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INVESTIGATING THE RELATIONSHIP BETWEEN COOKING TIME, DRY MATTER AND SENSORY ATTRIBUTES OF BOILED CASSAVA

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ABSTRACT

Cassava is a major staple food in many tropical regions, but certain varieties remain hard and difficult to chew even after boiling, making them less appealing to consumers. Preferences generally lean toward cassava roots that cook quickly and possess a sweet taste. This study explored the relationship between cassava's dry matter content and optimal cooking time (CT), specifically examining how these factors relate to sensory attributes like softness and chewability. Twenty cassava varieties, aged 10 to 12 months, were freshly harvested from the International Institute of Tropical Agriculture (IITA) research farm in Ibadan. After harvesting, the roots were peeled, washed, diced and then boiled. Standard procedures were used to evaluate each variety's cooking time, dry matter content and sensory properties. The sensory assessment focused on the softness and chewability of the cassava roots, both are key attributes that influence consumer satisfaction. The results indicated that most sweet cassava varieties with a dry matter content above 35 % cooked within 25 minutes or less, achieving a soft texture with easy chewability. Statistical analysis using Pearson's correlation coefficient revealed a strong positive relationship between sensory softness ($r > 0.94$) and chewability ($r > 0.81$) in varieties that had a CT of 25 minutes or less indicating that the softer a cassava variety is, the more chewable it is. This correlation underscores that dry matter content and cooking time are significant predictors of sensory quality in boiled cassava. This study emphasizes that cassava varieties with high dry matter content and shorter cooking times are not only easier to cook but are also better suited as a primary energy source in regions where cassava is a dietary staple. Consumers prefer varieties that cook quickly and have a soft, easily chewable texture, providing important insights for cassava breeding and selection programs. By focusing on these qualities, cassava breeders can develop varieties that meet consumer demands, enhancing the appeal of cassava as a food source. This research supports ongoing efforts to improve cassava quality, ensuring that it remains a versatile and desirable staple crop in the tropical regions where it plays a critical role in the diet.

Key words: dry matter, cooking time, chewiness, softness, sensory properties

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INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a major staple food in many tropical countries of the world, particularly in Africa [1, 2]. It is the most perishable root and starts deteriorating almost immediately after harvest due to its high moisture content. Cassava plays a major role in alleviating the African food crisis due to its efficient production of energy, year-round availability, tolerance to extreme stress conditions, and suitability to present farming and food system in Africa [2- 4].

Cassava is one of the most tolerant crops and can be successfully grown on marginal soils, giving reasonable yields where many other crops do not grow well. Cassava is the third-largest source of food carbohydrates in the tropics, after rice and maize [5]. Cassava can be classified as sweet or bitter and both the bitter and sweet varieties of cassava contain higher amount of starch [6]. Farmers often prefer the bitter varieties because they deter pest, animals and thieves [7]. Cassava is predominantly consumed in fried form, roasted and in boiled form, but substantial quantities are used to extract cassava starch, called tapioca which is used for food, animal feed and industrial purposes.

In 2020, the world cassava production was 302.66 million metric tons. Africa is the world's largest cassava growing region, with total production of 193.62 million metric tons and unarguably, Nigeria remains the highest producer of cassava in the world with about 63 million metric tons [8]. Also, global cassava production in terms of total area harvested has increased substantially in recent years. Nigeria led the world in this aspect with total harvested area of 7.7 million ha in 2020 [8].

Highest cassava producing states in Nigeria are Anambra, Delta, Edo, Benue, Cross River, Imo, Oyo, Ogun and Rivers and to a lesser degree are Osun and Ondo [6]. Benue and Kogi State in the North Central zone are the largest producers of cassava in Nigeria [9]. Cross River, Akwa Ibom, Rivers and Delta are the dominated cassava production states in the South South. Ogun, Ondo and Oyo in the South West while Enugu and Imo constitute the highest production in the South East. Kaduna alone in the North West is comparable in output to many of the states in the southern regions at almost 2 million tons a year with little currently being produced, in the North East.

