Journal of Sensory Studies

WILEY

Journal of Sensory Studies

ORIGINAL ARTICLE OPEN ACCESS

Consumer Perception and Sensory Profiling of Cassava Mealiness Attributes Using Hedonic, JAR, and CATA Methods

O. A. Osunbade[1,2] | E. O. Alamu[3] | W. Awoyale[4] | M. Adesokan[1] | G. Nwaoliwe[1] | B. A. Akinwande[2] | J. A. Adejuyitan[2] | M. Lungaho[1] | B. Maziya-Dixon[1]

[1]International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State, Nigeria | [2]Department of Food Science, Ladoke Akintola University of Technology, Ogbomoso, Nigeria | [3]International Institute of Tropical Agriculture, Southern Africa, Research and Administration Hub (SARAH), Chelstone, Lusaka, Zambia | [4]Department of Food Science and Technology, Kwara State University, Malete, Kwara, Nigeria

Correspondence: J. A. Adejuyitan (jadejuyitan@lautech.edu.ng) | B. Maziya-Dixon (b.maziya-dixon@cgiar.or)

Received: 19 January 2025 | **Revised:** 14 March 2025 | **Accepted:** 26 March 2025

Funding: This work was supported by the Bill & Melinda Gates Foundation (BMGF) funded this research and the APC through the grant number (OPP1019962).

Keywords: cassava root mealiness | Check-all-that-apply | chewiness | just-about-right | softness

ABSTRACT

The ability of cassava root to be softened within a short period, being easy to chew, and dissolving easily upon biting, otherwise known as cassava root mealiness, is one of the major attributes of boiled cassava roots. This study aimed to identify the attributes of cassava root mealiness from consumers' end and evaluate consumer acceptability of boiled cassava roots. A well-structured questionnaire comprising of a 9-point hedonic, Just About Right (JAR) and Check-All-That-Apply (CATA) test was administered to 120 respondents to elicit information on cassava root mealiness (CRM) attributes and to evaluate four cassava varieties (danwarri, suppi, akpu, dangbo) for consumers' acceptability of boiled cassava in the selected LGAs of Benue State, Nigeria (Vandekya, Ushongo, Konshisha and Gwer East) using purposive sampling techniques. Data collected were subjected to Analysis of Variance (ANOVA) using statistical packages for social science (SPSS) and XLSTAT packages. CRM for the four cassava root varieties were dissolving easily, easy to chew, and softness. The CATA test showed that the most important mealiness attributes of boiled cassava roots were dissolving easily (80%) > being easy to chew (78%) > being moderately soft (76%). The JAR test results also revealed that the softness and chewiness of danwarri and suppi cassava varieties scored above 50%, just about right (JAR) values. The acceptability test showed that danwarri variety was scored 7.48 > suppi (6.68) > akpu (5.44) > dangbo (4.19) in that order. This information, with an in-depth laboratory characterization of the raw roots, will assist breeders in developing improved cassava varieties that are mealable and acceptable to the consumers.

1 | Introduction

According to several countries of tropical origin and America, cassava (*Manihot esculenta Crantz*) is a significant staple food in Africa. It accounts for more food calories per unit weight than the yam. Due to its high moisture content, it is the most perishable root and begins to deteriorate nearly immediately after harvest. Its effective energy food production, year-round availability, resistance to highly stressful conditions, and compatibility with Africa's current farming and food system resolve the continent's food problem (Abass et al. 2012; IITA 2012). According to the Food and Agriculture Organization, Nigeria is the world's largest cassava producer, accounting for over 63 million metric tons (FAOSTAT 2021). Cassava is primarily grown

Summary

- Consumer preferences of food products measure consumers' acceptability of foods, and the preferred quality characteristics are the traits that consumers desire in a particular food product.
- A well-structured questionnaire comprising a 9-point hedonic, Just About Right (JAR) and Check-All-That-Apply (CATA) test was administered to 120 respondents.
- Hedonic test revealed Cassava Root Mealiness attributes were dissolving easily, easy to chew, and soft.
- The CATA test showed that the most important mealiness attributes of boiled cassava roots were dissolving easily, easy to chew, and moderately soft.
- The JAR test results also revealed that the softness and chewiness of some cassava varieties scored above 50%, just about the right (JAR) values.
- This research intends to establish information that will assist breeders in developing improved cassava varieties that are mealable and acceptable to the consumers.

in Imo, Anambra, Benue, Kogi, Enugu, Ogun, Ondo, Taraba, Delta, and Osun, while it is also grown in smaller amounts in other states of Nigeria (FAO 2017). Studies have revealed cassava farmers attach equal value to agronomic performance and end-user culinary quality traits (Alene et al. 2013).

Therefore, new cassava varieties must have improved culinary qualities to improve their adoption by farmers and end users. In Nigeria, breeding efforts focus on improving cassava cooking and eating quality traits, predominantly mealiness, to address the increasing demand for varieties suitable for the fresh consumption market segment (Miranda et al. 2020). Consumers' adoption of cassava genotypes largely relies on their agronomic performance and end-user culinary qualities, such as root mealiness (Miranda et al. 2020). For boiled cassava, mealiness and hardness are essential textural parameters.

Consumers have considered mealiness as the most critical attribute of boiled cassava roots. Mealiness is the ease of disintegration of the boiled cassava, and processors reported it as an indicator of poundable cassava quality (Miranda et al. 2020; Adinsi et al. 2021). Mealiness is a term used to describe boiled cassava that is soft, easy to chew, and dissolves easily upon biting. Consumers prefer cassava that cooks faster or dissolves easily during cooking, and that requires less energy to cook (Adinsi et al. 2021). Therefore, the mealiness and texture of boiled roots are very high-priority traits for breeders (Alamu et al. 2022). It is vital to elicit the mealiness attributes or the descriptors of mealiness from the consumers, especially in areas where boiled cassava is consumed as a staple food, especially in Nigeria and other parts of West Africa.

Consumer's acceptability test is usually conducted with the consumers using a hedonic test (degree of like and dislike) where the panelists can be asked to indicate the degree of like or dislike for the product, but recently, the Just-About-Right (JAR) test and Check-All-That-Apply (CATA) test were developed to complement the results of the hedonic test and Just About Right test (Varela and Ares 2012). JAR and CATA methods are novel methods for determination of consumer acceptability of food products in consumer studies.

The JAR question seeks to determine the optimum intensity of a sensory attribute by asking consumers if they consider it too strong, weak, or just-about-right (Osunbade et al. 2021). JAR

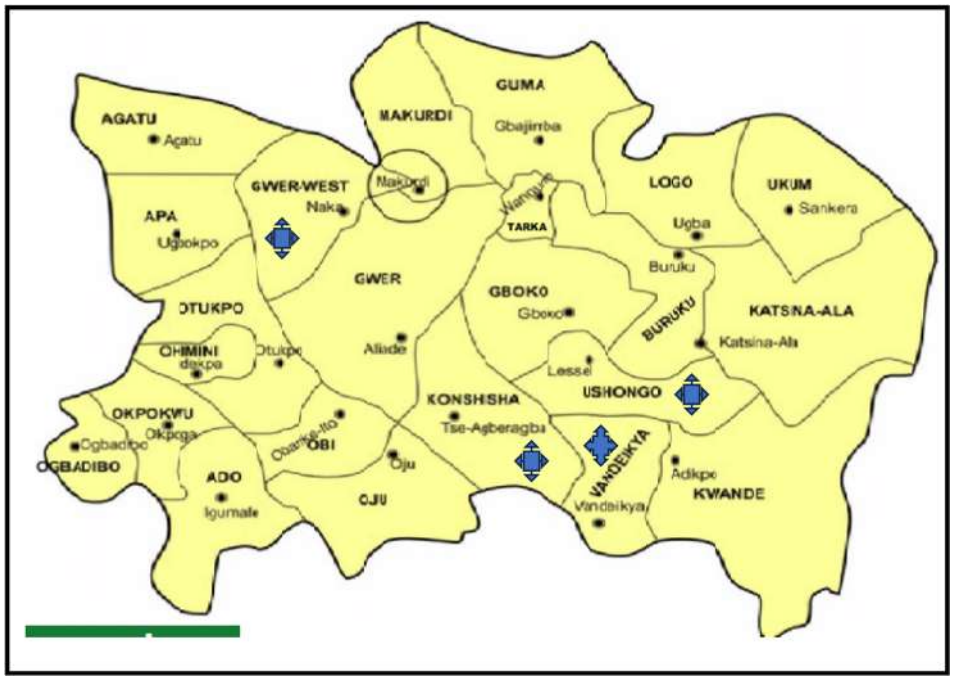

FIGURE 1 | Map of Benue state showing the selected local government area for the study.

