Hindawi
Journal of Food Quality
Volume 2022, Article ID 9904103, 13 pages
https://doi.org/10.1155/2022/9904103

Research Article

Biochemical Analysis of Cassava (*Manihot esculenta* Crantz) Accessions in Southwest of Ethiopia

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Received 13 March 2022; Accepted 22 April 2022; Published 9 May 2022

Academic Editor: Hadi Hashemi Gahruie

Cassava is a significant contributor to food security and an income source for smallholder farmers in southern Ethiopia. However, little research effort has been done so far based on designing field experiment samples for the biochemical composition of cassava accession at the country level. The study was conducted to assess the biochemical composition of cassava accessions in southwest Ethiopia. Flour samples from the storage roots of 64 cassava accessions were collected and were run in duplicates. Data on 13 biochemical characters were collected and analyzed using standard methods. The analysis of variance showed significant to very highly significant differences among the tested accessions for biochemical composition. The flour moisture ranged from 4.83–10.11%, dry matter (89.89-95.17%), organic matter (86.71–92.65%), ash (2.1–3.96%), fiber (1.14–3.00%), fat (0.26-1.4%), crude protein (1.28-2.86%), starch (65.1–74.2%), carbohydrate (81.29–87.94%), energy (341.44–367.61 kcal/100g DM), and cyanide (1.67–3.14). The highest GCV = 29.54% was shown for crude fat, followed by GCV = 16.94% for crude fiber, and GCV = 16.11% for tannin, whereas, among the characters, dry matter was observed to be the lowest (GCV = 0.84%). The GAM ranged from protein 0.30% to 54.94% for fat, while heritability ranged from flour moisture and dry matter (17.29%) to 84.88% for cyanide. The first five principal components explained 80.1% of the total variation, with PC I accounting for 37%, PC II 15.4%, PC III 11.6%, PC IV 8.4%, and PC V 8.20% of the total variation. This study found the presence of high biochemical variability among the tested accessions' roots and could be used to select accessions with desirable biochemical composition in future breeding work.

1. Introduction

Cassava (*Manihot esculenta* Crantz) is a lucrative crop in terms of food calories generated per unit of area and time, much exceeding other staple crops [1]. Cassava produces more than 250,000 food calories per hectare per day, compared to 200,000 for maize, 176,000 for rice, and 110,000 for wheat [1]. Nonetheless, cassava, like some crops, has poisonous and antinutritional components. Of particular concern are the cyanogenic glucosides of cassava, which include linamarin and lotaustralin at concentrations ranging from 150 to 300 mg/kg in peeled root or 300 to 900 mg/kg in a dry matter [2, 3]. These are hydrolyzed by the plant's endogenous enzyme, linamarase, to release free cyanide. Cyanide suppresses cellular respiration in all aerobic organisms by limiting mitochondrial electron transport and preventing oxygen intake [3].

The hazardous hydrogen cyanide concentration of cassava compromises its dietary value [4]. The presence of cyanide in cassava has been reported as a source of concern for human and animal consumption [5]. The amount of these antinutritional and potentially harmful glycosides varies greatly depending on variety, climate, and cultural factors [1, 6]. Cyanide content is used as a criterion for

selecting cassava cultivars and their flour for use in the food industry and breeding programs [7]. Cassava cultivars are divided into two classes based on their cyanide content: high-HCN or bitter cassava with more than 100 ppm of cyanogenic equivalents and low-HCN or sweet cassava with less than 50 ppm [8]. Some authors categorize cassava cultivars as bitter when the cyanide is spread throughout the tuberous root at levels greater than 100 mg/kg fresh root weight. The other (sweet/cool) cultivars are those in which cyanide is contained primarily in their peels at a low level. The sweet cassava can be cooked and eaten raw, whereas the bitter cassava requires processing before consumption [8].

As a result of inherent characteristics that differ from one cassava genotype to the other, cultivars play a vital role in the creation of a wide range of food products. Proximate composition (proteins, lipids, fiber, ash, and moisture), starch yield, and dry matter content are examples of such parameters [9]. These authors indicated that proximate, dry matter, starch yield, and cyanide content are some of the most important quality indicators in the food sector when selecting raw materials. As a result, determining the starch and other chemical components of cassava cultivars might be helpful in selecting cassava cultivars for various food formulations, processing, and ultimately industrial applications [10]. Cultivar, geographical location, plant maturity stage, and environmental variables are elements that influence chemical composition in plants [2, 11]. The biochemical composition of cassava roots varies based on cultural methods such as root pruning, age at harvest, maturity at harvest, storage environment, area of growth, and postharvest practices [10].

Cassava's nutritional value is determined by the plant portion (root or leaves), cultivar, age, geographical location, and environmental conditions [11, 12]. Cassava storage roots are a good source of energy, with carbohydrate content ranging from 32% to 35% on a fresh weight (FW) basis and from 80% to 91% on a dry matter (DM) basis [13]. Starch content varies with genotypes, in which improved, landraces, account for 73–85% of dry root weight [14]. The high starch content (18–24% amylose and 70% amylopectin) allows easy digestion [15]. Bitter cultivars have low levels of glucose, fructose, sucrose, and maltose [12], whereas sweet cultivars have a sucrose concentration of more than 17% [16]. The lipid content of cassava root varies between 0.1% and 0.3%of fresh weight [17, 18]. The protein content is low, ranging between 1% and 3%of dry matter and 1.5 mg/100 g of fresh mass [19]. Cassava cultivars with high moisture and reducing sugar contents could be employed as raw materials in the ethanol, organic acids, lactic bacteria, and biofuel industries [18]. Fresh cassava root, on the other hand, is very perishable due to its high moisture content (33–72%) [11, 20] and has a short postharvest life of fewer than 72 hours. Cassava is then processed into shelf-stable primary products such as flour, chips, and pellets shortly after harvest.

Many smallholder farmers in Ethiopia grow a variety of root and tuber crops due to the country's diversified agroecologies and favorable conditions [21]. In Ethiopia, Cassava has great adaptation and growth performance in a variety of agroecologies with varying productivity [22]. It is an important food crop in Southern Ethiopia, providing a significant amount of the family's daily meals and serving as a key source of carbohydrates. Currently, farmers are growing cassava as a food security crop and a significant source of household income. Despite the fact that cassava has a wide range of culinary applications, the majority of its products are consumed in Ethiopia by boiling the root and flour [23]. There has also been limited research information on the chemical composition of cassava accessions and knowledge in biochemical compositions. Therefore, the present study aimed to assess the biochemical composition *n* of cassava accessions collected from various areas and provide information for utilization and conservation.

