s.	n.s.	n.s.	1	4	1
Boli	64	56	79	55	n.s.	n.s.	0.075		4	3
Plantain with beans	53	56	54	50	n.s.	n.s.	n.s.	3	5	5
Porridge	50	6	71	64	<0.001	<0.001	n.s.		1	4
Boiled	48	50	58	36	n.s.	n.s.	n.s.	5	2	
Chips	47	39	54	45	n.s.	n.s.	n.s.		3	
Raw	36	22	38	45	n.s.	n.s.	n.s.	3	7	
Pepper soup	30	0	25	59	0.029	<0.001	0.019		4	2
Flour	28	67	21	5	0.003	<0.001	n.s.			
Pounded	17	11	8	32	n.s.	n.s.	0.066			6
Pudding	17	0	46	0	0.001		<0.001		3	
Pounded with yam/cocoyam/gari	19	50	8	5	0.004	<0.001	n.s.	4		
Amala	14	11	21	9	n.s.	n.s.	n.s.	2	6	
Men										
Dodo	75	78	88	64	n.s.	n.s.	0.099	1	2	3
Boli	69	61	88	64	0.069	n.s.	0.099	4	3	6
Boiled	61	74	63	45	n.s.	0.051	n.s.	4	6	4
Chips	49	57	63	32	n.s.	0.095	0.060		1	1
Porridge	48	13	69	68	0.001	0.022	n.s.	3	1	2
Plantain with beans	46	35	69	41	0.037	n.s.	0.090	4	5	
Flour	33	52	31	14	n.s.	0.011	n.s.			
Pepper soup	30	0	31	59	0.008	<0.001	n.s.		4	5
Raw	20	22	44	0	n.s.	0.049	0.001			
Pounded with yam/cocoyam/gari	25	39	31	5	n.s.	0.034	n.s.	2	5	
Pounded	15	0	6	36	n.s.	0.002	0.053			
Pudding	11	0	44	0	0.001		0.009	4		

Food products are listed according to the frequency (from high to low) of being mentioned across states. Data are then disaggregated by state. For the disaggregation into sex only, the food products that show significant differences between men and women are shown except for those that are part of the ranking exercise. Differences in frequencies between the sexes are tested for using chi-square test, $N = 125$ (Osun = 41, Delta = 40, Rivers = 44). For comparison, the last three columns show results of the qualitative ranking exercise on the importance of each product with a subset of people $N = 45$ (Osun = 13, Delta = 19, Rivers = 13).

*Only food products with total frequencies >5% are listed with n.s., not significant (P -value > 0.1).

than in Delta ($P = 0.004$). Porridge is ranked first in Delta and Rivers and not mentioned in Osun, while pepper soup is ranked second and fourth in Delta and Rivers, respectively, but is also not mentioned in Osun.

Boli is more important in Delta than Osun ($P = 0.018$) and Rivers ($P = 0.019$). Pounded is clearly more important in the South-South while pounded with yam/cocoyam/gari is particular to Osun. Pudding is