TABLE 1 | Demographic profile of the respondents.

Location	Gwer East	Konshisha	Vandekya	Ushongo
Characteristics	Percentage	Percentage	Percentage	Percentage
Age (years)				
18–25	35.6	34.9	20.5	36.2
26–35	31.1	41.9	33.3	36.8
36–45	28.9	10.0	33.3	21.6
46–55	4.4	13.2	12.9	5.4
56–65	—	—	—	—
65 and above	—	—	—	—
Gender				
Male	71.1	53.5	78.4	61.5
Female	28.9	46.5	21.6	38.5
Religion				
Islamic	—	—	—	—
Christianity	100	100	100	100
Marital status				
Single	33.3	37.2	16.2	17.9
Married	62.2	62.8	81.1	66.7
Widow	—	—	—	7.7
Divorced	4.5	—	2.7	7.7
Occupation				
Farming	97.8	97.8	100	97.4
Artisans	2.2	—	—	2.6
Civil servant	—	—	—	—
Trading	—	2.2	—	—
Students	—	—	—	—
Others	—	—	—	—

methods tell us why the consumer likes or dislikes the product. It has a 3-scale for evaluating food materials where 1 stands for not enough, 2 stands for like as it is, and 3 stands for too much. The CATA test describes the products with all the descriptors that best describe them (Ares et al. 2010). The CATA, also known as "choose-all-that-apply," is a question format used in recent years to obtain rapid consumer product profiles. Consumers are presented with attributes and asked to indicate which words or phrases appropriately describe their experience with the evaluated sample (Ares and Jaeger 2013).

Previous studies have published information on the texture of boiled cassava roots and their mealiness using penetration tests (Thierry and Andres 2020; Miranda et al. 2020). Thierry and Andres (2020), Miranda et al. (2020) and Bechoff et al. (2018) used cooking time, water absorption, and starch content to describe the mealiness of cassava root, but there were no details on establishing the descriptors of mealiness of cassava, particularly from the consumer's end and its acceptability using descriptive methods. This research intends to determine the consumer's perceptions and sensory profiling of the mealiness attributes of cassava roots through a survey using individual interviews (IDI) and determining the consumer's acceptability of boiled cassava roots from some selected varieties using a 9-point hedonic scale, JAR, and CATA test.

2 | Methodology

2.1 | Sample Preparation

Four (4) freshly harvested cassava varieties (*danwarri, suppi, akpu*, and *dangbo*) of age 10–12 months were sourced from the farmers in the selected communities in Benue State. The roots were peeled, washed, both extremes of 2 cm were discarded to ensure uniformity, and the middle sections were cut into pieces

TABLE 2 | Preferred cassava varieties and their characteristics.

Variety	Cooking time	Quality characteristics
Danwarri	24.5 min	Early maturity, high yielding, cook faster, sweet, cracky, scatter easily when biting, moderately soft when boiled, melt/dissolve easily, milk color, easy to chew and break easily.
Suppi	22.0 min	High yielding, early maturity, cook faster, sweet, cracky, moderately chew, scatter easily when biting, milk color, moderately soft when boiled, melt/dissolve easily, easy to chew and break easily.
Miande	23.0 min	High yielding, early maturity, cook faster, sweet, cracky, moderately chew, scatter easily when biting, break easily, moderately soft when boiled, melt/dissolve easily, milk color and easy to chew.
Daniel	24.0 min	Early maturity, high yielding, cook faster, sweet, cracky, scatter easily when biting, moderately soft when boiled, melt/dissolve easily, milk color, easy to chew and break easily.
Banarda	36.0 min	Late maturity, high yielding, big roots, hard to cook, prolonged cooking time, hard to chew, not break easily, not scatter easily, milk color, not cracky, not sweet/bland.
Akpu	42.0 min	Late maturity, high yielding, big roots, hard to cook, prolonged cooking time, hard to chew, not break easily, not scatter easily, yellow color, not cracky, not sweet/bland.
Dangbo	29.9 min	Late maturity, high yielding, big roots, hard to cook, prolong cooking time, hard to chew, not break easily, not scatter easily, milk/cream color, not cracky, not sweet/bland.

TABLE 3 | Percentage of consumers who have scored the descriptors using the jar method.

Products	Not enough	JAR	Too much
Softness			
Danwarri	14.2%	82.5%	3.3%
Akpu	63.3%	28.3%	8.3%
Suppi	25.0%	60.8%	14.2%
Dangbo	82.5%	15.8%	1.7%
Chewiness			
Danwarri	5.8%	89.2%	5.0%
Akpu	25.8%	40.8%	33.3%
Suppi	14.2%	58.3%	27.5%
Dangbo	25.0%	20.8%	54.2%
Scattering			
Danwarri	15.8%	83.3%	0.8%
Akpu	64.2%	29.2%	16.7%
Suppi	30.0%	58.3%	11.7%
Dangbo	83.3%	15.0%	1.7%
Cracky			
Danwarri	30.0%	67.5%	2.5%
Akpu	58.8%	25.0%	19.2%
Suppi	32.5%	52.5%	15.0%
Dangbo	71.7%	15.8%	12.5%

Note: $n = 120$ consumers.

of 6.0 cm long and 5.5 cm diameter (Thierry and Andres, 2022), and then cut into half cylinders, boiled in water until a fork penetrates the cooked root and when it dissolved easily in between the fingers and upon biting. The boiled cassava was wrapped in aluminum foil and kept in a warmer for consumers' acceptability test.

2.2 | Consumers' Acceptability of Boiled Cassava

A multistage sampling technique described by Forsythe et al. (2021) was adopted for this study. Stage one involved a purposive selection of Local Government Areas (LGAs) in the state based on a high level of cassava production and consumption of boiled cassava (Figure 1). Stage two comprised selecting one community from each of the selected local government areas. Stage three involved the random selection of respondents that frequently consume boiled cassava in the selected communities. A well-structured questionnaire (Appendix 1) was used for the collection of information on different cassava roots and, particularly, on cassava mealiness attributes and consumers' acceptability of boiled cassava roots using a 9-point hedonic scale, Just-About-Right (JAR) and Check-All-That-Apply (CATA) test from 120 respondents across four selected local government areas (Vandekya [6°56′40.11″ N 9°6′51.20″ E]; Ushongo [6°59′30.9″ N 9°15′28.7″ E]; Konshisha [7°15′28.7″ N 8°32′18.38″ E] and Gwer East [7°19′54.71″ N 8°31′5.31″ E]) in Benue State, Nigeria that consume more of boiled cassava roots for individual interview (IDI) (Figure 1). The respondents selected across the Local Government Areas of Benue State are the major consumers of boiled cassava.

2.3 | Data Collection

Qualitative data collected from respondents (farmers and processors) were analyzed by coding and categorizing information on the quality characteristics of the raw and boiled roots. The ranked quality characteristics were analyzed based on the methodology described by Forsythe et al. (2021) using pairwise ranking. Responses from the participants were then transcribed to a pivot table in Microsoft Excel for thematic coding.