2. Materials and Methods

2.1. Description of the Experimental Site. The experiment was conducted in the postharvest and animal nutrition laboratory of Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) in the year 2021.

2.2. Experimental Material. The study used 64 cassava accessions among which 15 were provided by the International Institute of Tropical Agriculture (IITA), Nigeria. The remaining 49 accessions were obtained from Jimma Agricultural Research Center (5) and Hawassa Agricultural Research Center (44) accessions (Table 1).

2.3. Samples Collection and Preparation. Root samples of 0.5 kg fresh weight each sixty-four cassava accessions were collected from the cassava field experiment located at Tarcha. Cassava roots were gathered when they were 18 months old and brought to the laboratory within three hours. To remove sand and other dirt particles, the samples were cleaned, peeled, and washed with room temperature water. A sample was then processed using three typical processing procedures (chipping, grating, and soaking). The peeled root was soaked for 48 hours in plastic drums filled with water, after which the cassava roots were removed, cut into pieces, and oven dried for 48 hours at 60°C. The dried chips were subsequently crushed into fine-powder cassava flour using an electric grinder [24, 25]. The flour was sieved through a 1 mm sieve, measured, placed into an airtight plastic bag, and kept in the refrigerator until the analysis was done. Triplicate analyses were performed on each sample of flour.

2.4. Biochemical Analysis. The biochemical analysis was performed with cassava flour, and triplicate samples were obtained for each accession in the postharvest and animal nutrition laboratory of Jimma University College of Agriculture and Veterinary Medicine (JUCAVM). Standard procedures [26–28] were used to determine the moisture content, dry matter content, ash, organic matter, crude fiber, crude fat, starch, tannin, crude protein, saponin, carbohydrate, cyanide, and total energy contents of the flour. The following are the details of the analyses.

Table 1: List of cassava accessions used in the study with their corresponding code and source.

Genotype	Code	Source	Genotype	Code	Source
J-local	G1	JARC	46330/12	G33	HARC
50583014	G2	HARC	1051741	G34	HARC
F-100	G3	HARC	AWC-4	G35	HARC
5028/73	G4	HARC	1071393	G36	ITTA
26/84	G5	HARC	1061630	G37	ITTA
5338-19	G6	HARC	191/0427	G38	HARC
1070952	G7	IITA	WALAMO	G39	HARC
45/72 white	G8	HARC	101	G40	HARC
156	G9	HARC	5532-4	G41	HARC
AWC-5	G10	HARC	1070337	G42	ITTA
MM96/3280	G11	HARC	Wajo bohe	G43	HARC
1011224	G12	ITTA	Korre (original)	G44	HARC
5048-33	G13	HARC	Gamo dhaske	G45	HARC
NALINDAM 96-41	G14	HARC	Korre-dhaske-8	G46	HARC
1050125	G15	ITTA	Bajk-8	G47	HARC
Kigoma Red	G16	HARC	1038	G48	HARC
1062630	G17	ITTA	M-94/0114	G49	HARC
1070593	G18	ITTA	1630	G50	HARC
AWC-3	G19	HARC	869	G51	HARC
45/72 Red	G20	HARC	1554	G52	HARC
MM 96/9361	G21	HARC	196/624	G53	HARC
10540	G22	ITTA	M-94/0125	G54	HARC
1980510	G23	ITTA	Umbure	G55	HARC
1011206	G24	ITTA	1708	G56	HARC
104	G25	HARC	Bajk-1	G57	HARC
200	G26	HARC	Korre-dhaske-7	G58	HARC
1061365	G27	ITTA	AAGT 192	G59	JARC
7070824	G28	HARC	Melko 108	G60	JARC
1070539	G29	ITTA	AAGT 191	G61	JARC
MM 96/9308	G30	HARC	Hawassa-04	G62	JARC
1010085	G31	ITTA	Kello	G63	HARC
1050127	G32	ITTA	Qulle	G64	HARC

IITA = International Institute for Tropical Agriculture, JARC = Jimma Agricultural Research Center, and HARC = Hawassa Agricultural Research Center.

2.4.1. Determination of Moisture Content. The moisture content of flour was determined using a typical standard analytical method [28], and a sample of 100 g duplicate flour was weighed in aluminum dishes and oven dried for three days at 65°C. The dried sample was then weighed after cooling at room temperature in a desiccator. The moisture content of flour was estimated by converting the weight loss due to drying to percent flour moisture content as follows: percentage flour moisture = (weight of moisture evaporated/weight of flour sample) × 100.

2.4.2. Determination of Dry Matter Content. The flour dry matter content (DM) was estimated by collecting a representative duplicate sample of 100 g (W1), oven drying it at 65°C for 72 hours, weighing it (W2), and expressing the value in percentage [29, 30]. The percentage of dry matter content was calculated as follows: % DM = (W2/W1) × 100 or % DM = 100 − % moisture content.

2.4.3. Determination Total of Ash Content. The guidance of [27] was followed to determine the ash content. The crucibles were rinsed and dried for 30 minutes at 105°C in a hot air oven (SM9053). These were weighed after cooling in desiccators. To get rid of the smoke, a five-gram sample was burned inside a heater in a fume cupboard. The sample was then placed in a preheated muffle furnace (SM9080) and heated to 550°C until a light grey ash appeared, after which the crucibles were cooled in desiccators and weighed. The ash content was determined as follows:

$$\%\ \text{ASH} = \frac{(\text{weight of crucible} + \text{ash}) - (\text{weight of empty crucible})}{(\text{Weight of sample})} \times 100. \quad (1)$$

2.4.4. Determination of Organic Matter Content. By removing the percent ash from the % total dry matter, the organic matter content was calculated and reported as a percentage. The organic matter content was determined as follows: organic matter content (%) = % DM − % ash.