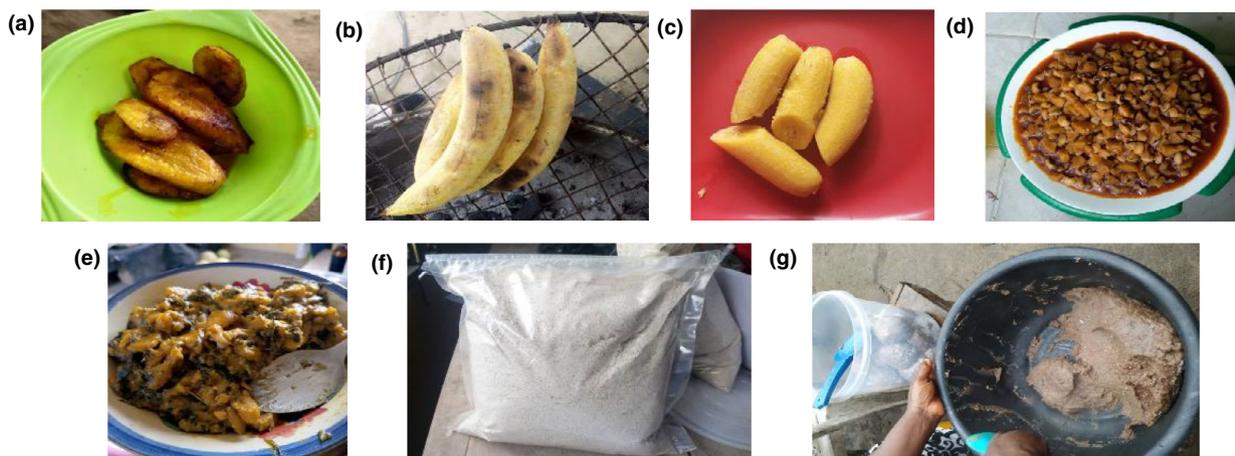


Figure 1 Most common plantain food products in Southern Nigeria. (a) Dodo (fried), (b) boli (roasted), (c) boiled, (d) plantain with beans, (e) porridge, (f) flour, (g) amala (thick dough reconstituted from flour).

exclusive to Delta with no mention in other states. The ranking exercise (Table 2) shows that amala is more important in Osun than the other two states, although this is not depicted in the frequencies. However, flour as a product is much more important in Osun compared to Rivers ($P < 0.001$) and Delta ($P = 0.002$). Considering that most flour is used to make amala, this finding, therefore, supports the overall higher importance of amala in Osun. Amala and flour (Fig. 1) are, however, kept apart in this study because flour is appreciated as a separate product since it is often for sale, while amala is prepared for home consumption.

When considering the difference in importance of food products between states within each sex (Table 2), some differences emerge that were not present when looking at responses from both sexes together. For example, the ranking exercise shows that pepper soup is more important for women than it is for men in Rivers. Amala is also more important for women in Osun than for women in other states. Similarly, raw is more important for women in Osun, and pepper soup is more important for women in Rivers than for women in other states. There is no significant difference between men and women with regards to the importance of food products for the three states together, as well as within each state. Two exceptions are as follows: the previously observed higher importance of pepper soup for women shown by the qualitative ranking in Rivers and pounded plantain with yam/cocoyam/gari being slightly more important ($P = 0.094$) for men than for women in Delta, although it is of minor importance in Delta and more specific to Osun.

All the plantain food products identified in this study were made with one or more similar processing

methods, including frying, roasting, boiling/steaming (sometimes in combination with other ingredients), pounding and drying. Although there are clear differences between the importance of food products in the various states, processing methods for each product were generally the same across respondents. However, there were slight differences based on individual preferences as food products were mostly made for home consumption. For example, some plantains were boiled/roasted with or without peels and there were variations in types and composition of additional ingredients used for food products like porridge, pepper soup and plantain with beans.

This diversity of plantain food products and processing methods needs to be considered, to evaluate and select breeding products that will meet the needs of consumers (Bechoff *et al.*, 2018). However, the relative importance of each food product is also key to enable prioritisation of efforts to address the complex challenge to relate food quality criteria to measurable quality traits for various consumer classes. Particularly, when selecting for new plantain hybrids, it should be considered that, among others, hybrids will need to be suitable for making good quality dodo, boli, boiled, plantain with beans and porridge which are the most important food products for Nigerian consumers.