Cassava roots can be utilized in different ways. There is food use, feed use and industrial use. Cassava roots can be eaten raw or eaten boiled and can be roasted. The fresh roots are boiled and pounded to obtain pounded cassava. This is most popular in Ghana, and to some extent, in Nigeria and Cameroon. The processed cassava, either in the form of flour, wet pulp or gari is cooked or eaten in three main food forms: *fufu, eba* and *lafun*. Gari can be eaten dry or it may be soaked in cold water to which sugar is added. Eba is a very popular food in Nigeria and gaining

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popularity in Cameroon, Benin, Ghana, Liberia and Sierra Leone because of its fast and easy reconstitution into a convenient food [10, 11].

Cassava is basically made into fermented and unfermented products. Fermented products include fermented starch, *fufu, lafun, attieke, agbelima* and *gari*, whereas the unfermented products include tapioca, cassava chips cassava *akara, abacha*, and high-quality cassava flour (HQCF). New food uses of cassava include as flour in gluten free or gluten-reduced products (for example bread and biscuits) [7]. In general, the food uses of cassava include biscuit, bread, cakes, meat pie, cassava starch, *pupuru, gari, eba*, sweeteners, odourless *fufu*, cassava flour, salad cream, kpokpo gari, doughnut, tapioca, noodles, tit bits, sausage rolls, *abacha, chinchin*, pellets, egg roll, starch flakes, *attieke*, cassava chips, cassava cake, *amala lafun* [12, 13].

According to Food and Agriculture Organization (FAO) [6], dried cassava has seen great success as an export good from Thailand and Indonesia as well as an ingredient in animal feed in Europe. According to reports, a significant amount of cassava is also used by Brazil, Paraguay, Thailand and China for non-intensive swine, poultry and fish production [6]. According to Ekop *et al*. [14], there are two exportable goods that are rapidly gaining popularity: cassava chips and pellets. The roots are dried and sliced into chips, with lengths ranging from 5 to 7 cm. Waste pulp and peels are turned into animal feed and compost. By-products from cassava roots are also used to make some environmentally beneficial throwaway items.

Industrial use of cassava includes gel, fuel, glue, biodegradable products, pharmaceutical products, ethanol, textiles, plywood, glues and paper and biofuels [14]. To improve the sustainable development of cassava-based industries, carbohydrate-rich wastes have been further explored for producing biofuels and chemicals. Alcohol, organic acid and amino acid derivatives such as monosodium glutamate can be obtained as by-products in the process of cassava starch production [14, 15].

This study aimed to evaluate the dry matter content and optimal cooking time (CT) of selected cassava varieties, as well as their sensory attributes, to determine the most suitable varieties for boiling and to establish the ideal cooking time for mealy cassava roots. Understanding these attributes is crucial for encouraging consumer adoption, as cassava varieties that cook quickly and have the preferred texture are more likely to be accepted.

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MATERIALS AND METHODS

Materials

Twenty (20) cassava varieties (both local and improved varieties) were obtained from the International Institute of Tropical Agriculture (IITA) Research Farm, Ibadan, Nigeria. The selected improved cassava varieties are TMEB693 (*isunikankiyan*), TMS16F2021P0044, TMS16F2022P0057, IBA961632, TMEB711, IBA011797, TMEB419, TMS16F2021P0011, IBA184416, IBA184433, IBA184427, IBA184429, IBA184445, IBA30572, IBA184422, IBA184449, IBA184439 and IBA070593. The local varieties selected were *ege funfun, and ege dudu.* The criteria for selection was based on farmers' preferences, availability and utilization of the roots for processing different food products.

Preparation and boiling of cassava roots

Freshly harvested cassava roots of age between 10 and 12 months old were peeled, washed, both extremes of 2 cm were discarded and the middle sections were cut into pieces of 6.0 cm long and 5.5 cm diameter [16] and then cut into half cylinder, boiled in water until fork penetrates softly. The boiled cassava was wrapped in aluminum foil and kept in a warmer prior to subjective and objective evaluation.