2.4.5. Determination of Crude Fiber Content. Nonenzymatic gravimetric technique was used to determine the crude fiber content [27,920.168]. After defeating the two-gram sample with petroleum ether, 200 ml of a solution containing 1.25 g of H_2SO_4 per 100 ml was heated in reflux for 30 minutes [31]. Finally, using a fluted funnel and linen, the solution was filtered. After 5 washings with hot water and trapping the particles with a two-food muslin cloth, the sample was quantitatively transferred back to the flask and boiled for 30 minutes in 200 ml of 1.25 g of carbonate-free NaOH per 100 ml, then washed before being transferred to a weighed Gooch crucible and dried in the oven at 105°C for three hours. After cooling in desiccators, it was reweighed. The percentage of crude fiber was estimated as follows:

$$\text{crude fiber \%} = \frac{(\text{weight of sample + crucible}) - (\text{weight of crucible + Ash})}{(\text{weight of sample})} \times 100. \quad (2)$$

2.4.6. Determination of Crude Fat. According to [27], the crude fat was calculated using a fat extractor with an automated control unit (FOSS Soxtec 2055). A one-gram sample was weighed into the thimble, which was then put into the extraction unit with its mouth plugged with defatted cotton wool. Eighty milliliters of petroleum ether were poured into each cup, which was then aligned with their respective thimbles at 135°C. For 30 minutes, each extraction and rinsing was performed, then the sample was aerated for 15 minutes, and the crude fat % was determined as follows:

$$\text{crude fat \%} = \frac{w3 - w2}{(w1)} \times 100, \quad (3)$$

where $w1$ = weight of sample, $w2$ = weight of empty cup, and $w3$ = weight of cup with the extracted oil.

2.4.7. Determination of Crude Protein. The technique 988.05 micro-Kjeldahl method of nitrogen analysis was used to determine the crude protein content of the samples [28]. About 0.3g of sample was measured using an analytical balance (Model: ABJ220-4M, Australia); 1g of K2SO4 and CuSO4 catalyst mixture, and 5 ml of sulfuric acid were added to each digestion flask (Kjeldahl flask KF250, Germany), which contained the mixture of sample and catalysts. The solution (0.3 gram sample + 1 g K_2SO_4 and copper sulfate + 5 ml H_2SO_4) was immediately placed in a digestion flask and heated to around 420°C for 3–4 hours, until it became clear.

The digested sample was then passed to the distillation equipment, where 25 ml of 40% (w/v) NaOH was continuously added until the solution became murky, indicating that the solution had become alkaline. The ammonia was collected into a 200 ml conical flask containing 25 ml of 4% boric acid with mixed methyl red indicator solution after the solutions were steam distilled. Then, with the delivery tube below the acid level, distillation was carried out into the boric acid solution in the receiver flask. The pink color solution in the receiver flask turned green as the distillation progressed, showing that ammonia was present. Distillation was maintained until the flask's contents reached the appropriate level. Titrations of the green color solution against 0.1 N HCl solutions were then performed. The green color changed to a reddish pink tone near the conclusion, indicating that all of the nitrogen bound as ammonium borate had been released as ammonium chloride. To get a reddish color, the distillate was titrated with 0.1 N sulfuric acid. Finally, using the formula below, the percentage of nitrogen content was calculated.

$$\text{total nitrogen percent by weight \%} N = \frac{(V_A - V_B) * N * 14.007 * 100}{W}, \quad (4)$$

where V_A = volume (ml) of the HCl solution consumed in the sample titration, V_B = volume (ml) of the standard solution used in the sample blank titration, N = Normality of hydrochloric used which was 0.1 N, and W = weight of the sample (g).

The crude protein content was estimated using the formula equation (5).

$$\text{Crude protein, percent by weight} = 6.25 * \text{total nitrogens}. \quad (5)$$

2.4.8. Starch Determination. The wet approach was used to extract starch [32]. Roots were washed, peeled, and diced into 1 cm cubes before being pulverized for 5 minutes in a high-powered blender (Model KING, Osaka, Japan). The pulp was suspended in ten times its volume of water, stirred for five minutes, and then filtered through a double-fold cotton towel. The top liquid was decanted and discarded after the filtrate had been allowed to settle for 2 hours. The sediment was restirred for 5 minutes after the addition of water. The starch from the filtrate was allowed to settle after

another round of filtration. The sediment (starch) was sun dried for 24 hours after decanting the top liquid, then kept and converted to a percentage by mass. %starch = (weight of starch isolated/weight of sample root) × 100.

2.4.9. Determination of Total Cyanide Contents. The AOAC method [26] was used to quantify total cyanide concentration. Cassava flour (20 g) was placed in a 1-liter distillation flask with 100 ml water and let to stand for 2 hours to hydrolyze the bound glucosides and liberate hydrocyanic acid. Following that, 100 mL of distilled water was added to the slurry in the distillation flask (autolysis), and the steam distillate was collected in 20 ml of 0.01 N $AgNO_3$ that had been acidified with 1 ml of HNO_3. The distillation was carried out for another 40 minutes with rapid boiling until approximately 150 ml of the distillate was collected twice. The distillates were pooled after being filtered through Gooch with some water. The excess of $AgNO_3$ was then measured using ferric alum indicator in the combined filtrate and washings with 0.02 N KSCN. After the addition of 0.02 N KSCN solutions, the titration reached its end point when a faint crimson tint appeared. The following equation was used to compute the amount of HCN present in the sample.

Volume (ml) of $AgNO_3$ consumed to complex CN- = 20 – 2V of the titer; V is the volume of the titrant consumed 1 ml 0.01 $NAgNO_3$ = 0.27 mg HCN.

2.4.10. Determination of Condensed Tannin. The technique adopted by Udosen [33] was used to determine the tannin concentration. Each sample was weighed and placed in a centrifuge tube with 2 ml of distilled water. It was centrifuged at 1500 rpm for 10 minutes. The supernatant (extract) was then dispersed after the centrifuge samples were poured into a beaker. In the beaker, 1 ml of $NaCO_3$ and Folin–Denis reagent was added and allowed to settle. A spectrophotometer was used to take the measurements. The following formula was used to determine the amount of tannin in the sample.

$$\text{tannin (mg/100g)} = \frac{\text{An} * C * Vf}{\text{As} * W * Va}, \tag{6}$$

where An = absorbance test sample, As = absorbance of standard sample, C = concentration of the standard solution, W = weight of the sample, Vf = total filtrate volume, and Va = volume of filtrate analyzed.

2.4.11. Determination of Condensed Saponin. The method described by Obadoni and Ochuko [34] for determining saponin content was used. In 200 ml of 20% ethanol, 20 grams of each ground sample were distributed. At around 55°C, the suspension was cooked for 4 hours in a hot water bath with constant stirring. The residue was re-extracted with 200 ml of 20% ethanol after the mixture was filtered. Over a water bath at around 90°C, the mixed extracts were reduced to 40 ml. The concentrate was poured into a 250 ml separator funnel, along with 20 ml of diethyl ether, and rapidly agitated. The aqueous layer was kept, while the ether layer was thrown away. It was necessary to repeat the purifying procedure, and n-butanol was added in the amount of 60 ml. The n-butanol and extract mixture was rinsed twice with 10 ml of 5% sodium chloride aqueous solution. In a water bath, the residual solution was heated to around 90°C. The samples were dried in an oven at 100°C until they reached a consistent weight. The saponin content was calculated in percentage and changed to mg/100 g.