Plantain varietal preferences for popular food products

A total of 55 unique plantain variety names were provided by respondents in this study. Eighteen names were provided in Osun, which were unique to the state. Twenty-three and twenty names were provided for Rivers and Delta, respectively, with five names common in both locations. There were a few

communities where plantain varieties were not distinguished. It is well-known that the naming of plantain varieties differs in a given area posing a complexity in precise identification (Adheka *et al.*, 2018). Therefore, it is highly likely that many of the names provided relate to the same plantain variety, or in fewer cases that one name may represent different plantain varieties. Morphological characterisation and genotyping of the diverse cultivars can provide a clear understanding of the plantain diversity in the study area and eliminate duplicates. Plantains are generally distinguished into three main subgroups (French, False Horn and Horn) based on their inflorescence morphology and fruit size (De Langhe *et al.*, 2005). French plantains are characterised by the presence of a complete inflorescence with a male bud while False Horn plantains are characterised by an incomplete inflorescence with the male bud degenerating before maturity. Horn plantains have no male bud. Across the study area, the variety *main plantain* (*agbagba* in Osun), a False Horn type is by far the most preferred. The top three plantain varieties mentioned in each state are characterised by big fingers typical of the False Horns. Previous studies have also documented the prevalence of the False Horn type plantain variety *agbagba* in Nigeria underscoring its use as checks in cultivar evaluation (Lemchi *et al.*, 2005).

While the study aimed to investigate varietal preferences for specific products, respondents were not very detailed in linking varietal preferences to their use for particular products. In general, preference for varieties was mostly based on bunch morphology (big bunch and big fingers), where the most preferred variety is a compromise between relatively big bunch size while maintaining a large finger size. Big fingers were also preferred in dishes where plantain is used as whole fruits or large slices such as boli and dodo, respectively. The size of a plantain bunch is one of the most important aspects for its marketability. Due to their lower market value, smaller plantain fingers were used in products where the size of individual plantain fingers is of lesser importance, such as flour in Osun or porridge in Delta and Rivers.

Differences in colour, taste and texture between identified varieties are less pronounced; hence, most plantain varieties are very similar in terms of use for different products. In the FGDs and KIIs, all participants state that all plantain varieties can be used for all products. For example, women in Patara (Osun) explain, 'We prefer *agbagba gidi*, *adaa loko* and *olomo nla* because of their big size, but in terms of pulp they are all the same'. Also, men in Akola Alaerebere (Osun) confirm 'We plant *agbagba*, *koloko* (*alabameta*), *asogba* (*olomoyoyo*), and *alabameji* (*twin*). All of them have the same pulp colour. All of them are used for flour, boli, boiled, dodo, and can be

eaten raw when hungry'. Although it was generally noted that most plantain products can be made with all plantain varieties, in some cases, preference for particular product(s) was vaguely linked to specific varieties. Difference in sugar content between varieties was also identified as a reason for varietal use for specific products. The key informants in Ago-Owu (Osun) explain, 'people prefer *olomoyoyo* because it is sweeter than other varieties. It can be boiled and used for dodo. The other varieties are used for flour because it has low sugar content'. Across states, varietal preference for particular products was also sometimes linked to pulp colour. Women in Ago-Owu, Osun explain, 'There is little difference in how we use the plantain with brown and white pulp. We use both for pounding, although the white one does not get as smooth as the brown one. It is also lighter in weight, it does not rise/swell in the pan. Also, customers prefer the plantain with brown pulp. The white one is good for chips, dodo, and flour, although the *amala* made from the flour from white pulp will be light weight'.

While most information on varieties across the study area relates to local varieties, a few hybrid or improved plantain varieties were also mentioned, particularly in Delta and Rivers. Hybrid varieties were often referred to as *improved variety*, *hybrid* or *agric variety*. The most commonly used suspected hybrid was a plantain called *efrum*, characterised by the fact it looks more like banana than plantain, is sweet in taste and softens easily when cooked. Improved varieties ranked high for their big bunches, big fingers and attractive look. However, they are less preferred because they spoil easily, soften when cooked, have big stones inside (possibly linked to the presence of seeds typical of tetraploid hybrids) and they are not as tasty as local varieties. Consequently, the use of improved varieties is sometimes limited to products like flour, chips, porridge and boli. This is also the case for cooking banana, which is both liked and disliked for its low sugar content and use for specific products like flour, pounded and fried. In contrast, hybrids were not mentioned in Osun, but community members explained that varieties referred to as *agric* simply means the plantain produces well. The limited use of improved varieties often linked to inferior fruit quality characteristics justifies the recent interests and emphasis in incorporating consumption attributes early in the breeding programme (Marimo *et al.*, 2020).