Methods to Determine Cassava Roots Cooking Qualities

The method to assess the texture of food is divided into two classes: the sensory evaluation (subjective) and the instrumental (objective). The sensory one involved sensory analysis panels that were trained. Instrumental method was done by attaching a sample to a universal testing machine, in order to measure the amount of force required to complete a test of the mechanical properties of the tested material as well as other parameters such as hardness, and work done.

Sensory evaluation (subjective)

The sensory attributes were evaluated by a trained panel of thirty judges consisting mainly of students and staff of International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, who were familiar with boiled cassava. Freshly harvested cassava roots of age between 10 and 12 months old were peeled, washed, both extremes of 2 cm were discarded and the middle sections were cut into pieces of 6.0 cm long and 5.5 cm diameter [9] and then cut into half cylinder, boiled in water using gas cooker and allowed to boil for 10 min, 20 min and 40 min. Water was drained, and roots were placed on labelled plates which were evaluated for softness, chewiness, mealiness, appearance and taste. The cooking time (CT) for each variety was measured using a fork to determine the ideal cooking point.

The panelists were served and asked to score the samples using three descriptors which describe softness (1= soft, 2= soft moderately, 3= hard),chewiness (1= chew easily, 2= chew moderately, 3= hard to chew), mealiness (1=cut/break easily, 2=

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melt/dissolve easily, 3=not break/melt easily), appearance (1=cracky, 2=slightly cracky, 3=not cracky) and taste (1=sweet, 2=bland, 3=bitter).

Instrumental texture analysis (hardness and work done)
The instrumental texture measurements of the boiled cassava roots were carried out using a Texture Analyser (Model TA-XTplus, Stable Micro System, Haslemere, U.K) coupled with an extrusion probe (Ottawa five blade grid) (Fig. 1). The texture parameters, such as hardness and work done during extrusion, were measured in six replications [17].

Dry matter content (DMC)
Six replicates of fresh pieces (from twenty different roots) were homogenized into a uniform paste with a food processor Essen Skymsen Model PA-7LE (Bateas, Brazil) with a stainless-steel disc (diameter 210 mm) perforated over 50% of its surface with 3 mm holes and rotating at 438 rpm. The DMC of the resulting mash was determined in duplicate by drying 11 to 14 g at 105 °C for 24h. Dry matter was expressed as the percentage of dry weight relative to fresh weight [18].

Correlation Analysis
Correlation matrix was used to correlate data obtained from sensory evaluation of boiled cassava root and the instrumental texture analysis. Sensory properties were also correlated with cooking time to show the significant difference ($p \leq 0.05$).

Statistical Analysis
Data generated was subjected to Analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS) version 13.0. Means were separated using Fischer's LSD at 5% level of probability.

RESULTS AND DISCUSSION

Cooking time
Cooking time of the cassava varieties processed is presented in Figure 2. It was measured from the time the pot and raw cassava roots were placed on a heat source to the time when fork penetrated the cooked cassava softly. Cooking time using cooking gas was significantly different among the varieties ($p \leq 0.05$). Some varieties (TMEB693, TMS16F2021P0044, TMS16F2022P0057, *ege funfun*, and IBA011797) had a relatively shorter cooking time of less than 25 min, some varieties (TMEB419, IBA184416, TMS16F2021P0011) had a medium cooking time between 25-40 min while other varieties like IBA184416, IBA184433, IBA184427, IBA184429, IBA184445 etcetera, had high cooking time above 40 min (Figure 2).