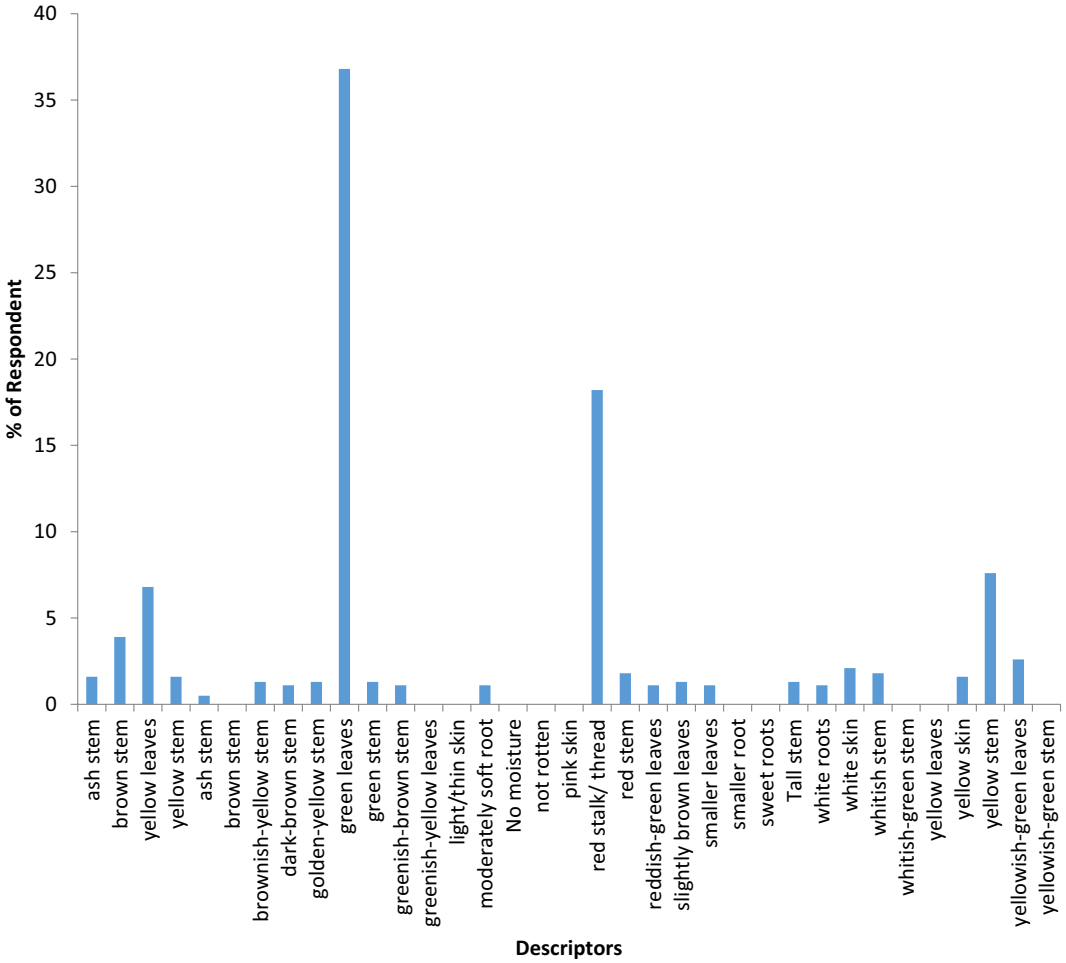

FIGURE 2 | Quality attributes of good cassava for boiling mentioned by male respondents.

2.4 | Statistical Analysis

The data obtained were analyzed using descriptive statistics such as percentages, frequencies, and chats from the Statistical Package for Social Sciences (SPSS version 16.0). The quality characteristics of cassava roots and boiled roots were analyzed using descriptive statistics such as percentages, frequencies, and chats.

3 | Results and Discussion

3.1 | Demographic Profile of the Respondents

The results obtained from demographic characteristics of the respondents on age, sex, marital status, and occupation in all the selected locations were presented in Table 1. The number of respondents interviewed in each community in Benue was between 36 to 43 people. The result of the age groups of the respondents in the selected communities, as shown in Table 1, in the categories of 18–25 years, 26–35 years, 36–45 years, 46–55 years, 56–65 years, and 65 years and above were 35.6%, 31.1%, 28.9%, 4.4%, 0.0%, and 0.0%, respectively, in Gwer-east. Konshisha's results were 34.9%, 41.9%, 10.0%, 13.2%, 0.0%, and 0.0% respectively. Vandekya reported 36.2%, 36.8%, 21.6%, 5.4%, 0.0% and 0.0%, respectively. Also, Ushongo's results were 20.5%, 33.3%, 33.3%, 12.9%, 0.0%, and 0.0%, respectively. The majority of respondents fall within the 18–55 age range, which suggests that they are likely to be more active consumers and likely to consume food products regularly based on cultural preferences and household needs. This is similar to the findings of the survey report of Levai et al. 2016, on consumer perceptions of cassava product (*gari*) prototypes in the Southwest region of Cameroon. More than 80% of the respondents were adults and above 20 years old. Also, in line with the findings of Honfozo et al. (2020) for boiled yam end-user preferences and implications for trait evaluation, where the respondents are 18–72 years old. Age plays a role in shaping food choices.

The results of the gender of the respondents showed that males had 71.1%, females had 28.9% in Gwer-east. In Konshisha, males had 53.5%, females had 46.5%; in Vandekya, males had 78.4%, females had 21.6%, and in Ushongo, males had 61.5% and females 38.5% (Table 1). This suggests that most of the respondents in the study area are males. This result aligns with the findings of Honfozo et al. (2020) that males constitute 57.8% of the respondents, while females were 42.2% in their study. Similarly, the finding is like the results of Tortoe et al. (2013), where males accounted for 69.1%, and females accounted for 30.9% in Sensory attributes and consumer preference for precooked vacuum-packaged yam from two varieties of Ghanaian yam (*Dioscorea rotundata*) in the Accra metropolitan area.

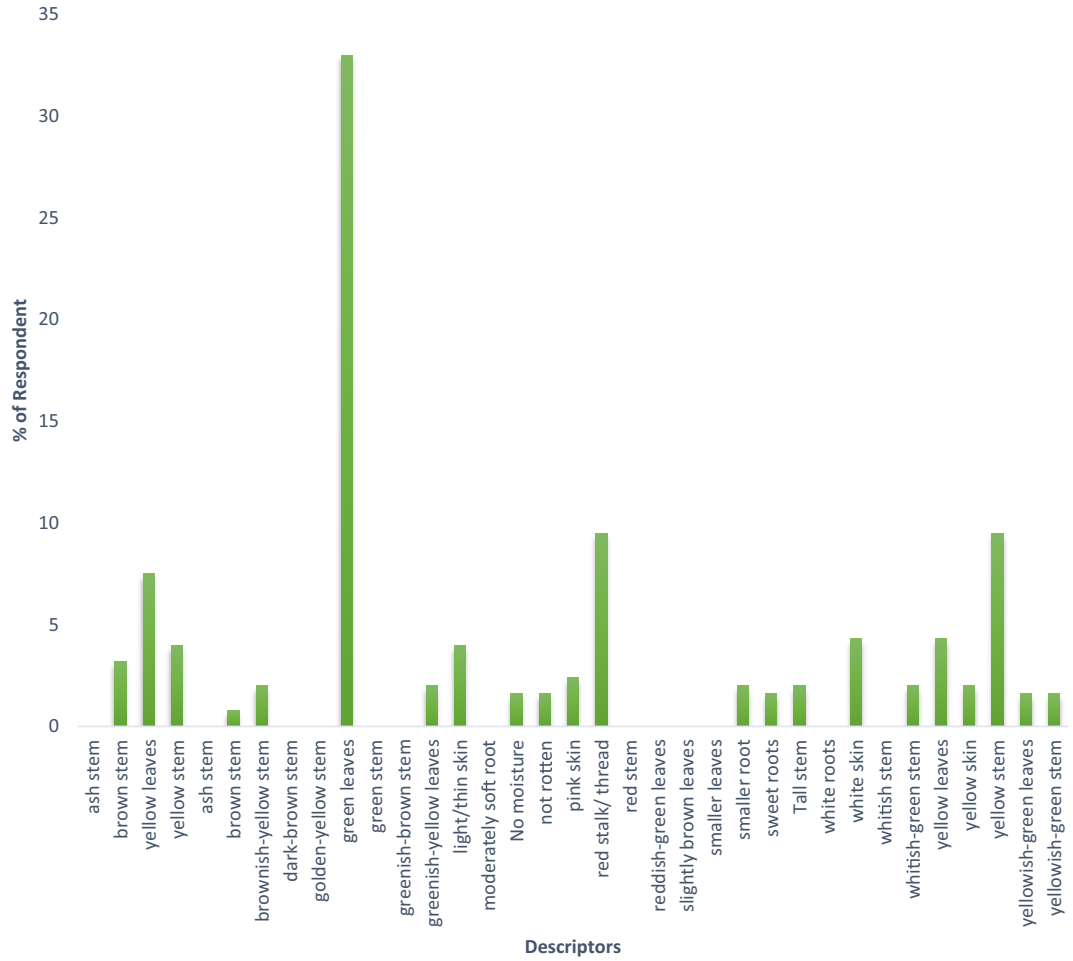

FIGURE 3 | Quality attributes of good cassava for boiling mentioned by female respondents.

