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HERITABILITY, VARIANCE COMPONENTS AND GENETIC ADVANCE OF GARRI QUALITY TRAITS IN CASSAVA VARIETIES CULTIVATED IN OKUKU OWERRI-WEST SOUTHEASTERN, NIGERIA

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ABSTRACT

The experiment was conducted at the Center for Agricultural Research, School of Agriculture and Agricultural technology of the Federal University of Technology Owerri, Imo State, Nigeria between January, 2023 – January, 2024 to estimate the heritability, variance components and genetic advance as the percentage of the mean of garri quality traits in cassava varieties cultivated in Okuku (Okuku locals) along some improved varieties. Three local varieties were sourced from a subsistence farmer in Okuku, Owerri-West, Imo State and five improved varieties were sourced from National Root Crop Research Institute (NRCRI), Umudike, Abia State. Each cassava variety was planted in a 12x1m ($_{12m^{2)}}$ plot size at a planting distance of 1mx1m. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. Cassava stem cuttings of about 20cm with at least four nodes were planted on ridges, at 48 weeks after planting; the eight cassava varieties were harvested and processed into garri. The garri quality traits were grouped into: functional properties, proximate composition and minerals composition. Data were collected on swelling index(%), bulk density(g/ml), water absorption capacity(%), moisture content(%), ash(%), dietary fiber(%), crude fat(%), crude protein(%), carbohydrate(%), calcium(%), sodium(%), phosphorus(%) and potassium(%). Data collected were subjected to analysis of variance (ANOVA) and means separation was done using Least Significant Difference (LSD). The Analysis of Variance showed significant differences ($p < 0.05$) among the cassava varieties evaluated. Nwajeni and TMS 164773 exhibited higher protein, swelling index, and mineral contents, and so, may be preferred for nutritional and functional quality. Conversely, IBA980505 with lower moisture content and higher carbohydrate may be favored for shelf stability and energy yield. Genetic parameters such as mean, range, coefficient of variation, variances, heritability in broad-sense and genetic advance as the percentage of the mean were estimated for the 13 different traits. The study demonstrated that the observed variation was predominantly genetic in nature for most traits. Heritability values range from 35.90 – 99.96%. Traits with the highest Genetic Advance as Percentage of Mean (GAM) were Ash (145.45%), Calcium (Ca) (122.22%), Crude Fiber (CFr) (45.45%), and Crude Fat (CF) (44.28%)., the combination of high heritability and high genetic advance for traits like Ash, Ca, CF, and CFr suggests that direct phenotypic selection remains the most efficient and rapid approach to improving key garri quality attributes

Key words: heritability, genetic, garri, cassava, traits, varieties

Introduction

Cassava (*Manihot esculenta Crantz*) is an important root crop in Africa, known for its broad adaptation. It is a major staple crop in Nigeria, mostly processed into food products by small or medium-scale farmers and processors (IITA, 2012; Onyenwoke & Simonyan, 2014). Some common products of cassava in Nigeria are garri, fufu and eba.

Garri a byproduct of cassava, is the most popular form in which cassava is sold and consumed in Nigeria and in many other African countries (Oluwole, Olatunji and Odunfa 2008). It is a staple food, stored and marketed in ready to eat form. Among all the processed products of cassava, garri takes up the largest percentage of cassava produced in West Africa, particularly Nigeria (Udoro, Kehinde, Olasunkanmi and Charles 2014). It can be consumed dry, or with cold water and / or reconstituted with hot to form a dough which is eaten with soup (Nweke, Spencer, and Lynam 2002) or stew. It may also be eaten with fried or roasted fish, coconuts, groundnuts, and palm kernel dry or mixed with cold with or without addition of sugar. Garri ease of preparation for consumption, storage, affordability and profitability to farmers and processors make it a high demand commodity (Oluwafemi, and Udeh, 2016). It is produced from fresh harvested cassava roots by the process of peeling, washing and grating of the cassava roots, fermentation (depending on region), and dewatering to obtain mash, sieving of the mash and toasting to garri.

Cassava improvement in West Africa has focused on increasing root yield, nutrition, and resilience to numerous biotic and abiotic constraints that affected the crop's productivity with insufficient consideration of the garri quality (Okechukwu and Dixon, 2008).