The results of cooking time (≤25 min, 25-40 min, and >40 min) obtained from the use of gas cooker was in line with the finding of Thierry *et al*. [19] on correlation of cooking time with water absorption and changes in relative density during boiling of

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cassava roots. This means that the cassava varieties that cooked within 25 min could be regarded as mealy cassava, those that cooked between 25-40 min could be regarded as partially mealy cassava, and those that cooked beyond 40 min could be referred to as non-mealy cassava. Thierry *et al*. [19] reported that 15 genotypes of cassava roots cooked in less than 25 minutes, the CT of eight clones varied from 25 to 40 minutes while the remaining 11 genotypes' roots took longer than 40 minutes.

Figure 1: A picture of the texture analyzer

Source: Food and Nutrition Science Laboratory, IITA, Ibadan

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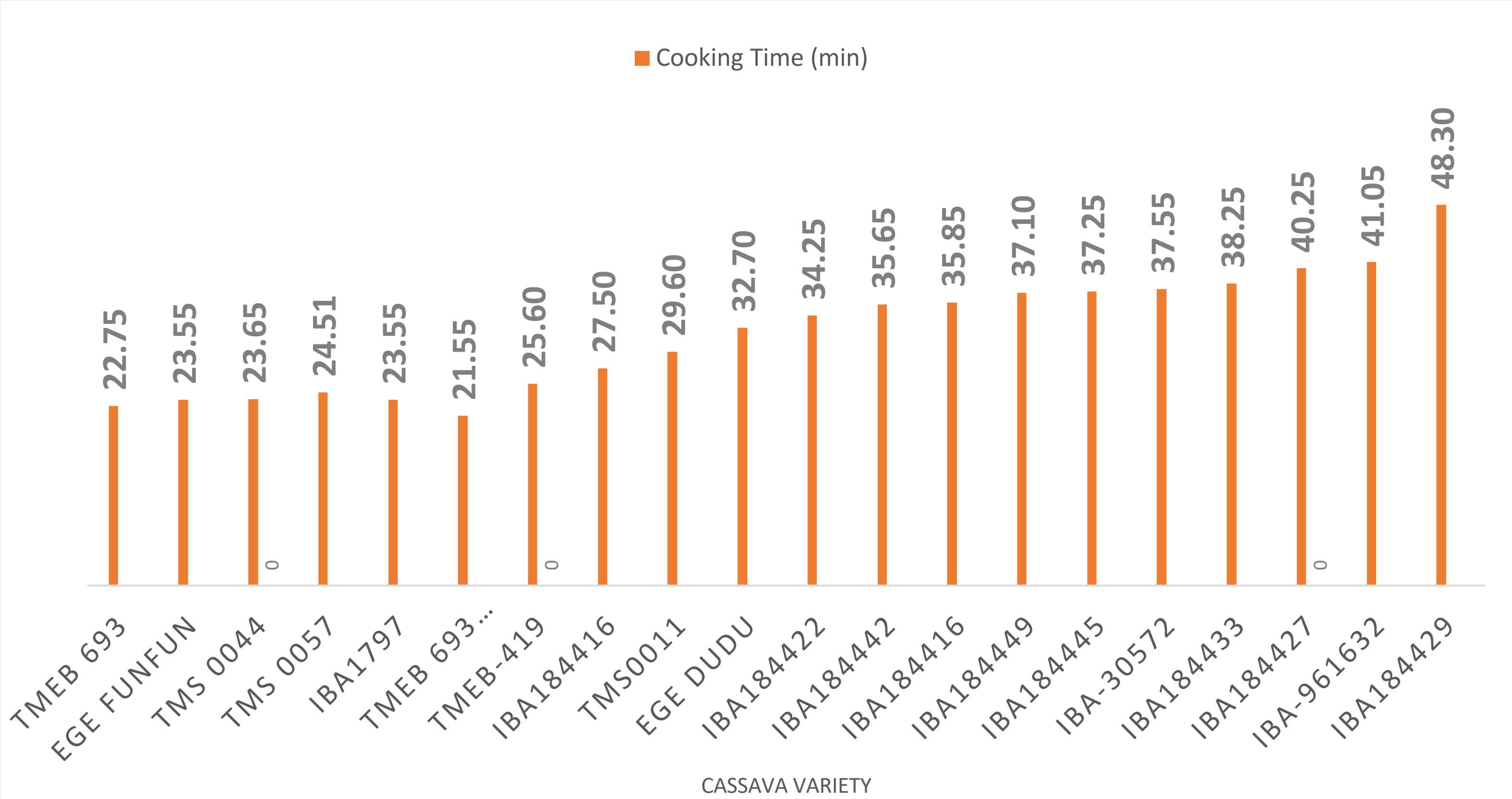

