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To cite this article: Laurenda F. Honfozo, Imayath M. Djibril Moussa, Laurent Adinsi, Alexandre Bouniol, Sounkoura Adetonah, Flora J. Chadare, Wilfried S. Padonou, Joseph D. Hounhouigan, Lora Forsythe & Noël H. Akissoe (2023) Cross-approaches for advising cassava trait-preferences for boiling, Cogent Food & Agriculture, 9:1, 2253716, DOI: [10.1080/23311932.2023.2253716](https://doi.org/10.1080/23311932.2023.2253716)

To link to this article: <https://doi.org/10.1080/23311932.2023.2253716>



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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Cross-approaches for advising cassava trait-preferences for boiling

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Received: 05 May 2022

Accepted: 26 August 2023

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Abstract: Cassava is one of the most common food crops grown and consumed in many parts of Africa, and boiled cassava is especially popular in West Africa. However, its quality characteristics and attributes are not well documented. This study aimed at generating data to produce useful information on cassava trait preferences for boiling. To understand end-users' trait-preferences for raw and boiled cassava, the study used a mix of approaches including a qualitative survey, process diagnosis and consumer testing. Gender-disaggregated data on cassava varieties were clustered into three categories: “common varieties with similar rank”, “common varieties but differently ranked” and “varieties exclusively cited by women or men”. Raw cassava root for making high-quality boiled cassava should have cracked peel, a sweet taste, and white flesh. Irrespective of cassava varieties, the three descriptors: “hard to break in the hand”, “not crumbly in the mouth” and “too bitter tasting” greatly penalized the overall liking, lowering values by a range of 2.2 to 2.6 on a nine-point scale (i.e. by about a quarter). Accordingly, high-quality boiled cassava should be attractive with white, homogenous flesh, a sweet taste, easy to break in the hand, crumbly in the mouth, and fiber-free.

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Subjects: Food Chemistry; Food Engineering; Gender Studies;

Keywords: cassava varieties; boiled cassava; gendered trait preferences; quality characteristics; consumer testing; penalty analysis

1. Introduction

Cassava (*Manihot esculenta* Crantz) root is an important starchy staple crop cultivated and consumed in tropical and sub-tropical areas including many countries in Africa, Asia and America (Abdullahi et al., 2014; Agre et al., 2015; Food and Agriculture Organization of the United Nations, [FAOSTAT] 2019; Hongbété et al., 2011). It is traditionally cultivated by many smallholder farmers, since it grows well in various soil types, ecologies and farming systems. Cassava roots are consumed in Benin in several forms, including boiled in water, roasted, fried, and fermented, or after conversion into intermediate products, such as *gari*, *agbeli*, flour (*lafun*), tapioca or starch (Padonou et al., 2005). In West Africa, there are many cassava varieties which are distinguished by specific characteristics, making them suitable for processing into a specific cassava-based product. For instance, roots from sweet cassava varieties with lower cyanogenic glucosides content are boiled or roasted prior to consumption (Bechoff et al., 2017; Boakye Peprah et al., 2020; Conn, 1994; Iragaba et al., 2021; Uchechukwu-Agua et al., 2015). Conversely, the bitter varieties with high cyanogenic glucosides content require further elaborated processing to reduce the cyanogenic glucosides content to an acceptable level prior to consumption (Bechoff et al., 2017; Boakye Peprah et al., 2020; Conn, 1994; Iragaba et al., 2021; Uchechukwu-Agua et al., 2015).

As far as boiled cassava is concerned, it is consumed at all meals and as a snack in rural and urban areas of Benin (Padonou et al., 2005). The main quality attributes of boiled cassava demanded by consumers are a white color (yellow-fleshed varieties being less attractive), a crumbly texture and a sweet taste (Hongbété et al., 2011; Iragaba et al., 2021; Padonou et al., 2005). The acceptance of a given cassava variety undoubtedly relies on its conformity with major quality descriptors used to assess its suitability for processed end-products. For boiled cassava, there is scant attention paid to prioritizing quality attributes or explaining reductions (penalty) in overall liking. Indeed, these quality characteristics were often examined through one-way surveys that exclusively focused on one specific stakeholder group (consumers or processors). We assume that a holistic study, that includes triangulation using different tools (qualitative survey, process diagnosis, and consumer testing) and sources of information (focus group discussion with farmers, processors, traders, and consumers) will more comprehensively elucidate the quality characteristics of the end-products.

The rationale for selecting and planting cassava varieties is gender-dependent (Masamha, 2018; Teeken et al., 2018). However, for boiled cassava, there are few studies focusing on gender preferences. Iragaba et al. (2021) reported that differential gender preferences are not transposable from one district to another; thus, any gender-preference study has to be thoroughly examined so breeders can cross-check available information. Understanding boiled-cassava quality characteristics should therefore receive more research attention, which would help in the selecting of the appropriate varieties for boiling.