The quality and consumer acceptability of garri are influenced by its functional properties, proximate composition as well as mineral composition. Despite the importance of these qualities, there is insufficient knowledge of the genetic parameters underlying them, particularly in cassava varieties cultivated in Okuku, Owerri-West, and a major cassava producing area in Southeastern, Nigeria. The lack of adequate information on heritability, variance components and genetic advance as the percentage of the mean of the functional properties, proximate composition and mineral composition of garri hinders efforts to identify superior cassava genotypes that combine good yield with desirable processing qualities. As a result, farmers and processors rely on local varieties without any clear understanding of their genetic potential for improving garri quality. This has led to inconsistencies in the quality of garri produced, limiting opportunities for value addition, reducing market competitiveness, and hindering the role of cassava in both market and international food system. It is therefore important to address this gap to strengthen cassava improvement programs and ensuring a sustainable production of high-quality garri.

Understanding the heritability and expected genetic advance of functional properties, proximate composition and mineral composition of garri is fundamental for guiding cassava breeding and selection programs. According to Tazeen, Nadia, Farzana, (2009) heritability plays a predictive role in breeding, expressing the reliability of phenotype as a guide to its breeding value. High heritability estimates for desirable traits suggest that genetic factors play a major role in trait expression, and selection based on phenotypic performance can reliably result in genetic improvement. Similarly, information on variance components and genetic advance provides breeders with predictive tools to evaluate the potential gains achievable through selection. Genetic advance with high heritability estimates offers the most effective condition for selection (Larik, Malik, Kakar, and Naz 2000). Such knowledge is important for developing

cassava varieties that consistently produce garri of superior quality. Studying cassava varieties cultivated in Okuku, Owerri-West is important because it is a cassava growing zone in Southeastern, Nigeria where garri serves as both staple and a major household income. Identifying varieties with heritable and superior functional and nutritional qualities will benefit not only farmers and processors but also consumers, by ensuring better product quality, improving market value and enhancing food security. In addition, the findings will provide baseline data for cassava improvement programs, strengthen the cassava value chain and support industrialization of cassava in Nigeria. The main objective of this study is therefore, to evaluate the genetic parameters influencing garri quality traits in local cassava varieties cultivated in Okuku. Specifically, the study seeks to determine the extent to which these traits are heritable, how much of their variation is due to genetic versus environmental factors and the potential for genetic improvement. This will provide baseline information for breeders aiming to enhance garri quality and consumer acceptability.

Specific objectives:

1. To estimate the variance components for key garri quality traits.
2. To determine the heritability of garri quality traits such swelling index, bulk density, moisture content, water absorption capacity etc.
3. To estimate the genetic advance and genetic gain expected from selection for improved garri quality traits.
4. To provide baseline genetic information that can guide cassava improvement programs focused on processing and end-use quality traits.

To identify cassava varieties with superior quality characteristics suitable for breeding and production in the Okuku environment.

Materials and method

The research was carried out at the Center for Agricultural Research, School of Agriculture and Agricultural technology of the Federal University of Technology Owerri, Imo State, Nigeria between January 2023 and January 2024. The center is located at latitude $5^0 27N$and longitude $7^0 02"E$ with mean temperature of 29°C, relative humidity of 89% and altitude of 50 to 70cm above sea level.

Sourcing of materials

Mature and healthy stem cuttings of three local cassava varieties were obtained from a local subsistence farmer in Okuku, Owerri-West local government area, Imo State, Nigeria, and mature and healthy stem cuttings of five improved cassava varieties were obtained from National Root Crop Research Institute (NRCRI), Umudike, Abia State, South-East Nigeria. The stem cuttings of each cassava variety were collected from the middle stems of the respective seven-month-old plant. The stem cuttings were covered with grass while transporting to the plantation area in order to reduce evaporation and dryings.

Treatments and experimental design

In this study, Randomized Complete Block Design (RCBD) was employed. The experiment was carried out under field condition using eight varieties as treatments, namely, Akwatakwa, Nwajeni, Obanyanyam, TMS154810, TMS164773, TME419, IBA980505, and TMS-IBA980581 with four replications. The experimental field was cleared, and ridges were made before planting. The plots were 12m long and 1m wide with intra row spacing of 1mx1m. Therefore, the total size of each plot was $12m^2$. The cuttings were planted with inclined stake orientation on the 3rd of January, 2023. Totally, there were 12 plants per plot

for each variety. Weeding was done with hoe, while harvest was done at 48weeks after planting, and the fresh harvested cassava roots were processed into garri

Garri processing

Garri was produced using the method described by Nweke et al (2002). The fresh harvested root from each plot were peeled, the peeled roots were washed with water and grated. The grated samples were packed in labeled jute bags, tied and pressed in a jack in order to remove water, the lumps were broken and sieved with an iron sieves to remove chaff and roughages. The sieved samples were toasted in a deep-frying pan until it became dry and brittle; the resulting garri was allowed to cool, packaged and stored in a zip lock bag for analysis.