Quality characteristics for plantain and food products

Important quality characteristics of fresh plantains

Preferred characteristics for fresh plantain fruits were assessed and up to twenty five characteristics that define a good crop for making a high-quality

product were elicited from respondents (Table 3). The predominant fresh plantain characteristics, listed in order of importance, are finger size, peel colour, pulp colour, tip colour, bunch size, maturity, number of fingers, peel appearance, finger firmness, fruit angularity and good taste. Although plantain is processed at various ripening stages, most of the listed fresh plantain characteristics elicited from farmers referred to unripe (green) fruits at maturity. It was not surprising that there was a high preference for yield-related traits indicated by big fingers, bunch size and number of fingers among respondents. However, it was interesting to note the importance of colour and preferences at the level of the fruit peel (dark green peel at maturity), pulp (yellow pulp) and even the fruit tips (black fruit tips indicative of scars of dehisced floral relicts at maturity). With regards to other important characteristics like finger firmness, there was a preference for strong fruits at maturity while for fruit angularity, there was a preference for fruits with minimal sharp edges

on the finger which is often indicative of proper fruit-filling at fruit maturity.

Some important differences in preferences for fruit quality characteristics were observed between states (Table 3). Peel colour is mentioned less in Rivers than in Delta ($P = 0.006$). Pulp colour, tip colour and peel appearance are significantly less important in Rivers than in Osun and Delta. This indicates that in general colour-related characteristics are less important in Rivers state. Maturity is more important in Delta than in Osun ($P < 0.001$) and Rivers ($P = 0.011$), while peel appearance is more important in Rivers than in Osun ($P = 0.050$) with no mention in Delta. Peel appearance includes notions such as presence/absence of black/brown spots, split fingers/peel, cracked fingers and smoothness of the peel and is therefore different from peel colour. Fruit angularity is more important in Osun than in Rivers ($P = 0.044$) while it is not mentioned in Delta.

Looking at the differences between states within each sex, pulp colour is more important for women in

Table 3 Importance of fresh plantain characteristics based on the frequencies as mentioned by plantain farmer-processors in Osun, Delta and Rivers states

Characteristic/sex*	Frequencies %				P-values		
	Total	Osun	Delta	Rivers	Osun/delta	Osun/rivers	Delta/rivers
Women and men							
Fruit (finger) size	72	73	73	70	n.s.	n.s.	n.s.
Peel colour	59	59	75	45	n.s.	n.s.	0.006
Pulp colour	33	41	38	20	n.s.	0.036	0.082
Tip colour	32	41	38	18	n.s.	0.019	0.046
Bunch size	29	24	30	32	n.s.	n.s.	n.s.
Maturity	18	5	38	14	<0.001	n.s.	0.011
Number of fingers	14	15	20	7	n.s.	n.s.	n.s.
Peel appearance	9	5	0	20	n.s.	0.050	0.003
Finger firmness	8	10	5	9	n.s.	n.s.	n.s.
Fruit angularity	8	20	0	5	0.005	0.044	n.s.
Good taste	6	7	3	7	n.s.	n.s.	n.s.
Women							
Pulp colour	30	56	25	14	0.044	0.007	n.s.
Tip colour	27	44	38	0	n.s.	0.001	0.002
Maturity	22	0	42	18	0.002	n.s.	n.s.
Bunch size	17	6	13	32	n.s.	0.054	n.s.
Peel appearance	13	11	0	27	n.s.	n.s.	0.008
Fruit angularity	8	17	0	9	0.071	n.s.	n.s.
Men							
Peel colour	62	61	88	45	0.069	n.s.	0.008
Pulp colour	36	30	56	27	n.s.	n.s.	0.071
Fruit angularity	8	22	0	0	0.066	0.049	
Leaf colour	7	4	19	0	n.s.	n.s.	0.066

n.s., not significant (P -value > 0.1).