TABLE 4 | Ranked agronomic characteristics of cassava varieties suitable for boiling.

Rank	Characteristic	Specific characteristics
1 **(Highest Priority)**	**Root quality**	Moderately soft root, low moisture, not rotten, sweet roots, white roots
2	**Stem characteristics**	Brown stem, dark-brown stem, golden-yellow stem, red stem, whitish stem, whitish-green stem, yellow stem, greenish-brown stem, greenish-yellow stem, brownish-yellow stem
3	**Leaf color and size**	Green leaves, yellow leaves, reddish-green leaves, slightly brown leaves, smaller leaves
4	**Skin and thread color**	Light/thin skin, pink skin, yellow skin
5	**Plant height and root size**	Tall stems, smaller root
6 **(Lowest Priority)**	**Other observations**	Green stem, ash stems, yellowish-green stem, yellowish-green leaves

The result of marital status revealed that 33.3% are single, 62.2% are married, 0% are widows, and 4.5% are divorced in Gwer East. In Konshisha, 37.2% are single, and 62.8% are married. Vandekya reported that 16.2% are single, 81.1% are married, and 2.7% are divorced. Also, in Ushongo, 17.9% are single, 66.7% are married, 7.7% are widows, and 7.7% are divorced (Table 1). This is in line with the report of Muhammad-Lawal et al. (2013) from the assessment of the economics of cassava processing in Kwara State, Nigeria, in which 89.0% of the respondents were married. This finding is also similar to the report of Nzeh and Ugwu (2014) on the production and marketing of cassava in Akoko, Ondo State, which revealed that 60% of the respondents are married. This was also similar to the findings of Adetarami and Olagunju (2022), in which 86.8% of the respondents were married among the farmers in Ogun State during the survey. This was also in line with the report of Bello et al. (2022), in which 89.0% of the respondents were married. This finding was also similar to the report of Teeken et al. (2019), in which

more than 60% of the respondents are married. Marital status may influence preferences, consumption patterns, and sensory acceptance due to factors such as household responsibilities, dietary habits, and food preparation roles. Married individuals, especially those responsible for meal preparation, may develop a stronger preference for cassava products that are easy to cook, versatile, and align with family preferences.

The results of occupation revealed the highest value in farming for Gwer-east (97.8%), Konshisha (97.8%), Vandekya (100%), and Ushongo (97.4%) (Table 1). This shows that the people of Benue State, Nigeria, occupation is mainly farming. This was similar to the findings of Ndjouenkeu et al. 2020 and Osunbade et al. (2021) conducted in Benue State, Nigeria. It was observed that regardless of the area (Region/State), agriculture is the main livelihood activity, with food crops and cash crops (coffee, palm oil trees, and cocoa) being commonly farmed in all localities of Benue State, with cassava as the primary food crop farmed. Though in all localities, actors involved in agricultural activities originate from different national ethnic groups, the ethnicity of actors is native-dominated in Nigerian states (Yoruba in Osun state, Tiv in Benue state). This finding was contrary to the survey report of Levai et al. (2016) on the respondents' occupations in the Southwest region of Cameroon, in which trading accounted for 45%, followed by studentship (29.6%) while farming accounted for 6.3% (Tables 2 and 3).

TABLE 5 | Ranking of cassava quality attributes by gender.

Rank	Males (%)	Females (%)
1	Green leaves (36.8%)	Green leaves (33%)
2	Red stalk/thread (18.2%)	Red stalk/ thread (9.5%)
3	Yellow stem (7.6%)	Yellow leaves (9.5%)
4	Yellow leaves (6.8%)	White skin (4.3%)
5	Brown stem (3.9%)	Light/thin skin (4%)
6	Yellowish-green leaves (2.6%)	Brown stem (3.2%)
7	White skin (2.1%)	Pink skin (2.4%)
8	Whitish stem (1.8%)	Brownish-yellow stem (2%)
9	Yellow skin (1.6%)	Not rotten (1.6%)
	—	Sweet root (1.6%)

3.2 | Quality Characteristics of Cassava Roots and Mealiness of Cassava

The findings from the respondents on the mealiness of cassava roots showed the quality characteristics of the cassava variety that is good for boiling, as mentioned by the farmers and consumers familiar with the varieties in Benue State, Nigeria (Figure 2 and Figure 3). According to the respondents from an agronomical point of view, a good cassava variety has green leaves, red stalk/thread, brown stem, yellow leaves, yellow stem, ash stems, brown stem, brownish-yellow stem, dark-brown stem, golden-yellow stem, green leaves, green stem, greenish-brown stem, greenish-yellow leaves, light/thin skin, moderately soft root, low moisture, not rotten, pink skin, red stem,

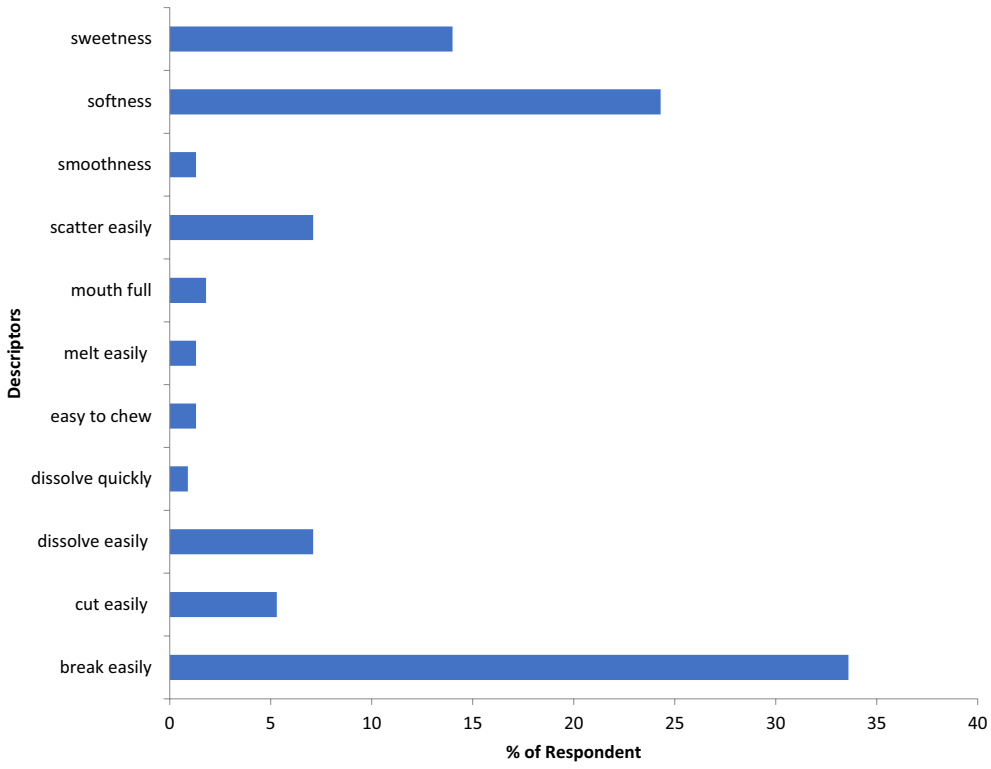

FIGURE 4 | Mealiness attributes of boiled cassava mentioned by male respondents.