Indeed, over the years, breeders have mostly focused on improving agronomic traits (pest resistance, drought resistance, improved yield) and to a much lesser extent nutritional status (through bio-fortification to improve micronutrient content). This reflects the nature of the new and improved cassava varieties that have been distributed to and promoted among local farmers in sub-Saharan and South American countries (Iragaba, 2019). Generally, consumer demand is mostly governed by sensory perceptions associated with the end-products (Awoyale et al., 2020; Forsythe et al., 2021). Thus, there is the need to explore quality characteristics of raw and boiled cassava for promoting a new alliance between end-users' preferences and breeding. Recently, an interdisciplinary and participatory methodology has been reported to assess user acceptability of

root, tuber and banana varieties, with the ultimate aim of informing breeding programmes in trait selection (Forsythe et al., 2021). This robust approach was developed to identify demand for quality characteristics among diverse users' groups along the food chain. From this perspective, the current study aimed at identifying the quality characteristics of raw and boiled cassava expected by farmers, processors, and consumers, and at understanding consumer demand for boiled-cassava quality characteristics employing cross-cutting studies.

2. Methodology

This study was undertaken following an interdisciplinary and participatory methodology reported by Forsythe et al. (2021) comprising three successive steps. The first step involves a gendered qualitative survey along the food chain to identify the priority quality characteristics of cassava roots and boiled cassava. The second step conducts a participatory processing diagnosis with skilled processors, to evaluate the desirable characteristics of cassava varieties for producing boiled cassava. The third step applies consumer-testing that combines "Check All That Apply" (CATA) questions, with hedonic testing and "Just About Right" JAR testing to build on previous quality characteristics and assess product preferences.

2.1. Study area and sampling

A qualitative survey focusing on raw and boiled cassava used gendered focus group discussions (men and women separately) and individual interviews along the food chain with stakeholders as key informants. The survey took place in two cassava producing and consuming rural districts of south-east Benin (West Africa): Bonou (6°53'N, 2°27'E) and Dangbo (6°34'N, 2°33'E). Eight rural communities/villages of these districts were involved (four villages per district). Informants (Table S1) were selected as described by Honfozo et al. (2021). Accordingly, 77 individual interviews and 16 focus group discussions (eight with men and eight with women) were undertaken. A processing diagnosis was held in the same districts (Bonou and Dangbo) using six skilled processors selected for their competences. In addition, the consumer testing was carried out in Porto-Novo (6°29'N, 2°36'E) and its neighborhood, as the urban area, and Bonou and Dangbo, as the rural areas. A total of 240 ordinary consumers (113 in urban and 127 rural areas) were recruited randomly and involved in the consumer testing. Participants were aged from 18 to 77 years old, of which 49% were male and 51% female.

2.2. Data collection tools

2.2.1. Qualitative survey

Interviews were conducted using a francophone questionnaire and administered to informants in French or translated into local language. Respondents were asked to rank varieties of cassava that they grow in order of importance and provide motives (end-uses) guiding these preferences, as well as information on the quality traits of raw and boiled cassava roots. Differences by gender were also examined.

2.2.2. Processing diagnosis

Six skilled women processors (having at least 10 years' experience) were recruited to make boiled cassava from six cassava varieties (selected among the ones cited during qualitative survey possessing contrasting quality characteristics) and to evaluate their sensory quality characteristics. These varieties, locally named *Agric*, *Adjaha*, *Alanmandou*, *Attinwéwé*, *Dossi* and *Koléahonmè*, were obtained from farmers at Bonou and Dangbo. The roots used were harvested at 5 months (*Agric*, *Adjaha* and *Dossi*), at 9 months (*Alanmandou* and *Attinwéwé*), and at 12 months (*Koléahonmè*) after planting. These harvesting periods were those usually adopted by stakeholders for each raw cassava variety intended for boiling. Freshly harvested cassava roots were labelled with a three-digit code and at least two roots of each variety (each weighing between 0.7 and 1.7 kg) were given to each processor, in a randomized order, for processing into boiled cassava. The ratio water/cassava pieces and cooking duration and temperature usually used by each processor were applied. The cooking was carried out one variety at a time, consecutively in previously defined

random order. At the end of processing, each processor was asked to propose the sensory descriptors associated with each cooked cassava variety.

2.2.3. Consumer testing

Roots from cassava varieties harvested under the above-described conditions were processed into boiled cassava by one skilled processor. Briefly, about 2 kg of cassava roots were peeled, washed, cut into pieces (about 40–50 g weight and 5 cm length) regardless of section (distal, central or proximal) and steam-cooked in 2 L of water for 40 min over charcoal. The five varieties were cooked simultaneously and stored in an insulated container in order to conserve the heat of the boiled cassava samples (at 60–65°C) until consumer testing. Each single sample (50–65 g) was successively and randomly presented to consumers in a plastic glass coded with a three-digit label. Bottled mineral water (at room temperature) was provided to wash the palate between samples tested. The consumers evaluated the samples in three steps, as described by Honfozo et al. (2021). Firstly, consumers described each sample using a CATA table including descriptors selected from (i) a gendered qualitative survey of boiled cassava, and (ii) a processing diagnosis, in order to consolidate previously collected quality characteristics. Thereafter, they scored the overall liking of each sample using a nine-point hedonic scale (1 = “dislike extremely”, 5 = “neither like nor dislike”, 9 = “like extremely”). Finally, the intensity of the key quality descriptors was evaluated using the three-point JAR scale (1 = “too weak” 2 = “JAR” and 3 = “too strong”). The descriptors included: white color, yellow color, easiness to break in the hand, crumbliness in the mouth, sweet taste, and bitter taste.