2.4.12. Determination of Carbohydrate and Energy. Using arithmetic difference, the carbohydrate content of the sample was estimated [35, 36]. With 4 calories for 1 g of carbohydrates, 4 calories for 1 g of proteins, and 9 calories for 1 g of crude fat, the energy value was estimated using Atwater and Rosa's thermal coefficients (1899). Using the formula below, the available carbohydrate (CHO) and energy value were calculated: CHO = [100 – (% moisture + % crude protein + % crude fat + crude fiber + % ash)] [35, 36].

$$\begin{aligned}&\text{Total energy (kcal)}\\ &= [(\%\,\text{CHO} \times 4) + (\%\,\text{CP} \times 4) + (\%\,\text{CF} \times 9)],\end{aligned} \tag{7}$$

where CHO = carbohydrate, CP = crude protein, and CF = crude fat.

2.5. Data Analysis. Data were subjected to one-way analysis of variance using the complete randomized design (CRD) by using the Statistical Analysis System (SAS) package [37] and R software package [38] to determine the presence of variation among the accessions for various biochemical content. The data were standardized by dividing each variable by its range, then clustered using the unweighted pair group method of arithmetic mean (UPGMA) and pairwise generalized square distances (D^2) between clusters, with principal component analysis (PCA) used to group the accessions based on biochemical character and assess correlations between principal components and the parameters measured.

2.5.1. Variance and Covariance Analysis. Phenotypic and genotypic variances and covariances were calculated according to the methods suggested by [39, 40].

(a) Genotypic variance component

(1) Genotypic variance $(\sigma^2 g) = (\text{MS}_g - \text{MS}_e)/r$, where Genotypic mean square = MS_g, error mean square = MS_e, and replication = r

(2) Genotypic coefficient of variation (GCV) = $(\sqrt{\sigma^2 g}\,/\ddot{\text{X}}) \times 100$, where $\ddot{\text{X}}$ is the grand mean value of the trait

(b) Environmental variance component (on genotypic mean basis) $\sigma^2{}_e = \text{MS}_e/r$

(c) Phenotypic variance component

(1) Phenotypic variance $(\sigma^2 p) = \sigma^2 g + \sigma^2{}_e$

(2) Phenotypic coefficient of variation (PCV) = $(\sqrt{\sigma^2 p}\,/\ddot{\text{X}}) \times 100$

(d) Covariance

Covariance was calculated using the following formula:

(1) Genotypic covariance (Cov A) = $r_A\sigma_{XA}\sigma_{YA}$, where r_A = correlation of breeding values arises from two sources, σ_{XA} = standard deviation of trait x, and σ_{yA} = standard deviation of trait y

(2) Environmental covariance (Cov_E) = $r_E\sigma_{XE}\sigma_{yE}$, where r_E = correlation of environmental deviations, σ_{XE} = environmental standard deviation of trait x, and σ_{yE} = environmental standard deviation of trait y

(3) Phenotypic covariance (Cov_P) = Genotypic covariance (Cov_A) + environmental covariance (Cov_E)

$$\text{Broad sense heritability}\left(h^2\right)\frac{\sigma^2 g}{\sigma^2 p}\times 100. \quad (8)$$

The genetic advance with one cycle of selection, supposing the selection intensity of 5% was estimated as proposed by [41].

$$\text{GA} = k\sigma_p h^2, \quad (9)$$

where σ_p = the standard deviation of the character phenotypic and k = the standardized selection differential at 5% selection intensity (2.063).

The extent of the estimated genetic advance of different traits under selection, GAM, has been calculated by the following formula:

$$\text{GAM} = \frac{\text{GA}}{\ddot{\text{X}}}\times 100, \quad (10)$$

where genetic advance as a percent of the mean = GAM, genetic advance = GA, and $\ddot{\text{X}}$ = grand mean for the character.

2.5.2. Correlation Analysis. Correlation coefficient (r) was calculated using the standard procedure suggested by [42].

The genotypic correlation coefficient between traits x and y was calculated as follows:

$$rg_{xy} = \frac{\text{Cov}g_{xy}}{\sqrt{\sigma^2 g_x \sigma^2 g_y}}, \quad (11)$$

where rg_{xy} = genotypic correlation coefficient between traits x and y, $\text{Cov}g_{xy}$ = genotypic covariance between trait x and y, $\sigma^2 g_x$ = genotypic variance of trait x, and $\sigma^2 g_y$ = genotypic variance of trait y.

Genotypic correlation coefficients were tested for their significance using the formula suggested by Robertson [43], using the t-table at $(g-2)$ degrees at 5% and 1% levels of alpha.

3. Results and Discussion

3.1. Analysis of Variance. The mean squares due to accessions were very highly significant ($P < 0.0001$) for ash, fiber, fat, protein, cyanide, tannin, and saponin content, whereas organic matter, starch, carbohydrate, and total energy were observed to have highly significant ($P < 0.01$) difference among the tested accessions. Similarly, flour moisture and dry matter content showed significant ($P < 0.05$) differences among accessions (Table 2). This implies the presence of high genetic variability of these characters among the tested accessions, and the observed variability is a good possibility for developing cassava cultivars having desirable biochemical characters.

3.2. Mean and Range Value of Biochemical Characters. The descriptive statistics of the cassava accessions root based on biochemical compositions are presented in Table 3, and wide ranges of variation were identified for most of the biochemical characters studied. The moisture percentage of cassava root flour varied greatly among the 64 accessions, ranging from 4.83% to 10.11%, with a mean value of 7.11 ± 0.16. Accessions G6, G13, G37, and G64 had high moisture levels, whereas accessions G8, G18, G28, and G42 had low moisture contents, among others (Tables 1 and 3). The variation in the moisture content of cassava root flour might own to differences in genetic makeup for solute constituents. According to this study, G8, G18, G28, and G42 were more suitable for long-term storage of their roots than those with a high moisture value. This finding agrees with those reported by Adejumo [44] and Baah et al. [45], in which the moisture content of cassava root flour ranged from 6.68% to 10.96%. The values of dry matter ranged from 89.89% to 95.17% with a mean of $92.89 \pm 0.16\%$. Similarly, organic matter varied from 86.71% to 92.65% with a mean of $89.82 \pm 0.16\%$ (Table 3). Among the tested accessions, G8 and G18 had higher dry matter and organic matter contents, while G13 and G27 had lower values (Tables 1 and 3). This implies that accessions G8 and G18 have good eating quality and are more storable than others because of their high dry matter content. With a mean value of 3.07 ± 0.05, the ash content ranged from 2.10% to 3.96%. Among the accessions studied, the G51 had the lowest ash level (2.10%), and the G30 had the highest (3.96%). These ash values were greater than those reported by Rojas et al. [46], which ranged from 1.5% to 2.7%, but were similar to those reported by Offor et al. [47], which ranged from 2.3% to 3.6%, with a mean value of 2.65%. This indicates that high ash content among the examined accessions results in high mineral content, and in contrast, low ash content indicates low mineral concentration in cassava [4].