Figure 2: Cooking time of some cassava varieties (≤ 25 min, 25-40 min and >40 min)

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Some cassava varieties cooked in less than 20 min. This was in-line with the result of Adinsi *et al*. [20] on sample preparation and cooking time for texture analysis of boiled yam. Finding from the respondents revealed that consumers prefer cassava roots that cook quickly. Differences in cooked cassava root textures could be influenced by several factors such as chemical composition, physicochemical properties, morphology and molecular structure of starch, age and season of the root, the arrangement of starch granules in cells, the organization of cells, and the arrangement of tissue in cassava root [21].

Sensory properties

The sensory properties of cooked cassava varieties are presented in Table 1. The sensory panelists' scores for the cassava varieties in softness ranged from moderately soft to hard and chewiness ranged from "easy to chew" to "hard to chew." Similarly, appearance ranged from cracky to non- cracky, taste ranged from sweet to bitter and mealiness ranged from cut/melt easily to not cut and melt easily. In-terms of chewiness, TMEB693, TMEB419, TMS16F2022P0057, IBA011797, *ege funfun*, TMS16F2021P0044 and IBA184429 were easy to chew, while IBA30752, IBA961632, IBA30572, IBA184422, TMS16F2021P0011, *ege dudu*, IBA184416, IBA1844433, IBA184445, IBA184427, IBA184449 and IBA184442 were moderately chewable. In terms of mealiness, TMEB693 and IBA184449 break easily, others scatter easily except IBA184416 that dissolve easily. In-terms of softness, TMS16F2021P0044 and *ege funfun* were soft, TMEB693, TMEB419, IBA30572, TMS16F2022P0057, IBA011797, IBA184416, IBA184449, IBA184442 were moderately soft while IBA30572, IBA961632, IBA184422, TMS16F2021P0011, IBA184433, IBA184445, IBA184427 and IBA184429 were slightly soft.

These results are in line with those of Miranda *et al*. [21], who found that one important factor influencing cassava varietal preference was the softness of boiling roots. These results are also in line with the findings of Adinsi *et al*. [20] which listed stickiness, softness, white color and sweet flavor as the top end-user qualitative attributes of cooked cassava. Some varieties processed were also cracky while others are slightly cracky. Conversely, the least desirable characteristics included a hard, glassy texture, yellowish color, fibrous, harsh flavor and non-mealy texture.

Instrumental texture analysis

The result of instrumental texture analysis showed that Instrumental hardness ranged from 1367.0 to 2946.7 g, while instrumental work during extrusion ranged from 1935.8 to 7900.6 g/s (Table 2).

Dry matters

The results for dry matters of cassava varieties harvested ranged from 30.84-54.89% as presented in (Table 4). The results indicated that TMEB693 had highest dry

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matter (54.89%) followed by IBA011797 (47.66%). Meanwhile, IBA184427 had the lowest dry matter (30.84%), followed by IBA184445 (33.04%), IBA184429 (33.07%). These results were in-line with the report of Kouadio *et al*. [22] with high dry matter on assessment of some cassava varieties. Table 4 shows that some cassava varieties with high dry matter such as TMEB 693 (54.89%), IBA011797 (47.66%), *ege funfun* (46.46%), TMEB419 (45.05%), TMS0055 (39.97%) were boiled in 21.5 min, 23.6 min, 23.6 min, 25.0 min and 24.5 min, respectively (Table 4). Those cassava varieties with lower dry matter boiled between 26 – 40 minutes. Dry matter content plays an important role in root cooking and tenderness. According to Miranda *et al*. [13], the higher the dry matter, the shorter the cooking time and the easier the cooking, the better the taste of the cooked product. From this, the importance of dry matter content for sweet cassava can be inferred.