2.3. Data analyses

A verbatim transcription was performed on qualitative data using MS Excel 2013 and descriptive statistics (mainly frequency, sum and average) were calculated. The data analysis was related to the qualitative survey, and the processing diagnosis was triangulated. The robustness of citations and items was checked by revisiting the similarity/synonymy between verbatim words used by respondents or transcribed by different interviewers. Important and robust characteristics were selected and prioritized for the classification of varieties. The frequency of citations of each important quality item was calculated and summed as described by Honfozo et al. (2021). With respect to consumer testing, a Principal Component Analysis was carried out on CATA data, with the overall liking scores as a supplementary quantitative variable. The overall liking scores were submitted to a one-way analysis of variance with a Tukey’s multiple-range test. A penalty analysis was performed on JAR descriptors and hedonic liking ratings in order to identify potential directions for consumers’ demand for the selected descriptors. The overall liking and JAR scores of all boiled cassava varieties were combined to determine important mean drops in overall liking when the descriptors were cited “too weak” or “too strong”. All statistical analyses were performed at a 5% significance level using XLSTAT version 2014.5.03 software (Addinsoft, Paris, France).

2.4. Ethical clause

This study was assessed and approved by the “Comité National d’Ethique pour la Recherche en Santé” of Benin under the approval number 16 of NaN Invalid Date and the CIRAD Ethics Committee. Participants were informed about the purpose of the study and were informed that their participation was entirely voluntary, that they could stop the interview at any point, and that their responses would be anonymized. They also signed a consent form before the qualitative survey, processing diagnosis and consumer testing.

3. Results and discussion

3.1. Gender-disaggregated cassava varieties ranking and rationale of planting

Fourteen cassava varieties were identified as the most-grown and -used varieties, in order of importance (in descending order of area of cultivation), across the study areas (with local name and synonymy), regardless of gender (Table 1). Among these varieties, six (*Agoula*, *Agric*, *Attinwéwé*, *Dossi*, *Hanmadou/Gbomadou*, and *Kpèkè*) were mentioned by both men and women.

Table 1. Gender-disaggregated ranking of the most preferred local cassava varieties

Rank	Men (n = 31)	Women (n = 46)
1 st	Agric ¹	Agric ¹
2 nd	Dossi ²	Dossi ²
3 rd	Kpèkè ⁴	Attinwéwé ⁸
4 th	Agoula ⁷	Kpèkè ³
5 th	Ahtonontin*	Hanmadou/Gbomadou ⁶
6 th	Hanmadou/Gbomadou ⁵	Koléahonmè
7 th	Djègodotin	Agoula ⁴
8 th	Attinwéwé ³	Vobosabatché
9 th	Dèkpèmazé	Mandadô
10 th	Coletin	Hêhoado

Upper script number in a column is the rank attributed by opposite gender for common ranked varieties.

*Varieties without upper script number are not common for men and women.

Irrespective of gender, the varieties *Agric* and *Dossi* were respectively ranked as the first and the second most-preferred cassava varieties. For all cassava varieties ranked, three classes were observed regarding the gender classification: the first group was that of the two “common and similarly” ranked varieties, the second group was that of common (four varieties) but differently ranked varieties across gender, and the third group was that of varieties solely ranked by men (four varieties) or by women (four varieties). This observation is consistent with the rationale of planting related to agronomic and processing traits (high frequency) since the first two cassava varieties (*Agric* and *Dossi*) fulfilled the expectations of farmers as well as those of processors (Table 2). Except for these two varieties, the ranking of other cassava varieties was gender-dependent. Indeed, some varieties were closely ranked (*Kpèkè* was the third for men and the fourth for women) while others were inversely ranked (*Agoula* was the fourth for men and the seventh for women while *Attinwéwé* was the eighth for men and the third for women). This gender-based difference can be linked to a planting rationale based on intended end-uses, which is gender-dependent. Accordingly, the cassava variety *Attinwéwé* was recognized as suitable for processing (Table 2), thus more important for women (third ranked, Table 1) while its market value (as raw root) is low (Table 2) and it is ranked as the eighth most-preferred cassava variety produced by men (Table 1).