The range of crude fat was 0.26% to 1.40%, with a mean value of $0.83 \pm 0.03\%$. Accessions G34 and G35 had the highest crude fat values, while G47 had the lowest (Tables 1 and 3). Findings of the current study differ from those of Sarkiyayi and Agar [7], who reported high-fat values (3.92% for sweet cassava varieties and 3.82% for bitter cassava varieties), while Manano et al. [10] found low crude fat values both for improved (0.48% to 0.63%) and local (0.39% to 0.48%) varieties. The difference in crude fat between accessions may be due to genetic differences rather than environmental factors. The fiber content of the various

Table 2: Analysis of variance of 13 biochemical characters in 64 cassava accessions.

Biochemical characters	Mean square			
	Accessions DF = 63	Error DF = 128	CV (%)	R^2
Flour moisture content (%)	4.75*	2.97	24.23	0.44
Dry matter content (%)	4.75*	2.97	1.86	0.44
Organic matter content (%)	4.99**	3.02	1.93	0.45
Ash (%)	0.47***	0.10	10.15	0.70
Crude fiber content (%)	0.45***	0.06	11.49	0.78
Crude fat (%)	0.20***	0.02	14.82	0.86
Crude protein (%)	0.15***	0.04	9.90	0.66
Starch (%)	11.07**	5.44	2.86	0.50
Carbohydrate (%)	5.49**	3.15	2.09	0.46
Total energy (kcal/100 g DM)	83.21**	49.22	1.98	0.45
Cyanide (mg/100 g)	0.38***	0.03	6.63	0.88
Tannin (mg/100 g)	0.01***	0.00	14.42	0.68
Saponin (mg/100 g)	0.25***	0.06	10.50	0.68

Table 3: Mean, maximum, and minimum values of biochemical contents measured from 64 accessions of cassava.

No	Biochemical characters	Mean ± SE	Minimum	Maximum
1	Flour moisture (%)	7.11 ± 0.16	4.83	10.11
2	Dry matter (%)	92.89 ± 0.16	89.89	95.17
3	Organic matter (%)	89.82 ± 0.16	86.71	92.65
4	Ash (%)	3.07 ± 0.05	2.10	3.96
5	Crude fiber content (%)	2.19 ± 0.05	1.14	3.00
6	Crude fat (%)	0.83 ± 0.03	0.26	1.40
7	Crude protein (%)	1.95 ± 0.03	1.28	2.46
8	Starch (%)	72.11 ± 0.24	65.1	74.2
9	Carbohydrate (%)	84.84 ± 0.17	81.29	87.94
10	Total energy (kcal/100 g DM)	354.65 ± 0.66	341.44	367.61
11	Cyanide (mg/100 g)	2.47 ± 0.04	1.67	3.14
12	Tannin (mg/100 g)	0.25 ± 0.01	0.17	0.36
13	Saponin (mg/100 g)	2.29 ± 0.04	1.74	2.84

cassava accessions roots ranged from 1.14% to 3% on a dry weight basis, with a mean value of 2.19 ± 0.05 (Table 3). Roots from the accessions G38 and G41 exhibited the highest fiber value (Table 1), while those from the accessions G54 and G 52 were identified as having the lowest value fiber content. Similar trends are shown by Manano et al. [10], who reported cassava varieties with fiber contents of 1.06% to 1.2%. The results, therefore, suggest that the accessions G38 and G41 are good sources of dietary fiber. This could be due to the high crude fiber content in these accessions. The starch content of the cassava root on a dry weight basis varied from 65.1% to 74.2% with a mean value of 72.11 ± 0.24% across the examined accessions. The highest starch content was found in accessions G11 and G46, while the lowest was found in accession G6 (Tables 1 and 3). This finding is consistent with that of Chijindu and Boateng [48], who reported 76.82% starch content for cassava varieties typically grown in Ghana, and Chiwona-Karltun et al. [49], who reported starch content of cassava varieties to vary from 54.7% to 76. 34%. The results of the current study indicate that the starch content is greater than 60%, and these accessions could potentially be used for various commercial products such as starch, alcohol, and glucose.

The crude protein and carbohydrate percentages ranged from 1.28% to 2.46% and 81.29% to 87.84% with a mean of 1.95 ± 0.03% and 84.84 ± 0.17%, respectively (Table 3). Accessions G10, G28, and G42 had high crude protein values, whereas G27, G33, and G50 had low crude protein value. These findings are similar to those of Rojas et al. [46], who reported crude protein levels ranging from 1.5% to 2.8%, with an average of 2%, and Nyirendah et al. [20], who observed values ranging from 1.2% to 3.5% in six cassava varieties. However, Manano et al. [10] found a lower crude protein content, ranging from 0.74% to 1.5%, and carbohydrate content ranging from 83.86% to 91.33%. The study suggests that crude protein content variation in cassava accessions may be due to genetic differences rather than environmental factors.

The amount of cyanide in each sample ranged from 1.67 mg/100 g to 3.14 mg/100 g with a mean performance of 2.47 ± 0.04 mg/100 g, and the amount of tannin in each sample ranged from 0.17 mg/100 g to 0.36 mg/100 g, with a mean value of 0.25 ± 0.01 mg/100 g. Saponin concentrations ranged from 1.74 mg/100 g to 2.84 mg/100 g, and the average was the performance of 2.29 ± 0.04 mg/100 g (Table 3). In comparison to other accessions, G38, G39, G40, and G63 had high cyanide concentrations, whereas G9, 29, and G51 had low cyanide content in the dry weight base (Tables 1 and 3), suggesting that accessions, G9, G29, and G51 might be suitable for the food industry. In line with this work, Charles et al. [50] reported 0.8 to 2.9 mg/100 g cyanide content on a dry weight basis. Nyakaisiki [51] reported cyanide contents ranging between 2.8 and 5.3 mg/100 g on a fresh weight basis. But Manano et al. [10] reported elevated values, ranging from 3 mg/100 g to 80 mg/100 g cyanide contents on a dry weight basis.