Pearson's correlation between instrumental texture profiling, sensory analysis and cooking time of boiled cassava

Results of Pearson's correlation showed that a significant ($p < 0.01$) and positive correlation ($r = 0.92$) exists between the sensory softness and the instrumental work done by extrusion (Table 3). There was no significant correlation between instrumental hardness and sensory texture attributes. Also, there was a significant positive correlation between sensory softness and cooking time ($p < 0.01$, $r = 0.94$) and between sensory chewiness and cooking time ($p < 0.05$, $r = 0.81$) (Table 3).

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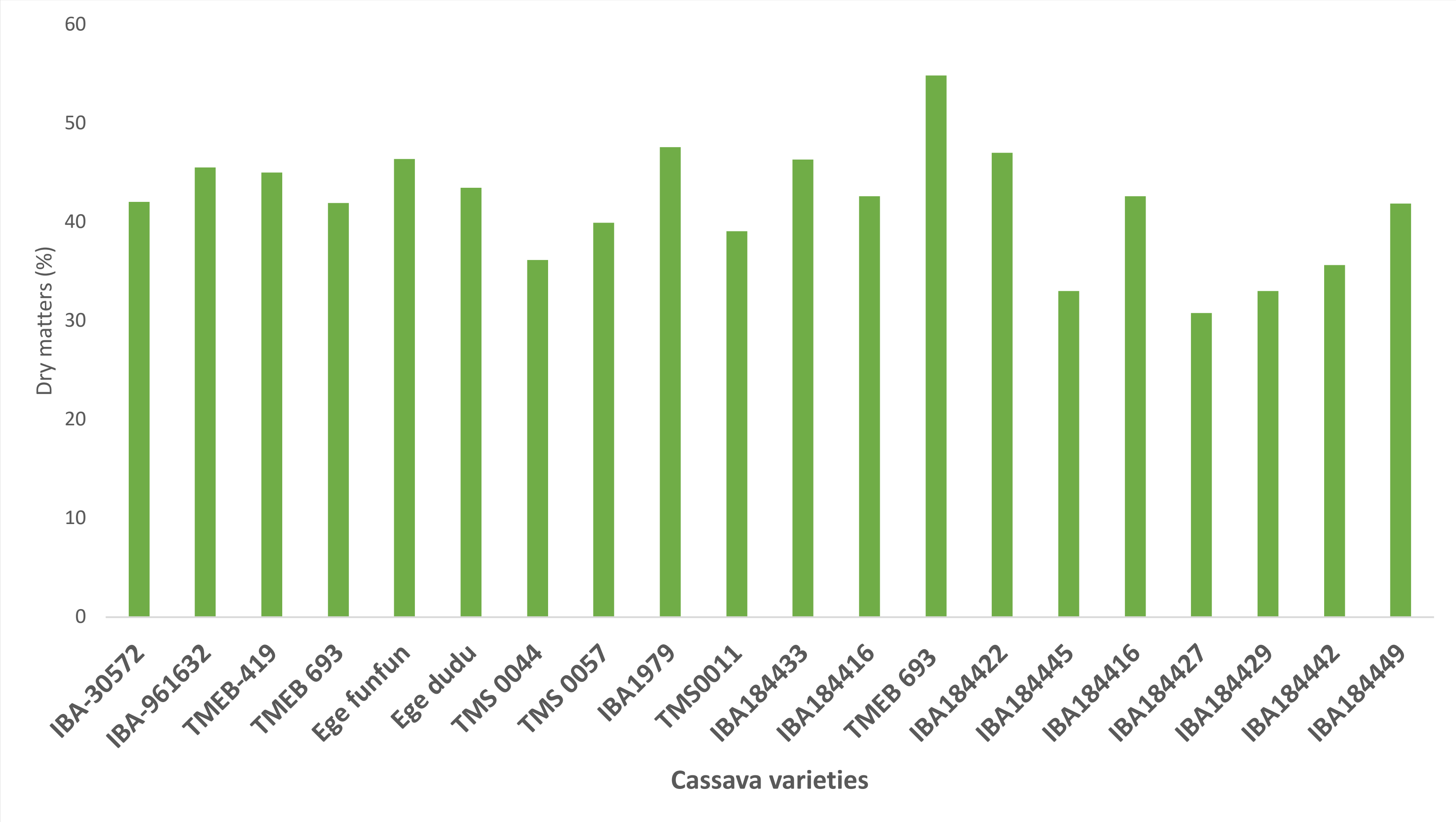