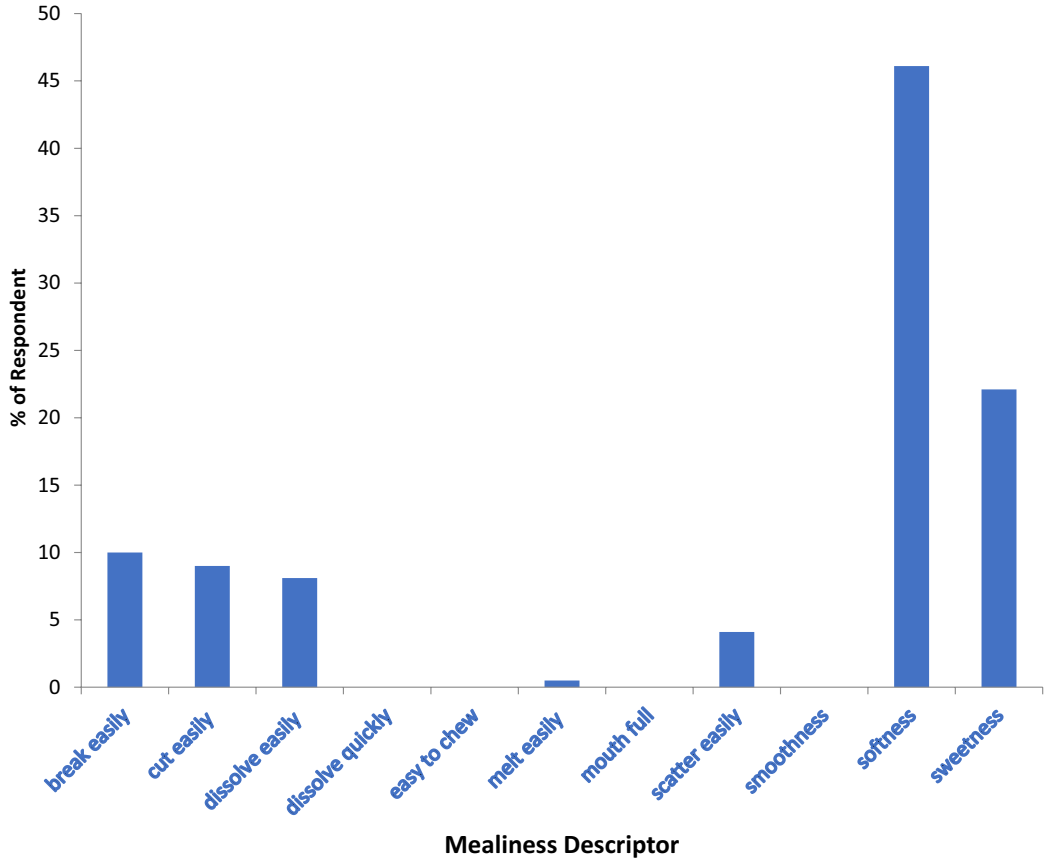

FIGURE 5 | Mealiness attributes of boiled cassava mentioned by female respondents.

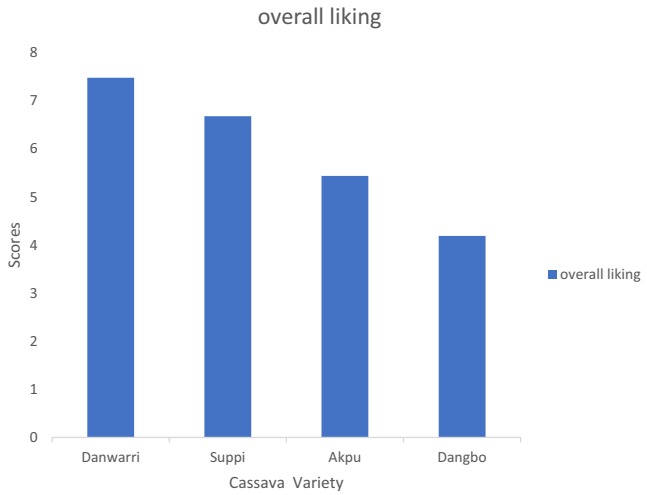

FIGURE 6 | Hedonic test: Overall liking of the boiled cassava.

reddish-green leaves, slightly brown leaves, smaller leaves, and smaller root. As mentioned by the respondents, other agronomic characteristics are sweet roots, tall stems, white roots, white skin, whitish stem, whitish-green stem, yellow leaves, yellow skin, yellow stem, yellowish-green leaves, and yellowish-green stem (Table 4). Among the quality attributes mentioned by the respondents, males ranked green leaves first (36.8%), followed by red stalk/thread (18.2%), yellow stem (7.6%), yellow leaves (6.8%), brown stem (3.9%), yellowish-green leaves (2.6%), white skin (2.1%), whitish stem (1.8%) and yellow skin (1.6%) in that order. Meanwhile, females ranked green leaves first (33%), followed by red stalk/thread (9.5%), yellow leaves (9.5%), white skin (4.3%), light/thin skin (4%), brown stem (3.2%), pink skin (2.4%), brownish-yellow (2%), not rotten (1.6%) and sweet root (1.6%) in that order. Table 5 highlights gender-based differences in ranking cassava quality attributes, with both males and females prioritizing green leaves but differing in subsequent preferences.

The descriptors of mealiness of boiled cassava upon biting in the mouth, as mentioned by the consumers during the survey, are shown in Figures 4 and 5. The quality attributes mentioned are softness, white color, sweetness, dissolve easily, melt easily, break easily, cut easily, dissolve quickly, easy to chew, mouth full, scatter easily, and smoothness. Among the quality attributes mentioned by the respondents, males ranked break easily first (33.6%), followed by softness (24.3%), sweetness (14%), scatter easily (7.1%), dissolve easily (7.1%), cut easily (5.3%), mouth full (1.8%), smoothness (1.3%) and dissolve quickly (0.9%) in that order (Figure 4). Some of the descriptors of mealiness of cassava, like softness, white color, sweetness, and easy to chew, mentioned by the respondents were similar to the findings of Osunbade et al. (2023) on end-user quality characteristics and preferences for cassava, yam, and banana products in rural and urban areas. On the other hand, females ranked softness (46.1%) as the most essential quality attribute of mealiness of cassava roots, followed by sweetness (22.1%), break easily (10%), cut easily (9%), dissolve easily (8.1%), and scatter easily (4.1%) in that order (Figure 5). This translates to the understanding that cassava roots with these attributes may be mealy and poundable. These results were similar to the findings of Bechoff