Regarding the varieties solely cited by one out of both genders, *Ahtonontin*, *Coletin*, *Dèkpèmazé*, and *Djègodotin* were only grown by men while *Hêhoado*, *Koléahonmè*, *Mandadô*, and *Vobosabatché* varieties were cultivated by women only. *Ahtonontin* variety was recognised with higher market value (Table 2), thus exclusively important for men. It seems that the drivers of the gendered ranking of cassava varieties were agronomic performance/yield, the market value and processing ability, with the latter being most valued by women. These findings were in agreement with previous reports that indicated the high priority men place on agronomic traits, while women more often valued product quality traits (Iragaba et al., 2021; Teeken et al., 2018), reflecting the different roles men and women play in cassava production and processing (Chiwona-Karltun et al., 1998, 2004; Masamha, 2018; Teeken et al., 2018). Studies of farmers’ preferences for crop variety traits of food crops show that such preferences vary in relation to the agronomic, technical, and socio-cultural contexts of production and processing modes (Nweke, 1999). Differential trait preferences based on gender divisions of labor and market access were observed across multiple crops in sub-Saharan Africa (Christinck et al., 2017). Therefore, men preferred the varieties they grow because of high yield, marketability, pest and disease resistant, root size, early maturing while women preferred the varieties for the same reasons but also for their ability to be processed in some products like *gari*, *fufu*, *lafun* and so on (Teeken et al., 2018).

Table 2. Rationale for planting some important cassava varieties

Preferred varieties (% of citation, N = 77)

Motive (Reasons why preferred)	Agric	Dossi	Kpèkè	Attinwéwé	Agoula	Ahotonontin	Hannmadou/ Gbomadou
Good production yield (many/big roots)	97.2	35.5	11.9	15.2	11.9	5.4	4.4
Market value (selling)	90.7	69.1	28.1	5.4	3.2	16.1	13.0
Home consumption	24.9	58.4	16.2	6.5	24.8	3.2	-
Processing into boiled cassava (ability and sensory)	30.3	82.1	15.2	16.2	27.0	11.9	-
Processing into Gari	57.4	23.8	29.1	16.2	-	6.5	37.8
Processing into others derived products (ablo, agnan, klacou, lafun, tapioca)	63.9	4.3	17.3	-	3.2	3.2	4.3
Short growth cycle (5-7 months)	8.6	2.2	2.2	-	-	8.7	-

3.2. Quality characteristics of cassava root and boiled cassava

The agronomic and sensory characteristics were evaluated for raw cassava while the sensory characteristics were assessed for boiled cassava. The most-cited characteristics for recognizing high-quality raw cassava (either in general or in roots destined for boiling) are respectively the state of the peel (physical appearance) and its color (Table 3). Indeed, red, pink, dark or black peel color, as well as cracked peel are cited as good-quality characteristics. Based on the survey and processing diagnosis, men's and women's citations followed the same trends. Regarding low-quality characteristics of raw cassava intended for boiling, the most important were respectively the smooth peel texture, and the presence of tough stem in the proximal root section. In addition, a white color and a sweet taste of the root flesh are reputed to be good-quality characteristics for raw cassava. In contrast, yellow-flesh color and bitter taste (evaluated after peeling with nail and tasting) were not appreciated.

Regarding quality characteristics of boiled cassava, both sensory (appearance, texture, odor and taste) and emotional (e.g., attractive, good aroma/odor, and good taste) descriptors governed the acceptance of a given variety (Table 4). High-quality sensory descriptors of boiled cassava included white color, easy to break with hand, sticky between fingers, crumbly in mouth and sweet taste. Among these characteristics, texture and taste descriptors were more highly valued. In this study, low-quality characteristics of boiled cassava (associated with consumer rejection), included mainly yellow color and poor texture (hard when touching and in the mouth, difficult to chew, and fibrous), and bitter taste. These results corroborated previous work that reported mealy/soft texture, sweet taste, white color, and good aroma as the highest quality characteristics of boiled cassava, with textural characteristics being the most important set of quality attributes (Favaro et al., 2008; Hongbété et al., 2011; Padonou et al., 2005). Otherwise, significant differences exist between varieties, relating to cooked cassava root taste and texture (Hongbété et al., 2011). Previous findings indicated high-quality characteristics of cassava varieties for boiling (white, soft, sweet and aromatic) are the most liked, while the converse low-quality characteristics are disliked (Iragaba et al., 2021).