Figure 3: Dry matters of some cassava varieties

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CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

The findings of this study showed that there was a positive correlation between cooking time and sensory softness and chewiness. Cooking time determines softness and ease of chewiness of boiled cassava. However, cassava with high dry matter cooked very fast. The study established that TMEB 693 (*isunikankiyan)*, TMEB 419, *ege funfun/okoiyawo*, IBA011797 and IBA184429 cassava varieties boiled within 25 min. These cassava varieties are soft and easy to chew and can be regarded as sweet cassava roots. Sweet cassava roots are usually eaten at home, cooked, fried, and as an ingredient of different formulations in food industries. Thus, appearance, taste and cooking time are the most desirable characteristics of boiled cassava roots.

This research contributes valuable insights for cassava breeding and selection programs focused on developing varieties with optimal cooking qualities. By identifying varieties that offer shorter cooking times and the right sensory texture, breeders can work toward improving cassava's quality and acceptance. This will support the widespread adoption of boilable cassava varieties, making this staple crop more accessible and enjoyable for consumers in cassava-growing regions.
It is recommended that TMEB693, IBA011797, TMS 0044, TMS 0057, *Ege fun fun* and TMEB419 are among the cassava types that are suitable for consumption as cooked roots. The roots cooked fast, were chewable and relatively soft. For these types, a cooking time of less than 25 minutes is advised.

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Author contribution

Adebowale Oluwaseun Osunbade: conceptualization (equal), initial draft writing (lead), writing, review and editing (lead). Emmanuel Oladeji Alamu: conceptualization (equal), writing-original draft (supporting), writing, review and editing (supporting). Wasiu Awoyale: conceptualization (equal), original draft writing (supportive), writing, review and editing (supporting). Michael Adesokan: conceptualization (equal), original draft writing (supportive), writing, review and editing (supporting). Gregory Nwaoliwe: conceptualization (assistance), data collection (supporting), writing, review and editing (supporting). Aishat Bolanle Akinwande: conceptualization (helpful), writing-first draft (helpful), writing-review and editing (supporting). Johnson Akinwumi Adejuyitan: conceptualization (assistance), writing-review and editing (supporting). Lungaho, Mercy: conceptualization

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(assistance), writing-review and editing (supporting). Busie Maziya-Dixon: conceptualization (assistance), writing, review and editing (supporting).

Conflict of interest

In this work, the authors declare that they have no competing interests.

Ethical guidelines

This study does not require ethical approval.

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Table 1: Descriptive sensory properties of boiled cassava roots