Data collection

Data were collected on swelling index(%), bulk density(g/ml), water absorption capacity(%), moisture content(%), dietary fiber(%), crude fat(%), crude protein(%), ash content(%), available carbohydrate(%), calcium(%), potassium(%), sodium(%) and phosphorus(%).

Data analysis

Data collected was subjected to analysis of variance (ANOVA) using GENSTAT, while treatment means were compared using Least Significant Difference of at 5% probability level (Obi, 2002). Genetic parameters were estimated by the formula given by Malek, Rafii, Afroz and Mondel (2014). These parameters include the following;

i) $\sigma^2 G$(or VA which is an estimate of genotypic variance) $= MS_G - MS_E/r$, where MS_G is an estimate of mean square of tested accession, $MS_E$is an estimate of mean square of error and r refers to the number of replications;

ii) $\sigma^2 p$ (or $v_p$which is an estimate of phenotypic variance) $= (\sigma^2 G + MS_E/r)$

iii) H_b^2(an estimate of broad sense heritability $= \frac{V_A}{V_P} \times 100$

iv) GCV(Genotypic coefficient of variation) $\frac{\sqrt{\sigma^2 G}}{\bar{x}} \times 100$, where $\sigma^2 G$ the genotypic component of variance and $\bar{x}$ is the mean of the trait.

v) PCV(Phenotypic coefficient of variation) $= \frac{\sqrt{\sigma^2 P}}{\bar{x}} \times 100$, where $\sigma^2 P$ is the phenotypic component of variance and $\bar{x}$is the mean of the trait.

vi) GA (Genetic advance, which is taken as percentage of the mean assuming selection of the superior 5% of the varieties $= k \times \frac{\sqrt{\sigma^2 P}}{\bar{x}} \times H_b^2 \times 100$, where K (the standard selection intensity)$= 2.06$ (at 5% selection intensity, $\sigma^2 P$ is the phenotypic component of variance, $H_b^2$is the heritability in broad sense and $\bar{x}$ refers to the mean of the trait being evaluated.

Results

Table 1 shows the mean values of the functional properties (swelling index (%), bulk density (g/ml) and water absorption capacity (%)) of garri produced from eight cassava varieties. The functional properties showed significance differences (P < 0.5) among the cassava varieties evaluated. The swelling index ranged from 9.09% in "IBA980505" to 10.28% in :Nwajeni" the bulk density ranged from 0.37g/ml in "TMS 164773" to 0.49g/ml in "IBA 980505" while water absorption capacity varied from 2.56% in "TMS 164773" to 4.13% in "Nwajeni".

Table 1: Mean Values Of Functional Properties Of Garri Produced From Eight Cassava Varieties Studied.

Cassava Varieties	Swelling index (%)	Bulk density (g/ml)	Water Absorption capacity (%)
Akwatakwa	9.84	0.47	3.17
IBA980505	9.09	0.49	2.86
Nwajeni	10.20	0.44	4.13
Obanyanyam	9.81	0.47	3.71
TME 419	9.88	0.47	3.52
TMS 154810	9.87	0.40	3.23
TMS 164773	9.85	0.37	2.56
TMS-IBA980581	10.13	0.42	3.75
LSD(0.05)	0.166	0.019	0.030

Table 2 shows the mean percentages of proximate composition (moisture content, ash, crude protein, crude fat, dietary fiber and carbohydrate) contents of garri produced from eight cassava varieties. The proximate composition showed significance differences (P < 0.5) among the cassava varieties. The moisture content ranged from 9.67% in "IBA 980505" to 13.54% in "Obanyayam," the ash content ranged from 0.27% in" TME419" to 1.22% in "Akwatakwa".Crude protein contents ranged from 3.26% in" IBA980505" to 4.25% in" Nwajeni". Crude fiber content varied from 0.14% in "Obanyayam" to 0.33% in "IBA 980505". Also, crude fat content varied from 0.01% in "Obanyayam" and "Akwatakwa" to 0.89% in "TME 419", while the available carbohydrate content (%) varied from 81.30 in "Obanyayam" to 85.87 in IBA 980505.