Fresh plantain characteristics are listed according to the frequency (from high to low) as being mentioned across states. Data are then disaggregated by state. For the disaggregation into sex only, the traits that show significant differences states are shown. Differences in frequencies between the sexes are tested for using chi-square test, $N = 125$ (Osun = 41, Delta = 40, Rivers = 44).

*Only the characteristics with total frequencies >5% are listed.

Osun than for women in Delta ($P = 0.044$) and Rivers ($P = 0.007$). Also, maturity is more important for women in Delta than it is for women in Osun ($P = 0.002$) while bunch size is more important for women in Rivers than for women in Osun ($P = 0.054$), possibly reflecting the larger role of women in agriculture and plantain cultivation in the South-South. All these trends do not hold when comparing men from all states. Only men in Delta value peel colour more than men in Rivers ($P = 0.008$) and Osun ($P = 0.069$). This suggests that except for a small contribution of men to the preference differences for maturity, the overall differences between states for pulp colour, tip colour, maturity and peel appearance can be ascribed to the differences in women preferences.

With regards to gender differences, men mention bunch size more often ($P = 0.003$) than women: overall, and also when looking at the differences between men and women within each state: Osun ($P = 0.025$) and Delta ($P = 0.005$). In Rivers, women and men mention bunch size equally often. Additionally, women in Rivers mention finger size significantly more often than men ($P = 0.021$) and in Delta men mention pulp colour more often than women ($P = 0.046$). This could indicate the larger value men ascribe to sales (where bunch size is crucial) than women who are relatively more concerned with food quality for home consumption as they are more involved in food preparation.

Important quality characteristics of plantain food products

The quality of a food product is defined by the quality of the crop used, processing methods employed as well

as interactions with additional ingredients. Table 4 shows the ranked importance of food product quality characteristics based on the total number of responses. Respondents provided similar characteristics for different products. Most identified food quality characteristics relate to colour, texture (softness, smoothness, firmness, stickiness/gumminess, crunchiness), taste and odour of the product (Table 4). For dried products like flour, crunchiness and size relate to the texture of the dried fruit slices intended for milling into flour and the size of the flour flakes (granules) respectively. Large flakes are mentioned as an indication that unripe plantain is the raw fruit used for producing the flour and not unripe sweet banana which provide smaller flakes that swells less. Similar quality characteristics, including swelling, are also often mentioned for dough like products like cassava fufu, cassava eba, pounded yam and amala (Teeken *et al.*, 2019; Oluwamukomi & Lawal, 2020). With regards to the textural properties, the most important seems to be the balance between keeping firm (dodo, boli) or thick (pepper soup, porridge) after preparation while still providing the required softness and absence of gumminess (stickiness of the paste-like substance to the hands and palate) combined with the right colour. Banana varieties exist with pulp colours intrinsically ranging from white to orange-yellow, also related to carotenoid content (Amah *et al.*, 2019) and this variability can be used for breeding. Beside this inherent variety trait, the colour of a final product may also result from different types of processing methods as well as the maturity/ripening stage of fruits used for processing. For

Table 4 Frequencies (%) of mentioned characteristics of the different food products in Osun, Delta and Rivers states