3.3. Consolidation of quality characteristics by sensory mapping of boiled cassava

Figure 1 depicts the five cassava varieties and CATA characteristics selected during survey and processing diagnosis. Three groups of varieties were distinctly established. The first group was boiled cassava made from *Dossi* and *Attinwéwé* varieties, categorized as high-quality products, and were specifically described as attractive and having a homogenous white color, good cassava smell, sweet taste and specific texture (crumbly in the mouth, easy to break with the hand, sticky between fingers, no fibers). The second group was boiled cassava from *Alanmandou* and *Koléahonmè* varieties which was defined as unpleasant to eat with a homogenous yellow color, bitter taste, bitter aftertaste (*Koléahonmè*), tasteless (bland, *Alanmandou*), and hard in texture (when breaking with the hand or in mouth, thereby being difficult to chew, with a sticky mucilage). Thus, these varieties were considered as making low-quality boiled cassava. The third group was boiled cassava from *Agric* variety, considered intermediate in quality, and described as having white outside and yellow inside, and with a slightly sweet taste or being tasteless (bland). This additional information from CATA revealed that the sensory descriptors associated with *Dossi* and *Attinwéwé* could be considered as the drivers of consumers' liking, while the sensory descriptors associated with *Koléahonmè* and *Alanmandou* could represent a reason for consumers' rejection of the boiled cassava. Thus, the CATA test supported defining the quality characteristics (either high or poor) of the boiled-cassava varieties collected during surveys and processing diagnosis. Some of the descriptors used for boiled cassava in this study matched up with the findings of previous work, which reported them as the major quality characteristics of boiled cassava (Iragaba et al., 2021). Moreover, consumer liking, as a driver or inhibitor of varietal adoption, is potentially the major constraint to stimulate the adoption of cassava varieties across sub-Saharan Africa (Alene et al., 2015; Bechoff et al., 2017). Thus, greater importance should be allocated to consumer preferences in breeding programmes (Chiwona-Karlton et al., 2015).

Table 3. Quality characteristics of raw cassava prioritized by gender (% citation)

Quality characteristics	High characteristic Survey (N = 77)				Low characteristic Survey (N = 77)			
	Men		Women		Men		Women	
	Processing		Processing		Processing		Processing	
Raw cassava (in general)	Cracked peel	45.2	43.5	16.7	-	-	-	-
	Big size	32.3	28.3	-	-	-	-	-
	White flesh	22.6	23.9	-	-	-	-	-
	Many derived products	22.6	17.4	-	-	-	-	-
	Heavy root	19.4	28.3	-	-	-	-	-
	Good yield	9.7	-	-	-	-	-	-
	Medium size	9.7	-	-	-	-	-	-
	Many roots	-	15.2	-	-	-	-	-
	Red/pink/dark/black peel	-	-	66.7	-	-	-	-
	Peel do not stick to parenchyma	-	-	16.7	-	-	-	-
	Tough stem at the root proximal part	-	-	33.3	-	-	-	-

(Continued)

Table 3. (Continued)

Quality characteristics	High characteristic				Low characteristic			
	Survey (N = 77)		Processing		Survey (N = 77)		Processing	
	Men	Women	Women (N = 6)	Men	Men	Women	Women (N = 6)	
Raw cassava intended to boiled cassava	Cracked peel	48.4	41.3	-	-	-	-	
	Sweet when raw	58.1	28.3	-	-	-	-	
	White flesh	25.8	10.9	-	-	-	-	
	Heavy root	22.6	13.0	-	-	8.7	-	
	Medium size	12.9	-	-	-	-	-	
	Easy to peel	-	28.3	-	-	-	-	
	Smooth peel	-	17.4	-	51.6	-	-	
	Bitter when raw	-	-	-	45.2	30.4	-	
	Long root	-	-	-	41.9	28.3	-	
	Fibrous flesh	-	-	-	32.3	6.5	-	
	Yellow flesh	-	-	-	25.8	-	-	
	Difficult to peel	-	-	-	-	10.9	-	
	Red/pink/dark/black peel	-	-	100	-	-	16.7	
	Peel appearance	-	-	16.7	-	-	16.7	
Presence of stripes	-	-	16.7	-	-	-		
Tough stem at the root proximal part	-	-	-	-	-	33.3		

Table 4. Significant quality characteristics of boiled cassava identified during survey and processing diagnosis

Characteristics	Descriptors	Frequency (% , N = 83)	
		High quality	Low quality
Appearance	White flesh	73.5 ^c	-
	Attractive	18.1c	-
	Yellow/yellowish flesh	-	26.5 ^c
	Dark/red/black flesh	-	13.8 ^b
Texture in touch	Crumbly/easy to break/soft	100 ^c	-
	Hard	-	42.2 ^c
	Fibrous	-	26.3 ^a
	Sticky between fingers	100b	-
Texture in mouth	Crumbly/easy to break/soft	72.3 ^c	-
	Difficult to chew	-	15.0 ^a
	Hard in the mouth	-	50 ^b
	Unpleasant to eat	-	66.7 ^b
Odour/aroma	Good smell/odour of cassava	74.4 ^c	50 ^c
Taste	Sweet/very sweet	75.9 ^c	-
	Good taste/very good	15.7c	-
	Slightly sweet	100b	-
	Tasteless	-	33.3 ^b
	Bitter ^a	-	83.3 ^c
	Bitter aftertaste ^{bc}	-	16.7 ^b