3.3. Variances, Heritability, Coefficient of Variation, and Genetic Advance. All characters evaluated were given their corresponding variance components and coefficients of variation values (Table 4). Total energy (11.31), followed by carbohydrate (0.78) and organic matter (0.65), had the

highest genotypic variation ($\sigma^2 g$), among the evaluated characters, while tannin (0.002) had the lowest genotypic variation ($\sigma^2 g$). Similarly, phenotypic variances ($\sigma^2 p$) ranged from 0.002 for tannin to 60.59 for total energy. Crude fat had the largest genotypic coefficient of variation (GCV = 29.54%), followed by crude fiber content (GCV = 16.94%) and tannin (GCV = 16.11%), while dry matter had the lowest (GCV = 0.84%). The phenotypic coefficients of variation (PCV) for dry matter content ranged from 2.02% to 32.74% for crude fat content (Table 4). According to Deshmukh et al. [52], PCV and GCV values greater than 20% are considered high, whereas values between 10% and 20% are considered medium, and values less than 10% are considered low. Based on this classification, crude fat content was the only character that met the high range of GCV (29.54%) and PCV (32.74%) values; tannin, cyanide, ash, saponin, flour moisture, and crude protein were categorized under the medium range of GCV and PCV values. The current study revealed that the biochemical composition of the tested accessions was highly variable. As a result, it is suggested that selecting a character of interest could be effective if high and medium PCV and GCV values are taken into account.

The expected genetic progress and estimated heritability in the broad sense for the investigated characters are reported in Table 4. Heritability in the broad sense in the current study ranged from 17.29% for flour moisture and dry matter percent to 84.88% for cyanide, while genetic advance as a percentage means ranged from 0.30% for crude protein to 54.94% for crude fat. According to Bhateria et al. [53], cyanide (84.88%), crude fat (81.32%), crude fiber (77.32%), ash (72.13%), tannin (66.67%), saponin (60.96%), and crude protein (54.94%) have high heritability, but the rest of the characters fall under low heritability (Table 4). This suggests that effective genetic progress can be made if some of these characters with high heritability broad sense estimates are viewed as selection criteria for the character of interest in the future cassava improvement program. Crude fat had the largest genetic advance (54.94%), followed by crude fiber (30.68%), tannin (27.11%), cyanide (26.73%), and ash (21.21%) (Table 4). High heritability along with high genetic advance as a percent of the mean was estimated for crude fat, crude fiber, tannin, cyanide, and ash (Table 4). It is hypothesized that these characters with high broad-sense heritability and high genetic progress as a percentage of the mean can be improved by using phenotypic expression to direct the selection of the character of interest.

3.4. Correlation among Character. The coefficients of person correlation for thirteen characters are shown in Table 5. The correlation results revealed that flour moisture content had highly significant ($P < 0.01$) strong negative correlation with dry matter ($r = -1$), organic matter ($r = -0.95$), starch content ($r = -0.89$), carbohydrate content ($r = -0.85$), and total energy content ($r = -0.85$) but a highly significant and medium negative correlation with crude protein ($r = -0.42$). Similarly, dry matter demonstrated a strong positive and very significant relationship with organic matter ($r = 0.95$), starch content ($r = 0.89$), carbohydrate content ($r = 0.85$), and total energy content ($r = 0.91$), and it was observed as a highly significant and medium-positive correlation with crude protein ($r = 0.42$) (Table 5). These results agree with the study by Adebola et al. [54], who reported that moisture content was strongly and negatively correlated with dry matter content ($r = -0.91$), crude protein ($r = -0.64$), and carbohydrate ($r = -0.67$). These authors found that dry matter contents correlated with crude protein ($r = -0.52$) and carbohydrate ($r = -0.63$). In the other study, Mégnanou et al. [55] discovered that moisture content was strongly correlated with dry matter ($r = -1$), carbohydrate ($r = -0.985$), starch ($r = -0.733$), and energy value ($r = -0.971$), while dry matter was correlated with carbohydrate ($r = 0.985$), starch ($r = 0.733$), and energy value ($r = 0.971$).

Organic matter content was observed to have a highly significant and strong positive correlation with starch content ($r = 0.91$), carbohydrate content ($r = 0.91$), and total energy content ($r = 0.95$); organic matter and ash were significant ($P < 0.05$) and inversely linked ($r = -0.3$). Likewise, starch content showed a highly significant and strong positive correlation with carbohydrate content ($r = 0.99$) and total energy content ($r = 0.89$). Crude protein was moderate, positive, and highly significantly correlated with starch ($r = 46$) and total energy content ($r = 0.42$). Tannin and saponin had a strong link with ash ($r = 0.26$) from the antinational component, while saponin had a substantial correlation with crude fat ($r = 0.43$) (Table 5).

Many characters have been found to have strong relationships in the current investigation. However, a few attributes are correlated with antinutritional factors, and the majority of these correlations are nonsignificant (Table 5). The biochemical characters show a stronger and more positive relationship with the parameters tested, implying that any rise in one biochemical character will raise many characters. Furthermore, the observed relationships between the biochemical characters suggest that improving one character will lead to improvements in the others.

3.5. Principal Component Analysis. The presence of genetic variation in the accessions was revealed by principal component analysis (PCA), with the first five principal components with eigenvalues >1 ranging from 1.004 to 4.808, contributing to a total variation as elevated as 80.01% (Table 6). The first principal component explained 37% of the total variation and was positively associated with organic matter (0.450), dry matter (0.440), total energy (0.439), and carbohydrate (0.423), while flour moisture content (−0.44) contributed negatively (Table 6). Principal component II was correlated with crude fat (0.513), saponin (0.461), ash (0.444), and fiber content (0.376) and explained 15.4% of the total variation, whereas principal component III was correlated with starch content (0.649), tannin (0.407), cyanide (−0.401), and crude protein (0.343) and explained 11.6% of the total variation (Table 6). With increased crude fat, saponin, ash, and fiber content, the principal component of the second increases. Therefore, it implies that with an increase

Table 4: Variances, heritability, coefficient of variation, and genetic advance of 13 characters of 64 cassava accessions.