S/N	Varieties	Chewiness	Mealiness	Softness	Appearance	Taste
1	TMEB693	1.53	2.09	2.04	1.92	1.25
2	IBA30752	2.06	1.56	3.17	1.74	1.60
3	TMEB419	1.71	2.05	2.34	2.17	1.13
4	IBA961632	2.26	2.42	3.75	2.42	1.59
5	IBA30572	2.42	2.54	2.75	2.08	1.25
6	IBA184422	2.04	2.63	3.13	2.00	1.38
7	TMS0057	1.92	2.21	2.21	2.17	1.54
8	TMS0011	2.00	2.17	3.50	1.71	1.67
9	IBA1797	1.54	2.42	2.25	2.00	1.33
10	*EGE FUNFUN*	1.21	2.63	1.83	1.92	1.17
11	*EGE DUDU*	2.54	2.92	3.58	1.88	1.42
12	IBA184416	2.64	3.00	2.83	2.42	1.54
13	IBA184433	2.38	2.96	3.75	2.29	1.33
14	IBA184416	2.52	2.13	3.25	2.08	1.08
15	TMS0044	1.29	2.63	1.08	1.83	1.08
16	IBA184445	2.00	2.17	3.33	1.81	1.29
17	IBA184427	2.50	2.28	3.17	2.04	1.25
18	IBA184429	1.75	2.09	3.04	1.96	1.33
19	IBA184449	2.38	1.83	2.68	2.17	1.25
20	IBA184442	2.00	2.00	2.80	2.21	1.83

Key:	Chewiness	Mealiness	Softness	Appearance
	1=chew easily	1=cut easily	1=soft	1=cracky
	2=chew moderately	2=melt/dissolve easily	2=moderately soft	2=slightly cracky
	3=hard to chew	3=not break/scatter/ melt easily	3=slightly soft	3=non-cracky

Sweetness
1=sweet
2=not sweet
3=bitter

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Table 2: Sensory and Instrumental texture attributes, and cooking time of boiled cassava roots

	Sensory texture attributes		*Instrumental texture attributes		
Cassava roots	Chewiness	Softness	Hardness (g)	Work done (g/sec)	Cooking time (min)
TMEB 419	1.40	1.90	2946.70	2250.88	15
TMEB 693	1.50	1.50	1367.00	1935.88	10
TMS16F2021P0044	2.30	3.50	2682.60	7900.64	21
IBA 30572	2.10	2.80	2164.00	4870.31	20
TMS16F2022P0057	2.50	3.00	2767.40	4114.63	19
IBA 011797	2.00	2.30	2029.00	2821.65	17

*Texture results are an average of six measurements; Chewiness: 1=easy to chew, 2=moderately chew, 3= hard to chew; Softness: 1=soft, 2= moderately chew, 3=hard to chew

Table 3: Pearson's correlation coefficient between instrumental texture, sensory and cooking time

	Work done (g/sec)	Cooking time (min)	Chewiness	Softness
Hardness	0.39ns	0.61ns	0.32ns	0.54ns
Work done (g/sec)		0.81ns	0.70ns	0.92**
Cooking time (min)			0.81*	0.94**
Chewiness				0.89*

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

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Table 4: Relationship between the cooking time and dry matters of cassava root

Cassava Varieties	Cooking time (min)	Dry matter (%)
IBA-30572	36.7^{h}	42.08^{k}
IBA-961632	41.1^{b}	45.55^{f}
TMEB-419	25.6^{n}	45.05^{g}
TMEB 693 check	22.8^{r}	41.95^{l}
Ege funfun	23.6^{q}	46.46^{d}
Ege dudu	32.7^{k}	43.52^{h}
TMS 0044	23.7^{p}	36.21^{o}
TMS 0057	24.5^{o}	39.97^{m}
IBA1797	23.6^{q}	47.66^{b}
TMS0011	29.6^{l}	39.10^{n}
IBA184433	38.3^{d}	46.40^{e}
IBA184435	35.9^{i}	42.65^{j}
TMEB 693	21.6^{s}	54.89^{a}
IBA184422	34.3^{j}	47.04^{c}
IBA184445	37.3^{e}	33.04^{r}
IBA184416	27.5^{m}	42.68^{i}
IBA184427	40.3^{c}	30.80s
IBA184442	35.7^{g}	35.70^{p}
IBA184449	37.1^{f}	41.93^{l}
IBA184429	48.3^{a}	33.07^{q}

Mean values with the same superscript along the column are not significantly different ($p<0.05$)

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