^asurvey

^bprocessing

^csurvey and processing compilation

3.4. Consumers' overall liking preference of boiled cassava

The overall liking scores for boiled cassava varieties varied significantly ($p < 0.05$) according to specific variety and dwelling places (rural or urban areas) of consumers (Table 5). Irrespective of dwelling place, *Dossi* was the most liked variety (score of 8.0, like very much) while *Koléahonmè* was scored the least (2.7, dislike slightly). These findings are consistent with CATA test (Figure 1) results which revealed that boiled cassava from *Dossi* variety was attractive while that from *Koléahonmè* variety was unpleasant to eat. The effect of dwelling places (rural and urban areas) was specifically observed for *Attinwéwé* and *Alanmandou* varieties which were rated significantly higher by urban consumers. This observation indicated that urban dwellers were less able to discriminate the quality differences between boiled cassava samples, probably because they are accustomed to consuming any types of boiled cassava and are less demanding concerning specific quality characteristics. Thus, to avoid the risk of food poisoning, more attention should also be paid to urban areas, especially where bitter varieties may not be common. Teeken et al. (2018) reported differences in the preference for the cassava root products in specific areas. Hence, based on varieties and dwelling places (urban and rural areas), the significant differences recorded in overall liking of boiled cassava indicated various sensitivities to liking boiled cassava and this should be addressed in cassava varietal improvement (Nyirenda et al., 2011).

3.5. Key sensory descriptors affecting overall liking of boiled cassava

The way to improve quality attributes of boiled cassava was evaluated by consumers based on color (white or yellow), texture (easy to break with the hand and crumbly in the mouth) and taste (sweet or bitter) (Table 6). For white color, the majority of consumers found the boiled cassava as JAR (65.3% of

Figure 1. Principal component analysis on sensory characteristics of the five boiled cassava varieties.

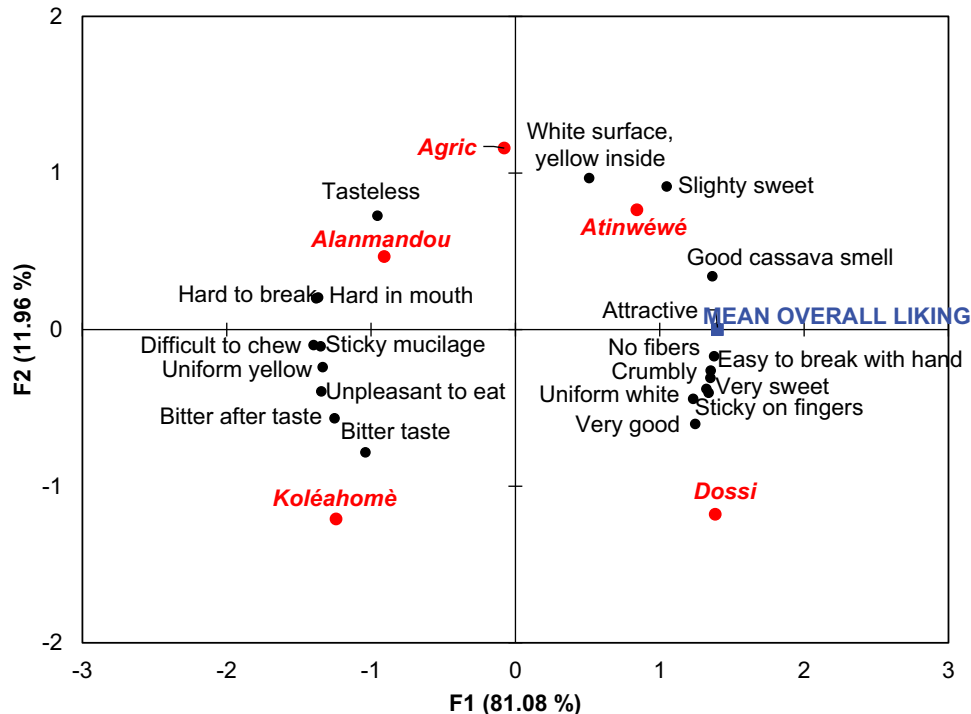


Table 5. Overall liking score of boiled cassava as affected by cassava varieties and dwelling place of consumers

Dwelling place	Cassava varieties				
	Dossi	Atinwéwé	Agric	Alanmandou	Koléahomé
Rural area (n = 127)	7.9 ^{a1}	6.4 ^{b1}	5.0 ^{c1}	3.4 ^{d1}	2.7 ^{e1}
Urban area (n = 113)	8.0 ^{a1}	6.8 ^{b2}	5.2 ^{c1}	4.0 ^{d2}	2.7 ^{e1}
Rural and urban areas (n = 240)	8.0 ^a	6.6 ^b	5.1 ^c	3.7 ^d	2.7 ^e

Mean scores with different letters within the same row are significantly different ($p < 0.05$).