Biochemical characters	Msg	Mse	$\sigma^2 g$	$\sigma^2 p$	H^2 (%)	GCV (%)	PCV (%)	GA	GAM (%)
Flour moisture (%)	4.75	2.92	0.61	3.53	17.29	10.99	26.42	0.67	9.41
Dry matter (%)	4.75	2.92	0.61	3.53	17.29	0.84	2.02	0.67	0.72
Organic matter (%)	4.99	3.04	0.65	3.69	17.68	0.91	2.14	0.71	0.78
Ash (%)	0.47	0.05	0.14	0.19	72.13	12.12	14.27	0.65	21.21
Crude fiber content (%)	0.46	0.04	0.14	0.18	77.32	16.94	19.26	0.67	30.68
Crude fat (%)	0.21	0.02	0.06	0.07	81.32	29.54	32.74	0.46	54.94
Crude protein (%)	0.15	0.03	0.04	0.07	54.39	10.12	13.72	0.55	0.30
Starch (%)	3.60	2.19	0.47	2.66	17.86	0.89	2.14	0.59	0.78
Carbohydrate (%)	5.49	3.14	0.78	3.92	19.93	1.04	2.34	0.81	0.96
Total energy (kcal/100 g DM)	83.21	49.29	11.31	60.59	18.66	0.95	2.21	2.99	0.85
Cyanide (mg/100 g)	0.38	0.02	0.12	0.14	84.88	14.09	15.29	0.66	26.73
Tannin (mg/100 g)	0.006	0.001	0.002	0.002	66.67	16.11	19.73	0.07	27.11
Saponin (mg/100 g)	0.25	0.04	0.07	0.11	60.96	11.35	14.54	0.42	18.26

Msg = Mean squares of genotype, Mse = mean square of errors, $\sigma^2 g$ = genotypic variance, $\sigma^2 p$ = phenotypic variance, H^2 = heritability broad sense, GCV = genotypic coefficient of variation, PCV = phenotypic coefficient of variation, GA = genetic advance, and GAM = genetic advance as % of mean.

Table 5: Pearson correlation coefficients among biochemical characters.

Characters	DM	OM	AS	FB	FT	CP	ST	CHO	TE	CN	TN	SP
MC	-1^{**}	-0.95^{**}	-0.17^{NS}	-0.11^{NS}	-0.02^{NS}	-0.42^{**}	-0.89^{**}	-0.85^{**}	-0.85^{**}	-0.01^{NS}	-0.05^{NS}	-0.24^{NS}
DM		0.95^{**}	0.17^{NS}	0.11^{NS}	0.02^{NS}	0.42^{**}	0.89^{**}	0.85^{**}	0.91^{**}	0.01^{NS}	0.05^{NS}	0.24^{NS}
OM			-0.3^{*}	0.09^{NS}	-0.11^{NS}	0.46^{**}	0.91^{**}	0.91^{**}	0.95^{**}	-0.04^{NS}	-0.07^{NS}	0.11^{NS}
AS				0.03^{NS}	0.29^{*}	-0.12^{NS}	-0.30^{*}	-0.34^{**}	-0.194^{NS}	0.11^{NS}	0.26^{*}	0.26^{*}
FB					0.29^{*}	0.01^{NS}	0.09^{NS}	-0.42^{**}	-0.25^{NS}	0.13^{NS}	0.14^{NS}	0.11^{NS}
FT						-0.06^{NS}	-0.12^{NS}	-0.49^{**}	0.13^{NS}	0.22^{NS}	-0.06^{NS}	0.43^{**}
CP							0.46^{**}	0.21^{NS}	0.42^{**}	-0.09^{NS}	-0.04^{NS}	00.01^{NS}
ST								0.99^{**}	0.89^{**}	-0.04^{NS}	-0.07^{NS}	0.11^{NS}
CHO									0.91^{**}	-0.13^{NS}	-0.11^{NS}	-0.07^{NS}
TE										-0.02^{NS}	-0.16^{NS}	0.21^{NS}
CN											-0.02^{NS}	0.01^{NS}
TN												0.12^{NS}

*and **refers to significant at 5 % and 1% levels of probability, NS = not significant, MC = flour moisture content (%), DM = dry matter (%), OM = organic matter (%), AS = ash content (%), FB = crude fiber content (%), FT = crude fat (%), CP = crude protein (%), ST = starch (%), CHO = carbohydrate (%), TE = total energy (kcal/100 g DM), CN = cyanide (mg/100 g), TN = tannin (mg/100 g), and SP = saponin (mg/100 g).

in crude fat, saponin, ash, and fiber contents tend to increase too. The principal component of the second may be regarded as a measure of the content of crude fat, saponin, ash, and fiber. Similarly, the third principal component increases simultaneously with increasing starch content, tannin, and crude protein but decreases cyanide content. This indicates that cassava genotypes containing high starch, tannin, and crude protein content tend to have decreased cyanide content.

The fourth principal component (PC IV) accounted for 8.4% of total variability and was mainly associated with crude protein (0.551), fiber (0.414), ash (−0.430), and tannin (−0.464), whereas the 7.7% total variation for the fifth principal component (PC V) was positively correlated with the fiber (0.542), cyanide (0.461), and tannin (0.346) but was negatively correlated with saponin (−0.477) (Table 6). The VI, VII, and VIII principal components accounted for 6.5%, 5.4%, and 4.4% of the total variation, correspondingly, and these principal components were strongly correlated with cyanide (0.596) and crude protein (0.546) for PC VI, ash (−0.608) and tannin (0.511) for VII, and starch (0.599) for PVIII (Table 6).

3.6. Cluster Analysis. It is essential to group accessions according to their similarity or difference. In the present study, a total of 64 cassava accessions were clustered into six diverse groups based on thirteen biochemical characters (Figure 1 and Table 7). Among the clusters, cluster I was the largest, comprising 30 (46.87%) accessions, of which 6 accessions were collected from the International Institute for Tropical Agriculture, 2 accessions from Jimma Agricultural Research Center, and 22 accessions from Hawassa Agricultural Research Center (Figure 1 and Table 7). The clusters II, III, and IV were represented by 20, 6, and 6 accessions within diverse origin sources, respectively, and the whole clusters contributed about 50.01% of the total variations. Finally, clusters V and VI were represented by 1 accession separately and contributed 3.2% of the total variation (Figure 1 and Table 7).

The cluster means for different biochemical characters revealed that wide variations were observed among the cluster means for biochemical characters (Table 8). The highest flour moisture content was shown in cluster mean IV (9.58%), followed by cluster mean II (7.89%) and cluster mean I (6.55%), while cluster mean III (5.41%) was the

Table 6: Eigenvalues, difference, proportion, cumulative variance, and component scores.