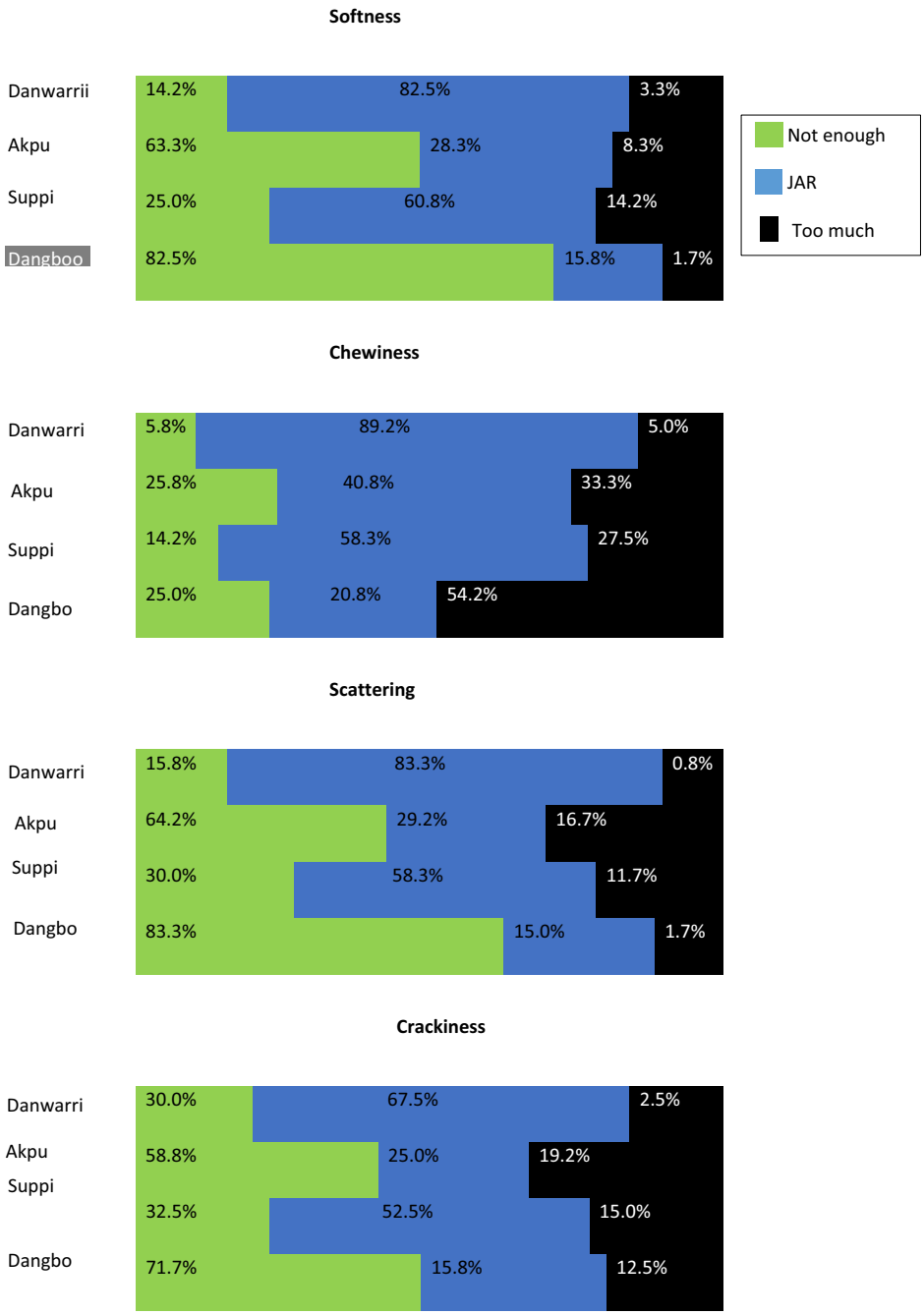

FIGURE 7 | JAR results of consumers' acceptability of boiled cassava roots.

et al. (2018), who revealed that good-boiled cassava is not hard and soft (ease of cooking). According to them, softness is a fundamental criterion for the sensory quality of boiled cassava. Demographic characteristics play a crucial role in this study as they provide insights into how factors such as age, gender, marital status, and occupation influence consumer preferences, food choices, and quality perceptions of cassava roots and boiled cassava mealiness.

3.3 | Preferred Varieties and Their Characteristics

The cassava varieties the participants cultivated were landraces and improved varieties from the *Manihot esculentus* species. The commonly cultivated varieties in Benue State were *danwarri, banada, imande, TMS 419, akpu, suppi, dangbo, daniel*, and *miande*. From the survey findings, *the respondents mentioned daniel, danwarri, and suppi* as good cassava roots for boiling and pounding. According to the consumers, those varieties cooked faster, scattered easily when biting, were easy to chew in the mouth, soft, cracky, broke easily, and were sweet (Table 2). They are consumed alone, with groundnut, oil, and stew. On the other hand, *akpu, dangbo, 419*, and *banada* were not suitable for boiling and pounding because they are hard to cook, strong, and bitter.

This finding showed that cassava varieties such as *daniel, danwarri, and suppi* are consumed as boiled cassava in the selected

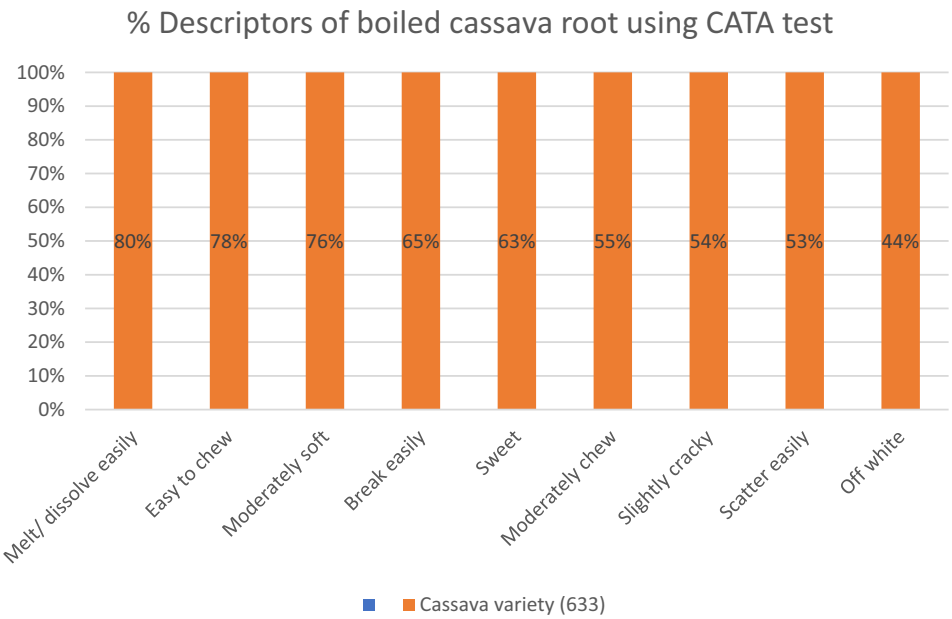

FIGURE 8 | Percentage descriptors of boiled cassava root using Check-All-That-Apply. Cassava variety: *Danwarri*.

TABLE 6 | Descriptors of mealiness of boiled cassava using CATA test for the most preferred variety.

Attribute	Cassava variety (*danwarri*)	Rank
Melt/dissolve easily	80%	1
Easy to chew	78%	2
Moderately soft	76%	3
Break easily	65%	4
Sweet	63%	5
Moderately chew	55%	6
Slightly cracky	54%	7
Scatter easily	53%	8
Off white	44%	9

LGAs of Benue State. This finding was in line with the work of Bechoff et al. (2018), which revealed that the most crucial cassava product consumed is freshly boiled cassava, followed by *gari* (70% of the production of Nigeria), *fufu*, and *lafun*. A study by Iragaba et al. (2020) also found that smallholder farmers in different districts grow different varieties due to ease of access to planting materials within a community. Information gathered from FGDs indicated that these local varieties are most preferred because they produce white, soft, sweet, and aromatic boiled cassava (Table 2). Similar to our finding, previous studies reported that local varieties were preferred (Nakabonge et al. 2018). On the other hand, akpu, dangbo, and 419 varieties are strong, hard to cook, hard to chew, and bitter. Bechoff et al. (2018) revealed that cassava varieties that do not cook well can still be hard after a prolonged cooking period, affecting the product's acceptability.

3.4 | Consumer's Acceptability Test Using 9-Point Hedonic Test, JAR Test, and CATA Test

The results of overall liking scores revealed that *danwarri* and *suppi* varieties were rated high (7.48 and 6.68) while *akpu* and *dangbo* varieties were rated low (5.44, 4.19) (Figure 6). *Danwarri*, *suppi*, and daniel are good for boiled cassava and can be eaten just like boiled yam alone, with groundnut, palm oil, and vegetable oil. *Akpu* and *dangbo* varieties are strong, hard to chew, do not break easily, and are bitter upon biting in the mouth (Table 2). Overall liking of the selected four boiled cassava varieties in Benue State shows that *danwarri* varieties were the most preferred, followed by *suppi*, *akpu*, while *dangbo* is the less preferred one.