Mean scores with different numbers within the same column are significantly different ($p < 0.05$).

consumers) while yellow color was considered too pronounced/strong (68.1%). On the sweet taste scale, the majority of consumers considered as JAR for boiled cassava (76.6% of consumers), while for 86.8% of consumers, boiled cassava is too bitter. Regarding the two texture descriptors, the majority of consumers considered that the boiled cassava was hard to break with the hand (61.6%) and not crumbly in the mouth (61.3%). The drops in overall liking were observed for the six studied descriptors because they were judged too weak or/and too strong by at least 20% of consumers. The highest drops in overall liking were observed for the descriptors “hard to break” or “not crumbly”, or both. These two descriptors greatly reduced overall liking, with the penalty value of 2.2 on a nine-point scale (Table 6). A bitter taste had the highest penalty value (2.6). Inversely, the descriptor “not white enough” had the lowest penalty value (0.6). The texture descriptors (“easy to break with the hand” and “crumbly in the mouth”) were the key descriptors driving the high quality of boiled cassava followed by white color and sweet taste. As with our findings, previous reports indicated that a soft/crumbly texture is the most

Table 6. Mean drops and penalty of overall liking of boiled cassava

Descriptors	Just—About-Right categories	Frequency (%)	Mean drops in overall liking ^a	p-value ^b	Penalty
White colour	Not white enough	34.7	1.7	<0.0001	0.6
	As I like	65.3			
	Too white	0.0			
Yellow colour	Not yellow enough	17.2	-0.2		
	As I like	14.7			
	Too yellow	68.1	1.4	<0.0001	0.9
Easy to break with the hand	Hard to break with hand	61.6	3.5	<0.0001	2.2
	As I like	38.3			
	Too easy to slice with hand	0.2	-0.6		
Crumbliness in the mouth	Not crumbly in the mouth	61.3	3.6	<0.0001	2.2
	As I like	38.4			
	Too crumbly in the mouth	0.3	2.1		
Sweet taste	Not sweet enough	23.4	2.8	<0.0001	0.7
	As I like	76.6			
	Too sweet	0.0			
Bitter taste	Not bitter enough	7.0	2.5		
	As I like	6.2			
	Too bitter	86.8	3.0	<0.0001	2.6

^aScore of liking loose for having a product “not-JAR categories”.

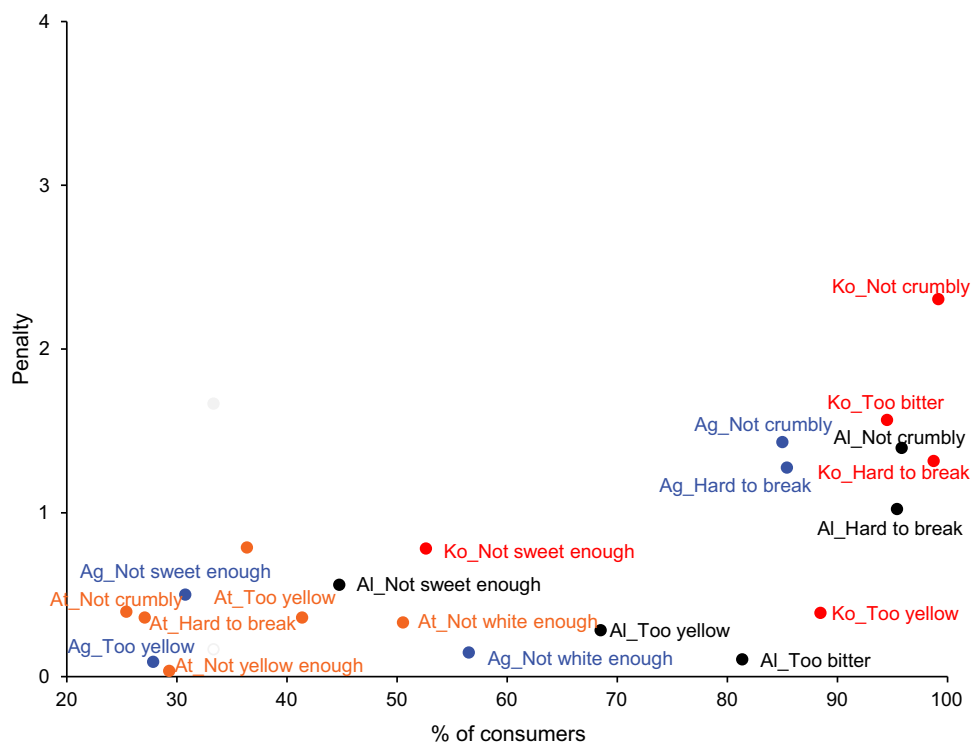
^bp-value indicates that mean drops in overall liking is significant based on 2-samples t-test.

important characteristic for consumer acceptance followed by sweet taste, white color and aromatic smell of boiled cassava (Bechoff et al., 2017; Hongbété et al., 2011; Iragaba et al., 2021; Padonou et al., 2005). The sweetness is often a driver of food acceptability in general and one of the drivers for the acceptance of cassava by farmers while a bitter taste is not unanimously appreciated by consumers (Bechoff et al., 2017). A bitter taste might not be acceptable to cassava consumers due to its association with cyanogenic glucosides risk (Bechoff et al., 2017). Color plays an important role in assessing the quality of foods although most cassava grown in Africa has white or cream-colored flesh, along with most of its derived products including boiled cassava (Assanvo et al., 2018; Bechoff et al., 2017). The development of aromatic smell of boiled cassava during the cooking process at high temperatures may result from volatile components of the products as already reported by Boudhrioua et al. (2003) who attributed the increase the aromatic content to the Maillard reaction and Strecker degradations.