Food product characteristic	Dodo (N = 98)	Boli (N = 44)	Boiled (N = 53)	Plantain with beans (N = 16)	Porridge (N = 64)	Chips (N = 29)	Flour (N = 45)	Pepper soup (N = 32)	Pounded (N = 4)	Pounded with yam/ cocoyam/gari (N = 17)	Amala (N = 22)
Colour	33	48	36	19	26	41	40	31		23	41
Softness	28	32	36	56	44	3		34	25	12	23
Taste	17	7	9	13	8	7	2	6		6	
Smoothness	1		2				4		25	23	14
Firmness	13	9	7	6	5	3		9		12	
Stickiness/ Gumminess	2		4		14			9	50	12	18
Crunchy						38	4				
Odour	4		6		3	7	9	3		6	
Moisture content		2					22				
Absorption capacity	2									6	4
Thickness				6				3			
Size		2					7				
Swelling							7				
Flakes (granules)							4				
Starch content								3			

Frequencies represent the fraction of the answers of all the characteristics mentioned on each food product.

example, colour is often linked to acrylamide formation from reducing sugars during frying or oxidation of phenolics during drying (in flour/amala), and both processes are affected by maturity/ripening stage of the fruit used in making the product (Falade & Olugbuyi, 2010; Shamla & Nisha, 2017). The genetic variability for colour and biochemical parameters which can contribute to colour and texture changes during processing can be used for breeding and new hybrids should be evaluated for their processing quality. Sanya *et al.* (2020) also documented that better consumption attributes such as taste, texture and colour could increase the likelihood of adoption of improved banana hybrids by farmers in Uganda.

Non-preferred attributes of fresh plantains and processed fruits

Elucidating the characteristics of a bad product can critically inform breeding programmes on traits to avoid during selection to increase the likelihood of acceptability of new varieties. Table 5 sums up the

Table 5 Frequencies of mentioned non-preferred fresh fruit and food characteristics (listed from high to low) of the different food products across Osun, Delta and Rivers states

	Frequencies	
	No. of answers	%
Non-preferred fresh fruit characteristic		
<i>All negative characteristics</i>	60	100
Immature	20	33
Small fingers	11	18
Light green peel	5	8
Small bunch	4	7
Bruises	3	5
Pest/disease	2	3
White pulp	2	3
Other minor characteristics*	13	22
Non-preferred food product characteristic		
<i>All negative characteristics</i>	235	100
Improper cooking/processing/preparation procedure	57	24
Softness (related to overripe fruits)	28	12
Burnt	17	7
Not well cooked	17	7
Overripe	15	6
Gummy/sticky (porridge, boiled, dodo)	12	5
Immature	12	5
White colour (boli, porridge)	10	4
Bad taste	9	4
Lumps (pounded/with yam/gari, amala)	9	4
Bad smell/odour	9	4
Bad oil (chips, dodo)	7	3
Black/too brown colour (dodo, chips)	7	3
Other minor characteristics*	26	11

*Characteristics with total frequencies of 2% or less not listed.

negative characteristics for fresh fruits and products and there were no discernible differences between state or gender for the mentioned characteristics. Negative characteristics for fresh fruits can be summarised with immature, small fingers and light green peel. Light green peel is often related to immaturity or insufficient nutrients during growth, but it is listed as a separate category because it is typical for some varieties. It is critical to choose fruits at the right maturity and ripening stage for processing. If the ripening stage is too advanced, it results in a very soft product that does not maintain desired firmness/thickness and that is too sweet in taste (except for the localised product dodo Ikire, typical in Osun, that is made from overripe plantain/banana fruits). On the other hand, if an immature plantain is used, this will result into gumminess/stickiness, hardness and starchiness.

The characteristics for developing a good variety, therefore, lie in one that provides enough firmness even when the starch has been almost fully transformed into simple sugars (ripe/semi ripe plantain), desired by people who prefer a sweet and soft dodo, plantain with beans or boli, and enough softness for those preferring a less sweet product (unripe/semi ripe plantain) thus emphasising the need for evaluating new plantain varieties for processing at different ripening stages. This relative uniformity of traits among local varieties is possibly a key reason that many respondents did not easily provide answers when asked for non-preferred quality characteristics of food products. Most of the characteristics mentioned relate to choosing the right ripening/maturity stage in combination with the right frying and cooking procedures (Table 5).