Table 2: Mean Percentages of Proximate Composition of Garri Produced from Eight Cassava Varieties Studied.

Cassava Varieties	Moisture content (%)	Total ash (%)	Crude protein (%)	Crude fiber (%)	Crude fat (%)	Carbohydrate (%)
Akwatakwa	12.70	1.22	3.52	0.23	0.01	82.39
IBA980505	9.67	0.90	3.26	0.33	0.02	85.87
Nwajeni	12.51	0.58	4.25	0.23	0.03	82.41
Obanyanyam	13.54	0.91	4.14	0.14	0.01	81.30
TME 419	13.12	0.27	4.17	0.24	0.89	81.32
TMS 154810	12.43	0.65	3.75	0.17	0.02	83.13
TMS 164773	11.72	1.18	3.75	0.16	0.11	83.03
TMS-IBA980581	11.31	0.91	3.84	0.24	0.02	83.60
LSD(0.05)	0.198	0.061	0.16	0.042	0.028	0.339

Table 3 shows the mean percentages of mineral contents (calcium, phosphorus, sodium and potassium) of garri samples of eight cassava varieties. The mineral contents showed significant differences (P < 0.5) among the cassava varieties .The calcium contents ranged from 0.04% in "Akwatakwa" to 0.22% in TMS 164773, the potassium ranged from 0.03% in TMS 164773 to 0.08% in "Akwatakwa" and "Nwajeni", and the sodium content varied from 0.06% in "TME 419"

to 0.13% in "TMS 164773" and "IBA980505" while the phosphorus content varied from 0.02% in "Nwajeni" to 0.06% in "TMS-IBA980581".

Table 3: Mean Percentages of Mineral Composition of Garri Produced from Eight Cassava Varieties Studied.

Cassava Varieties	Calcium (Ca) (%)	Potassium (K) (%)	Sodium (Na) (%)	Phosphorus (P) %
Akwatakwa	0.04	0.08	0.11	0.05
IBA980505	0.06	0.04	0.13	0.04
Nwajeni	0.11	0.08	0.08	0.02
Obanyanyam	0.07	0.04	0.09	0.03
TME 419	0.07	0.04	0.06	0.03
TMS 154810	0.08	0.05	0.12	0.03
TMS 164773	0.22	0.03	0.13	0.04
TMS-IBA980581	0.05	0.04	0.11	0.06
LSD(0.05)	0.024	0.021	0.024	0.019

Table 4 shows the estimate of range, mean. Variances, coefficient of variances, heritability and genetic advance as the percentage of the mean of the 13 traits studied.

Phenotypic Variability and Mean Performance

The analysis of 13 garri quality traits across 8 cassava varieties revealed significant variability, as evidenced by the wide Range for most traits .

Nutritional and Proximate Composition: Carbohydrate (CBH) had the highest mean value (82.88%), reflecting the starchy nature of the product.

The mean Crude Protein (CP) was 3.81%, and Moisture Content (MC) was 12.13%, which is slightly above the recommended 8−10% for long-term storage, indicating potential post-processing variability

Functional Properties: Swelling Index (SI) had a mean of 9.83, and Water Absorption Capacity (WAC) had a mean of 3.37.

These values are within the acceptable range for quality garri, which is highly appreciated by consumers for its high volumetric expansion (swelling).

High Variability: Crude Fat (CF) and Ash exhibited the widest range in their absolute values, from 0.00 to 0.96 and 0.25 to 1.24, respectively.

The mineral elements, particularly Calcium (Ca), showed a large proportional range (0.02 to 0.23), suggesting distinct varietal differences in nutrient uptake or retention during processing.

Estimates of Variances and Coefficients of Variation

The study demonstrated that the observed variation was predominantly genetic in nature for most traits. Phenotypic Coefficient of Variation (PCV) was marginally higher than the Genotypic Coefficient of Variation (GCV) for almost all traits, confirming a minimal environmental influence. The PCV and GCV were very close for traits like Crude Fat (CF) (217.63% and 217.19%), Ash (38.49% and 38.16%), and Calcium (Ca) (66.25% and 63.78%).

The highest coefficients of variation were recorded for Crude Fat (GCV=217.19%), Ash (GCV=38.16%), and Calcium (GCV=63.78%).