As far as the studied varieties are concerned, the penalty analysis was performed to demonstrate how many scores of overall liking were significantly reduced when a characteristic of boiled cassava varieties was not evaluated JAR by at least 20% of the consumers (Figure 2). The penalty values were diversely associated with the selected sensory descriptors linked to yellow color, texture (easy to break with the hand, and crumbly in the mouth), and taste (sweet and bitter) of four boiled cassava varieties (*Agric*, *Alanmandou*, *Attinwéwé* and *Koléahonmè*). The white color of

Figure 2. Significant penalties of overall liking per percent of consumers for studied varieties.

Legend: Variety_ not JAR category based on sensory descriptor (ex: Ko_Too bitter).
Varieties: Agric (Ag), Alanmandou (Al), Atinwéwé (At), Dossi (Do), Koléahomé (Ko).
Sensory descriptors: white colour, yellow colour, easy to break with the hand, crumbly in the mouth, sweet taste, bitter taste.
Not JAR categories: too weak (Not enough), too strong (Too much).



Agric and *Atinwéwé* decreased the overall liking for more than 20% of consumers. The lack of enough easiness to break with the hand and crumbliness in the mouth of boiled cassava from *Agric*, *Alanmandou* and *Koléahomé* varieties, along with the too bitter taste of *Koléahomé* boiled cassava received the highest mean reductions in overall liking scores (penalty >1.0, consumers > 65%). In addition, boiled cassava from *Alanmandou* and *Koléahomé* varieties were more penalized by too yellow a color (penalties of 0.3 and 0.4 for 68% and 88% of consumers, respectively) when compared to that from *Agric* and *Atinwéwé* varieties. *Agric* and *Alanmandou* boiled cassava were less penalized by the lack of enough sweetness (penalties of 0.5 and 0.6 for 31% and 45% of consumers, respectively). These observations indicated that too yellow a color and too bitter a taste could significantly contribute to consumers' rejection of boiled cassava, together with lack of enough easiness to break with the hand and crumbliness in the mouth (as recorded for *Koléahomé* and *Alanmandou* varieties, Table 5). The lack of enough easiness to break with the hand and crumbliness in the mouth of *Atinwéwé* boiled cassava was less penalized (penalty <0.5, consumers < 30%) than that of *Agric* variety (penalty >1.3, consumers > 85%), and this may explain why consumers gave higher overall liking scores to *Atinwéwé* boiled cassava and lower scores to *Agric* boiled cassava (Table 5).

4. Conclusion

The main reasons for which cassava varieties have been grown are high yield, marketability and their capability to be processed in diverse products. The crumbly texture, the sweet taste and the white color of boiled cassava roots are the three most important characteristics preferred by most stakeholders. Good and poor sensory characteristics of boiled cassava with a clear discrimination between varieties were evidenced in this study, and this can likely improve the success of breeders' investment. The drop in overall liking of boiled cassava related to some quality attributes may guide cassava varietal improvement. Therefore, a crumbly texture, a sweet taste and a white color are considered as priority quality traits that must be passed on to breeders for integration into breeding priorities in order to produce higher value, more desirable boiled cassava varieties for a significantly larger number of consumers.

Acknowledgments

The authors are grateful to Dr Dominique Dufour, RTBfoods Project Leader and to the Agricultural Research Centre for International Development (CIRAD), Montpellier, France. “This work was supported, in whole or in part, by the Bill & Melinda Gates Foundation [ID: OPP1178942: Breeding RTB products for end user preferences (RTBfoods)]. Under the grant conditions of the Foundation, a Creative Commons Attribution 4.0 Generic License has already been assigned to the Author Accepted Manuscript version that might arise from this submission.” The authors would like to thank Vincent Johnson of Green Quills for his editorial support.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Supplementary material

Supplemental data for this article can be accessed online at <https://doi.org/10.1080/23311932.2023.2253716>

Citation information

Cite this article as: Cross-approaches for advising cassava trait-preferences for boiling, Laurenda F. Honfozo, Imayath M. Djibril Moussa, Laurent Adinsi, Alexandre Bouniol, Sounkoura Adetonah, Flora J. Chadare, Wilfried S. Padonou, Joseph D. Hounhouigan, Lora Forsythe & Noël H. Akissoe, *Cogent Food & Agriculture* (2023), 9: 2253716.

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