Just-About-Right (JAR) test further confirmed *danwarri* variety as the most preferred sample by 86.3% of consumers in term of softness, 89.2% of consumers' in term of chewiness, 83.3% of consumers in term of scattering and also in term of cracky, 67.5% consumers like it as it is (Table 3; Figure 7). JAR test showed that *danwarri* variety was the most preferred sample in term of softness, chewiness, scattering, and cracky, followed by *suppi, akpu*, and *dangbo* varieties. This was in accordance with 9-point hedonic results that scored danwarri highest, followed by *suppi, akpu*, *and dangbo*.

Check-All-That-Apply (CATA) test established the good quality characteristics and the poor-quality characteristics of boiled cassava sample focusing on the most preferred sample (*danwarri*) by the consumers in Benue State according to frequency distributions (Figure 8; Table 6). By using frequencies descriptive statistics, the characteristics of cassava roots that are good for boiling and pounding were dissolve easily (80%), easy to chew (78%), moderately soft (76%), break easily (65%), sweet (63), moderately chew (55%), slightly cracky (54%), scatter easily (53%), and off white (44%) (Table 6). Similarly, the non-preferred descriptors established by consumers in Benue State include not

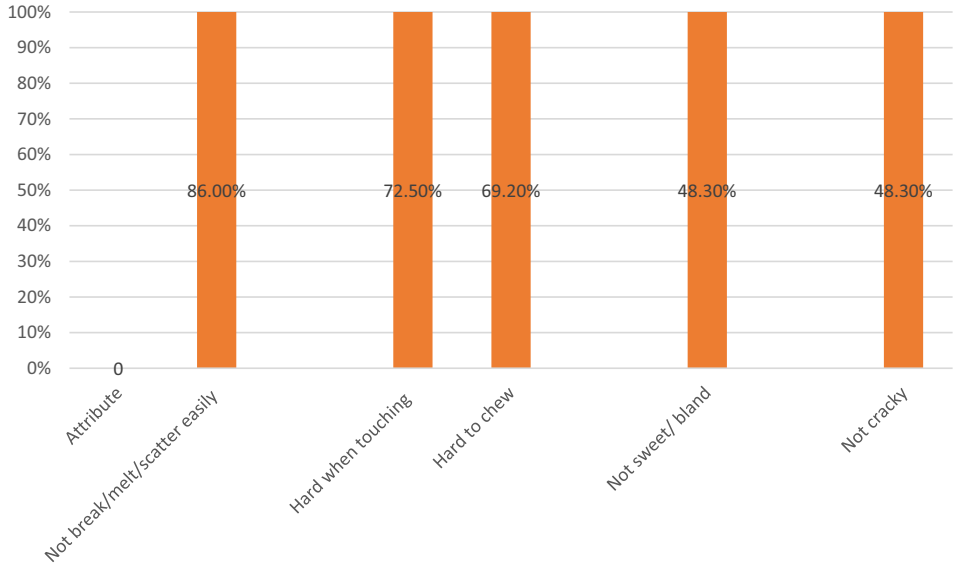

FIGURE 9 | Non-preferred quality of cassava root using Check-All-That-Apply. Cassava variety: *Dangbo*.

TABLE 7 | Quality attributes of non-preferred boiled cassava using CATA test.

Attribute	Cassava variety (*Dangbo*)	Rank
Not break/melt/ scatter easily	86.0%	1
Hard when touching	72.5%	2
Hard to chew	69.2%	3
Not sweet/bland	48.3%	4
Not cracky	48.3%	5

breaking/melting/scattering easily, hard when touched, hard to chew, not sweet/bland, and not cracky associated with *dangbo* variety (Figure 9; Table 7). CATA questionnaires have proved to be simple alternatives in order to assess consumers' perceptions with regard to food products (Osunbade et al. 2021). The information presented in this paper with an in-depth laboratory characterization of the raw roots and the product is essential to identify product profiles within breeding. The findings will help breeders to develop improved cassava varieties that will be acceptable to multi-end-users.

4 | Conclusion

The studies revealed that the mealiness attributes of cassava mentioned by the consumers using individual interviews were softness, chewiness, dissolving easily, and scattering easily. The 9-point hedonic test established that *danwarri* and *suppi* varieties were the most preferred boiled cassava with an overall liking score of 7.48 and 6.68. The CATA test also established that mealiness attributes of boiled cassava were dissolving easily, followed by easy to chew and moderate softness. The Check-All-That-Apply (CATA) test shows that *danwarri* dissolved easily upon biting in the mouth, is easy to chew, moderately soft, and breaks easily. The Just-About-Right (JAR) test further revealed that *danwarri* and *suppi* varieties are good in terms of softness, chewiness, scattering, and crackiness. The three methods established those mealiness attributes and revealed that *danwarri* and *suppi* varieties were the acceptable boiled cassava by the consumers.

5 | Recommendation

After careful evaluation of the results obtained from cassava roots mealiness using four selected cassava roots (*danwarri, suppi*, *akpu*, and *dangbo*) cultivated in Benue State, this study recommends that *danwarri and suppi* varieties are the best mealy cassava good for boiling generally acceptable to the consumers. Other varieties cultivated in South-West and South–South Nigeria, such as *okoiyawo, odongbo, molekaga*, and *banada*, should be evaluated for mealiness attributes for consumption as boiled roots.

Author Contributions

O. A. Osunbade: conceptualization (equal); initial draft writing (lead); writing, review and editing (lead). **E. O. Alamu:** conceptualization (equal); writing-original draft (supporting); writing, review and editing (supporting). **W. Awoyale:** conceptualization (equal); original draft writing (supportive); Writing, Review and Editing (supporting). **M. Adesokan:** conceptualization (equal); original draft writing (supportive); writing, review and editing (supporting). **G. Nwaoliwe:** conceptualization (assistance); data collection (supporting); writing, review and editing (supporting). **B. A. Akinwande:** conceptualization (helpful); writing-first draft (helpful); writing-review and editing (supporting). **J. A. Adejuyitan:** conceptualization (assistance); Writing-review and editing (supporting). **M. Lungaho:** conceptualization (assistance); writing-review and editing (supporting). **B. Maziya-Dixon:** conceptualization (assistance); writing, review and editing (supporting).

Acknowledgments

This work was made possible through the assistance of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Our appreciation also goes to Mr. Adebayo Olatunji (LAUTECH), Ayodele Adenekan, and Hakeem Adebowale (IITA) for assisting in data collection. The authors also acknowledge the support of the cassava breeding unit of IITA, Ibadan, Nigeria (especially Mr. Peter Elluebey).

Ethics Statement

This study does not require ethical approval.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

Abass, A., N. T. Dziedzoave, B. E. Alenkhe, and B. D. James. 2012. *Quality Management Manual for the Production of "Gari"*, 11–12. IITA.

Adetarami, O., and O. O. Olagunju. 2022. "Use of Agricultural Programmes' Technical Information on Adoption of Improved Technologies by Cassava Farmers in Ogun State." *Nigerian Agricultural Journal* 53, no. 1: 113–123. https://www.researchgate.net/publication/361765109.

Adinsi, L., L. Honfozo, and N. Akissoe. 2021. *Sample Preparation and Cooking Time for Texture Analysis of Boiled Yam. Biophysical Characterization of Quality Traits, WP2*, 15. Cotonou, Benin: RTBfoods Laboratory Standard Operating Procedure.

Alamu, E. O., M. Adesokan, W. Awoyale, et al. 2022. "Assessment of Biochemical, Cooking, Sensory and Textural Properties of the Boiled Food Product of White Yam (*D. rotundata*) Genotypes Grown at Different Locations." *Heliyon* 8: 1–7 e11690.

Alene, A. D., R. Khataza, C. Chibwana, P. Ntawuruhunga, and C. Moyo. 2013. "Economic Impacts of Cassava Research and Extension in Malawi and Zambia." *Journal of Development and Agricultural Economics* 5, no. 11: 457–469.

Ares, G., C. Barreiro, R. Deliza, A. L. Giménez, and A. Gámbaro. 2010. "Application of a Check-All-That-Apply Question to the Development of Chocolate Milk Desserts." *Journal of Sensory Studies* 25, no. 1: 67–86. https://doi.org/10.1111/j.1745-459X.2010.00290.x.