Conversely, Carbohydrate (CBH), Swelling Index (SI), and Crude Protein (CP) showed the lowest GCV values, indicating less relative genetic variability in these core quality traits.

Estimates of Heritability and Genetic Advance

The heritability estimates and genetic advance revealed the potential and ease of genetic improvement. Ten out of the 13 traits displayed very high heritability (h^2 >90%). Notably, Crude Fat (CF) (99.59%), Moisture Content (MC) (98.79%), Ash (98.31%), and Carbohydrate (CBH) (97.55%) had near-unity heritability values, suggesting that phenotypic selection for these traits would be highly reliable. Water Absorption Capacity (WAC) had a heritability of 99.96%, indicating that the trait is almost entirely controlled by additive genetic effects, and selection should be extremely effective. Traits with the highest Genetic Advance as Percentage of Mean (GAM) were Ash (145.45%), Calcium (Ca) (122.22%), Crude Fiber (CFr) (45.45%), and Crude Fat (CF) (44.28%).

The high heritability coupled with high GAM indicates that the traits are governed by additive gene action, which can be effectively fixed through breeding. Phosphorus (P) recorded the lowest heritability (35.90%) and corresponding low GAM (25.00%), while Carbohydrate (CBH) had a very low GAM (3.54%) despite high heritability, suggesting limited genetic variation for this trait. This combination indicates that non-additive gene action and environmental effects may have a greater influence, making selection challenging.

Table 4: Range, Mean, Variances, Coefficient Of variances, Heritability and Genetic Advance as the Percentage of the Mean of the 13 Traits Studied.

raits	Range	Mean	$(\sigma^2 g)$	$(\sigma^2 p)$	h_B^2	GCV	PCV	GA	GAM
ASH	0.25 – 1.24	0.83	0.10036775	0.10208875	98.31	38.16	38.49	0.64	145.45
CP	3.20 – 4.35	3.81	0.123245	0.135035	91.26	9.21	9.64	0.60	15.74
CF_r	0.12 – 0.39	0.22	0.0032119	0.004021	79.87	25.76	28.82	0.10	45.45
MC	9.52 – 13.81	12.13	1.4896525	1.50776255	98.79	10.06	10.12	2.49	20.52
CF	0.00 – 0.96	0.14	0.092459525	0.092833925	99.59	217.19	217.63	0.62	44.28
CBH	80.94 – 85.96	82.88	2.125165	2.178405	97.55	1.76	1.78	2.94	3.54
SI	9.05 – 10.25	9.83	0.1086175	0.1213775	89.48	3.35	3.54	0.64	6.51
VAC	2.60 – 4.18	3.37	0.2639405	0.26280895	99.96	15.20	15.20	1.05	31.31
BD	0.35 – 0.50	0.44	0.001778275	0.001953975	91.00	9.58	10.04	0.08	18.18
Ca	0.02 – 0.23	0.09	0.00329525	0.003360275	98.06	63.78	64.41	0.11	130.22
K	0.02 – 0.09	0.05	0.000332425	0.000530825	62.62	36.47	46.08	0.02	40.00
Na	0.03 – 0.14	0.10	0.00049525	0.00075535	65.56	22.25	27.48	0.03	30.00
P	0.01 – 0.07	0.04	0.000091375	0.000254475	35.90	23.89	39.88	0.01	25.00

CP - Crude protein, CFr - Crude fiber, MC- Moisture content, CF- Crude fat, CBH - Carbohydrate, SC-Swelling index, WAC-Water absorption capacity, BD- Bulk density, Ca - Calcium, K - Potassium, Na - Sodium, P - Phosphorus.

Discussion

The results obtained from the functional, proximate composition, and mineral analyses of garri produced from eight cassava varieties revealed that significant ($p < 0.05$) variations exist among all the parameters evaluated. This indicates that cassava variety exerts a strong influence on the functional performance, nutritional composition and mineral profile of garri.

Functional properties

Swelling index is the ability of samples to absorb water and swell at room temperature. According to Ukpabi and Ndimele (1990) a good quality garri has been described as that which can swell at least 3 times to its original volume. The significant variation observed in the functional properties (swelling index, bulk density, and water absorption capacity) indicates that cassava variety affects the physicochemical behavior of garri.

The swelling index ranged from 9.09% to 10.20%, which aligns with the report of Sanni, Kosoko, Adebowale, and Adeoye, (2006) that garri typically, exhibits a swelling capacity between 8% and 12%. Varieties with higher swelling indices, such as Nwajeni and TME 419, may produce more voluminous products when reconstituted, which is desirable to consumers.