Conclusions

This study has provided insights into the important plantain food products consumed in three critical plantain producing states in Nigeria, as well as important quality characteristics for plantain fruit and food products. Fruit pulp texture (firmness/softness) and colour stand as the most critical fruit quality traits with an impact on derived processed food products. However, we found a limited diversity among local varieties for quality characteristics, which probably explains the lack of specificity in the use of varieties for particular food products. On the other hand, although there were few bred varieties mentioned in the study, they provided an important set of non-preferred traits that breeders need to be aware of. This points to the important principle that even if consumers are not demanding improved quality traits, breeders need to be aware of critical traits that may need to be monitored in order not to develop varieties that may have higher yield and better resistance, for example, but without 'must-have' quality traits. This

study focuses on rural communities, but a large quantity of the plantain produced is sold out and transported for sale to consumers in urban areas. This study has therefore not captured the food uses of plantains in urban areas, which is a general knowledge gap for many African grown staples (Bricas *et al.*, 2016). Further research on preferences related to urban use will be necessary to complement the end-use preferences highlighted in this study.

Important characteristics such as fruit and bunch size are already incorporated in plantain breeding programmes as yield components, but more efforts should be devoted to incorporating selection criteria for colour and texture parameters. This study also shows a considerable emphasis by consumers on taste, underscoring its importance for fruit quality improvement. These important quality attributes should be considered in combination with other production attributes, when selecting parents for genetic improvement. However, most rapid progress will depend on developing effective high throughput selection tools based on elucidating underlying physico-chemical factors, especially those responsible for the most important quality attributes such as texture, colour and taste across the different stages of ripeness.

This study has clearly indicated the difference in importance of plantain food products in the study area that can principally be explained by different regional and ethnic traditions. On the other hand, there were few gender differences for preferred or non-preferred food product characteristics. This finding indicates that plantain breeders can have little potential impact (positive or negative) on gender inequality through their choice of quality traits for improvement. The gender difference observed in relation to the importance of bunch size might indicate that men focus more on yield (for sale) while women might have spread their preferences more over the other characteristics (related to home consumption). This could reflect the dominance of women in plantain food product processing, involving more hands-on interaction with the food product quality-related aspects of the plantain. To ensure end-user oriented and socially inclusive breeding, there is a need for standardisation of professional food science protocols for participatory varietal selection in breeding and evaluation trials. Such evaluation protocols should include processing/preparation by users, particularly including women, because of the important expertise they possess in identifying potentially acceptable products.

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Conflict of interest

The authors declare no conflict of interest in this work.

Author contributions

Delphine Amah: Conceptualization (equal); investigation (supporting); project administration (lead); supervision (supporting); validation (equal); writing-original draft (lead); writing-review & editing (lead). **Esmé Stuart:** Data curation (lead); formal analysis (supporting); investigation (lead); methodology (supporting); validation (equal); writing-review & editing (equal). **Djana Mignouna:** Data curation (supporting); formal analysis (supporting); validation (equal); writing-original draft (supporting); writing-review & editing (equal). **Rony Swennen:** Conceptualization (equal); funding acquisition (lead); resources (lead); supervision (supporting); validation (equal); writing-review & editing (equal). **Béla Teeken:** Conceptualization (equal); data curation (supporting); formal analysis (lead); investigation (supporting); methodology (lead); supervision (lead); validation (equal); writing-original draft (supporting); writing-review & editing (equal).

Ethical approval

This study was approved by the National Research Ethics Committee. Research teams obtained ethical approval prior to the fieldwork. IITA has the mandate to carry out research including human subjects that is approved by their Internal Review Board. Participants were informed about the study through a consent form, they could stop the interview at any point and the research respected the rules of voluntary participation and anonymity.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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