Ares, G., and S. R. Jaeger. 2013. "Check-All-That-Apply Questions: Influence of Attribute Order on Sensory Product Characterization." *Food Quality and Preference* 28, no. 1: 141–153. https://doi.org/10.1016/j.foodqual.08.016.

Bechoff, A., U. Chijioke, A. Westby, and K. I. Tomlins. 2018. "'Yellow Is Good for You': Consumer Perception and Acceptability of Fortified and Biofortified Cassava Products." *PLoS One* 13, no. 9: 1–8. https://doi.org/10.1371/journal.pone.0203421.

Bello, A., O. Olaosebikan, O. A. Osunbade, et al. 2022. *Consumer Testing of "Eba" in Rural and Urban Areas in Nigeria. Understanding the Drivers of Trait Preferences and the Development of Multi-User. RTB Product Profiles, WP1, Step 4. Ibadan*, 26. RTBfoods Field Science Report. https://doi.org/10.18167/agritrop/00631.

FAO. 2017. "Food Outlook." Biannual Report on Global Food Markets.

FAOSTAT. 2021. "Commodities by Country Ranking." www.fao.org/faostat/en/#rankings/commodities_by_country.

Forsythe, L., H. Tufan, A. Bouniol, U. Kleih, and G. Fliedel. 2021. "An Interdisciplinary and Participatory Methodology to Improve User Acceptability of Roots, Tuber and Banana Varieties." *International Journal of Food Science & Technology* 56: 1115–1123.

Honfozo, H., L. Adinsi, A. Bouniol, et al. 2020. "Boiled Yam End-User Preferences and Implications for Trait Evaluation." *International Journal of Food Science and Technology* 56, no. 3: 1–11. https://doi.org/10.1111/ijfs.14707.

IITA. 2012. "An Annual Report on Cassava Production." http://newint.iita.org/wp-content/uploads/2016/04/Annual-Report-2012.pdf.

Iragaba, P., R. S. Kawuki, G. Bauchet, et al. 2020. "Genomic Characterization of Ugandan Smallholder Farmer-Preferred Cassava Varieties." *Crop Science* 60, no. 3: 1450–1461. https://doi.org/10.1002/csc2.20152.

Levai, L. D., M. A. Nsimi, G. Nana, et al. 2016. "Consumer Perception of Gari Prototypes and Prospects for Improvement and Marketing in the Southwest Region of Cameroon." *International Journal of Agriculture and Environmental Research* 2, no. 5: 1304–1318.

Miranda, L. A., W. A. Spinosa, T. M. Destro, H. Souza-Junior, and V. Nascimento. 2020. "Sweet Cassava Cooking Time." *Agronomy Science and Biotechnology* 6: 1–16. https://doi.org/10.33158/asb.r109.v6.2020.

Muhammad-Lawal, A., O. A. Omotesho, and F. A. Oyedemi. 2013. "An Assessment of the Economics of Cassava Processing in Kwara State, Nigeria." A Paper Presented at the 4th International Conference of the African Association of Agricultural Economists, September 22–25, Hammamet, Tunisia.

Nakabonge, G., C. Samukoya, and Y. Baguma. 2018. "Local Varieties of Cassava: Conservation, Cultivation and Use in Uganda." *Environment, Development and Sustainability* 20, no. 6: 2427–2445. https://doi.org/10.1007/s10668-017-9997-6.

Ndjouenkeu, R., F. N. Kegah, B. Teeken, et al. 2020. "From Cassava to Gari: Mapping of Quality Characteristics and End-User Preferences of Food Products in Cameroon and Nigeria." *International Journal of Food Science and Technology* 56: 1223–1238.

Nzeh, E. C., and J. N. Ugwu. 2014. "Economic Analysis of Production and Marketing of Cassava in Akoko North-West Local Government Area of Ondo State, Nigeria." *Research Journal of Agriculture and Environmental Management* 3, no. 7: 310–314.

Osunbade, A. O., E. O. Alamu, W. Awoyale, A. B. Akinwande, J. A. Adejuyitan, and B. Maziya-Dixon. 2023. "End-User Quality Characteristics and Preferences for Cassava, Yam and Banana Products in Rural and Urban Areas -A Review." *Cogent Food and Agriculture* 9, no. 1: 1. https://doi.org/10.1080/23311932.2023.2205720.

Osunbade, O. A., T. S. Ajiboye, O. A. Adisa, O. Olatunji, and I. Oyewo. 2021. "Evaluation of Consumers Acceptability of Cassava Cooked Paste (EBA) Using 9-Points Hedonic, JAR and CATA Methods." *International Journal of Multidisciplinary Research and Publications* 4, no. 4: 48–54.

Teeken, B., B. Abolore, O. Olaosebikan, and D. Owoade. 2019. Synthesis Report of the State of Knowledge for the Cassava Food Product *Gari-Eba* Ibadan, Nigeria. RTBfoods Project Report.

Thierry, T., and E. Andres. 2020. "Biophysical Characterizations of Quality Traits." SOP: Preparation of Samples for Water Absorption, Cooking Time and Texture: *Boiled cassava*, 5–7.

Tortoe, C., S. Nketia, M. Owusu, P. T. Akonor, S. Dowuona, and E. Otoo. 2013. "Sensory Attributes and Consumer Preference of Precooked Vacuum-Packaged Yam From Two Varieties of Ghanaian Yam (*Dioscorea rotundata*) in the Accra Metropolitan Area." *Advances in Research* 2, no. 1: 40–51.

Varela, P., and G. Ares. 2012. "Sensory Profiling, the Blurred Line Between Sensory and Consumer Science. A Review of Novel Methods for Product Characterization." *Food Research International* 48: 893–908.

Appendix 1

Questionnaire on Consumer Acceptability Test for Boiled Cassava

1. Name of the village/town/City: .....

2. Name of the respondent:.....

3. Sex:.....

4. Age:.....

5. Religious.....

6. Ethnicity.....

7. Nationality.....

8. Occupation.....

9. Education.....

10. **Consumption pattern:**

a. How often do you consume boiled yam? Every day [ ], several times a week [ ], once a week [ ], Several times a month [ ], once a month [ ].

b. What do you consume boiled cassava with? Eat alone [ ], eat with palm oil [ ], eat with vegetable oil [], eat with beans [ ], eat with groundnut [ ].

How can you describe cassava that is mealy upon biting in the mouth (*ki ege tuu*).....

Tasting of boiled cassava

You are invited to taste the four products, one after the other and in the order indicated in the questionnaire. Tick the score that best describes the sample.

Product no **(633)**

Overall liking (9-point hedonic scale).

☐ 1 = dislike extremely.

☐ 2 = dislike very much.

☐ 3 = dislike moderately.

☐ 4 = dislike slightly.

☐ 5 = neither like nor dislike.

☐ 6 = like slightly.

☐ 7 = like moderately.

☐ 8 = like very much.

☐ 9 = like extremely.

Overall comments.....

Which sample is the best.....

Why.....

JAR TEST

How do you appreciate the descriptors below, tick the scale that best describe the sample

SOFTNESS

1=Not soft enough **2=As I like** **3=Too soft**

CHEWINESS

1=Too easy to chew **2=As I like** **3=Too hard to chew**

SCATTERING

1=Not scattered enough **2=As I like** **3=Too scattered**

CRACKY

1=Not enough **2=As I like** **3=Too crack**

CATA (CHECK-ALL-THAT-APPLY) TEST

Click all the descriptors that describe the samples.

☐ Slightly soft	☐ scatter easily	☐ bitter
☐ Moderately soft	☐ melt/dissolve easily	☐ milk/cream
☐ Too soft	☐ Not break/melt/scatter easily	☐ off white
☐ Hard	☐ cracky	☐ yellow
☐ Easy to chew	☐ slightly cracky	
☐ Moderately chew	☐ not cracky	
☐ Hard to chew	☐ sweet	
☐ Break easily	☐ not sweet/bland	

Overall comments……..

Which sample is the best……

Why……