Bulk density is a physical property that reflects how compact or lose a food powder (like garri) is, and it affects packaging, storage, transportation, and consumer preferences. The bulk density (0.37–0.49 g/ml) values also differed significantly, suggesting variations in particle size distribution and packing behavior. This agrees with Akingbala, Oyewole, Uzo-Peters, and Karim, (2011) who observed that bulk density of garri depends on granule size and degree of roasting.

Water absorption capacity is the ability of flour to absorb water and swell for improved consistency in food. It is desirable in food to improve yield, consistency and give body to the food (Osundahunsi, Fagbeni, Kesselman and Shimoni (2003). The water absorption capacity (2.56–4.13%) also varied significantly, implying differences in starch gelatinization properties and fiber content. Varieties with higher water absorption capacity can absorb more water during soaking or reconstitution, which affects texture and mouth feel.

Proximate composition

Significant differences were observed in the proximate components (moisture, ash, protein, fiber, fat, and carbohydrate) among the cassava varieties studied. Moisture content is an indication of shelf life of a garri sample.

The moisture content ranged from 9.67% to 13.54%, which falls within acceptable limits (<12%) for safe storage of garri as reported by Oluwamukomi and Adeyemi (2015). However, varieties with higher moisture contents (such as Obanyanyam and TME 419) may have shorter shelf lives due to increased susceptibility to microbial growth. The observed variation could be attributed to differences in the dry matter content of the roots, processing efficiency, and drying duration.

Ash content is a measure of minerals in a food substance. According to the specification of the Nigerian National Standard Specifications for garri, the maximum ash content of garri should not exceed 2.75% (Oti, Onadipe, Sebastienne, Egounlety, Detouch, Gregory, and Loueke 2010).

The ash content (0.27–1.22%) varied significantly, indicating differences in mineral content and purity. This is consistent with findings by Oluwole, Olatunji, and Odunfa, (2020) who reported that varietal differences and processing methods can influence mineral retention in cassava products. Similarly, the crude protein content (3.26–4.25%) observed is within the typical range for garri (2–4%), as reported by

Oluwatayo, Akinyemi, and Akingbala, (2019). The variation suggests that some cassava genotypes may possess higher nitrogen content or lower protein loss during fermentation and roasting.
The crude fiber (0.14–0.33%) and crude fat (0.01–0.89%) values differed significantly among varieties. Fiber variation may result from differences in root fiber density and the degree of sieving during garri processing. The relatively low fat content agrees with the findings of Akingbala et al. (2011) and is expected, since cassava is a low-lipid crop). Carbohydrate, the chief nutrient in garri has been known as the major energy "giving food" for consumers in West Africa and other regions of the world where cassava and its processed derivative are widely consumed. Carbohydrate content (81.30–85.87%) formed the bulk of the proximate composition and varied significantly, which reflects varietal differences in starch accumulation. Varieties with higher carbohydrate content may yield garri with better energy value and economic advantage.

Mineral Composition
Significant differences were observed in the mineral elements (Ca, K, Na, and P) among the cassava varieties. These findings agree with Oduro, Ellis, Dziedzoave, and Nimako-Yeboah (2013) who reported that mineral levels in garri are influenced by cassava genotype and the leaching effect during fermentation.

The calcium content ranged from 0.04% to 0.22%, with TMS 164773 recording the highest value, suggesting higher mineral density in that variety. Potassium (0.03–0.08%) and sodium (0.06–0.13%) contents varied significantly, reflecting differential mineral uptake from the soil and loss during processing. Phosphorus content (0.02–0.06%) also showed significant variation and is consistent with previous findings by Ayenor and Oduro (2002). The relatively low mineral levels across all varieties may be probably due to roasting temperature.
The significant differences across all parameters highlight the influence of genetic and processing factors on garri quality. Varieties such as TMS 164773 and Nwajeni, which exhibited higher protein, swelling index, and mineral contents, may be preferred for nutritional and functional quality. Conversely, varieties with lower moisture and higher carbohydrate (such as IBA980505) may be favored for shelf stability and energy yield.

The Supremacy of Genetic Control on Garri Quality
The finding that the Phenotypic Coefficient of Variation (PCV) is very close to the Genotypic Coefficient of Variation (GCV) for most garri quality traits, and that ten traits possess very high broad-sense heritability (h^2 >90%), strongly suggests that the expression of these traits is minimally influenced by environmental factors and is primarily under genetic control.
This high genetic control is vital for breeding programs. It indicates that breeders can rely on a variety's observed phenotypic performance to predict the performance of its progeny, making direct selection highly effective. Recent studies on cassava quality traits, such as Karim and Akintayo (2021) reported high heritability for key processed product traits like Garri Yield and Dry Matter Content (DMC), supporting the genetic stability observed here for related traits.

Breeding for Desirable Proximate and Functional Traits

The goal of cassava breeding for garri is to select for varieties with high nutritive value and superior functional properties. Functional quality traits such as Swelling Index (SI) (89.48%) and Water Absorption Capacity (WAC) (99.96%) exhibited high heritability, implying strong genetic control. These traits determine garri's "swellability," a major consumer preference attribute (Ndjouenkeu , Franklin, Béla, Benjamin, Tessy, Olamide, Ugo, Abolore. (2020).). The high heritability and moderate GAM for these traits suggest that consistent genetic improvement for superior swelling ability is achievable through selection.

The extremely high GCV and GAM for Ash (145.45%) and Calcium (Ca) (122.22%) indicate that the existing germplasm harbors immense genetic variation for these mineral elements. This presents an opportunity for biofortification to improve mineral content in garri. Conversely, selection pressure can be applied to reduce undesirable components like Crude Fat (CF) and Crude Fiber (CFr), both showing high heritability and GAM, allowing efficient selection for lower values

Challenges in Mineral and Core Content Selection

While most traits show excellent potential for improvement, the results for Phosphorus (P) and Carbohydrate (CBH) pose distinct challenges. Low heritability for P suggests unreliable phenotypic selection due to strong environmental influence, requiring complex breeding approaches such as hybridization or progeny testing to capture non-additive effects. CBH, despite extremely high heritability, had a low GAM (3.54%), indicating limited exploitable variation — cassava may have reached its genetic limit for starch accumulation. Future breeding could therefore focus on improving starch quality rather than quantity.

Overall, the combination of high heritability and high genetic advance for traits like Ash, Ca, CF, and CFr suggests that direct phenotypic selection remains the most efficient and rapid approach to improving key garri quality attributes.

Conclusion

The study showed significant differences among the cassava varieties regarding all the traits studied. TMS 164773 and Nwajeni exhibited higher protein, swelling index, and mineral contents, and so, may be preferred for nutritional and functional quality. Conversely, IBA980505 with lower moisture content and higher carbohydrate may be favored for shelf stability and energy yield. Phenotypic Coefficient of Variation (PCV) was marginally higher than the Genotypic Coefficient of Variation (GCV) for almost all traits, confirming a minimal environmental influence. The PCV and GCV were very close for traits like Crude Fat (CF) (217.63% and 217.19%), Ash (38.49% and 38.16%), and Calcium (Ca) (66.25% and 63.78%). The highest coefficients of variation were recorded for Crude Fat (GCV=217.19%), Ash (GCV=38.16%), and Calcium (GCV=63.78%). Conversely, Carbohydrate (CBH), Swelling Index (SI), and Crude Protein (CP) showed the lowest GCV values, indicating less relative genetic variability in these core quality traits. Heritability values range from 35.90 – 99.96%, ten out of the 13 traits displayed very high heritability (h^2 >90%). Notably, Crude Fat (CF) (99.96%), Moisture Content (MC) (98.79%), Ash (98.31%), and Carbohydrate (CBH) (97.55%) had near-unity heritability values, suggesting that phenotypic selection for these traits would be highly reliable. Water Absorption Capacity (WAC) had a heritability of approximately 100%, indicating that the trait is almost entirely controlled by additive genetic

effects, and selection should be extremely effective.. Traits with the highest Genetic Advance as Percentage of Mean (GAM) were Ash (145.45%), Calcium (Ca) (122.22%), Crude Fiber (CFr) (45.45%), and Crude Fat (CF) (44.28%)., the combination of high heritability and high genetic advance for traits like Ash, Ca, CF, and CFr suggests that direct phenotypic selection remains the most efficient and rapid approach to improving key garri quality attributes.

Recommendations

1. Selection efforts should focus on these traits with high heritability and high genetic advance.
2. Multi-environment trials should be conducted to quantify genotype-by-environment interaction patterns
3. Studies should be conducted on processing parameters (pressing /dewatering, roasting temperature/time.

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