Variables	PC I	PC II	PC III	PC IV	PC V	PC VI	PC VII	PC VIII
Eigenvalue	4.807	1.997	1.513	1.094	1.004	0.842	0.701	0.571
Difference	2.810	0.485	0.418	0.091	0.162	0.140	0.130	0.101
Proportion	0.370	0.154	0.116	0.084	0.077	0.065	0.054	0.044
Cumulative	0.370	0.523	0.640	0.724	0.801	0.866	0.920	0.964
MC	−0.440	−0.141	0.010	0.059	−0.071	0.000	0.155	0.033
DM	0.440	0.141	−0.010	−0.059	0.071	0.000	−0.155	−0.033
OM	0.450	0.002	−0.044	0.073	0.102	−0.096	0.035	−0.020
As	−0.065	0.444	0.112	−0.430	−0.104	0.312	−0.608	−0.040
FB	−0.031	0.376	0.089	0.414	0.542	−0.449	−0.156	−0.043
FT	−0.045	0.513	−0.281	0.228	−0.260	−0.091	0.009	−0.207
CP	0.138	0.008	0.343	0.551	−0.177	0.546	0.083	−0.396
ST	0.091	0.037	0.649	0.146	0.017	0.043	−0.093	0.599
CHO	0.423	−0.205	−0.072	−0.183	0.019	−0.036	0.063	0.097
TE	0.439	0.015	−0.137	0.005	−0.123	0.018	0.082	−0.058
CN	−0.030	0.220	−0.410	0.067	0.461	0.596	0.240	0.391
TN	−0.010	0.231	0.407	−0.464	0.346	0.028	0.511	−0.393
SP	0.050	0.461	0.045	−0.042	−0.477	−0.161	0.460	0.339

MC = Flour moisture content (%), DM = dry matter (%), OM = organic matter (%), AS = ash content (%), FB = crude fiber content (%), FT = crude fat (%), CP = crude protein (%), ST = starch (%), CHO = carbohydrate (%), TE = total energy (kcal/100 g DM), CN = cyanide (mg/100 g), TN = tannin (mg/100 g), and SP = saponin (mg/100 g)

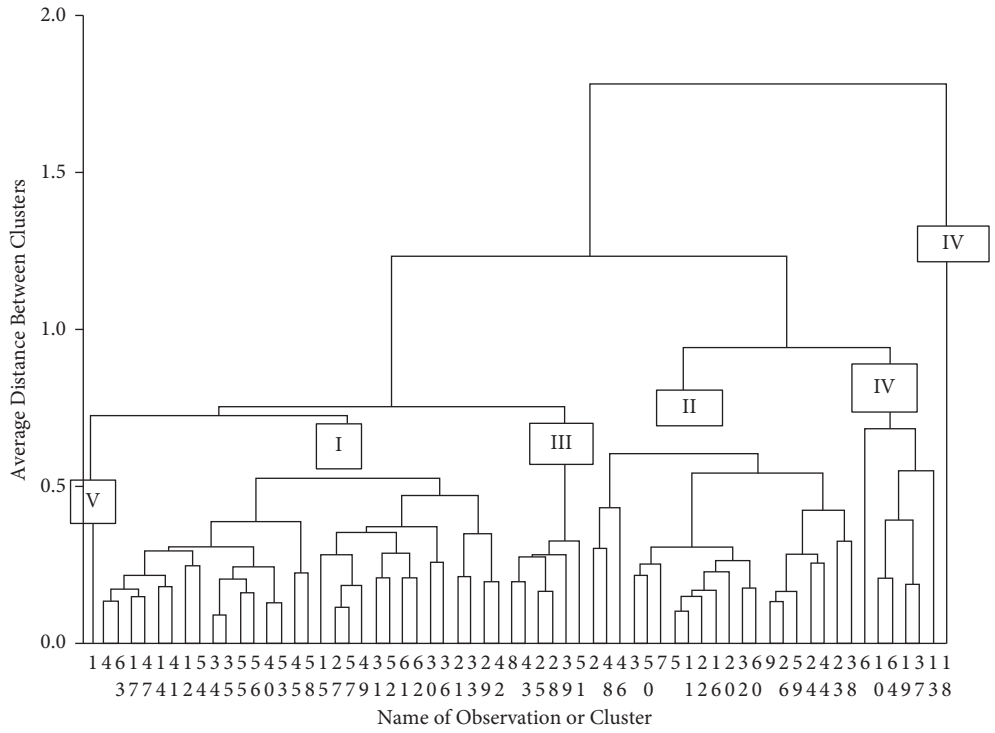

Figure 1: Dendrogram showing hierarchical clustering patterns of 64 cassava accessions (UPGMA) based on 13 biochemical characters.

lowest flour moisture content among the clusters (Table 8). This indicates that cluster means III accessions are better suited for long-term root storage than cluster means IV and II, which have higher moisture values. In their clusters, accessions from cluster means I and III produced the highest levels of dry matter (93.45% and 94.59%) and organic matter (90.38% and 91.71%), respectively (Table 8). Likewise, the maximum cluster mean was shown for ash and fiber in cluster II; for crude protein, starch, carbohydrate, and total energy in cluster III; for cyanide in IV; for tannin in II; and for saponin in III. In the cluster means, the lowest anti-nutritional was observed for cyanide in cluster III and for tannin and saponin in IV (Table 8). This suggests that genotypes from cluster mean III can be employed for the development of variety in terms of high nutritional compositions.

Table 7: Clusters of cassava accessions based on 13 biochemical characters.

Clusters	Number of accessions in each cluster	Serial number of 64 accessions	% of contribution
I	30	34, 35, 27, 57, 40, 53, 4, 63, 17, 47, 55, 56, 14, 41, 49, 29, 42, 61, 62, 31, 52, 21, 33, 45, 58, 12, 54, 30, 36, 15	46.87
II	20	5, 11, 9, 26, 22, 59, 16, 32, 60, 3, 50, 20, 7, 24, 44, 2, 48, 23, 38, 46	31.25
III	6	25, 28, 8, 43, 39, 51	9.38
IV	6	19, 37, 10, 64, 13, 6	9.38
V	1	1	1.56
VI	1	18	1.56

Table 8: Cluster means for 13 biochemical characters of cassava accession grown at southwest Ethiopia.

Cluster mean	MC	DM	OM	AS	FB	FT	CP	ST	CHO	TE	CN	TN	SP
I	6.55	93.45	90.38	3.07	2.14	0.83	1.96	81.62	85.45	357.13	2.51	0.24	2.31
II	7.89	92.11	88.96	3.15	2.28	0.83	1.91	81.84	83.94	350.84	2.44	0.27	2.27
III	5.41	94.59	91.71	2.88	2.18	0.83	2.07	81.98	86.64	362.28	2.27	0.25	2.38
IV	9.58	90.42	87.40	3.02	2.19	0.81	1.82	79.52	82.58	344.92	2.51	0.22	2.15
V	6.21	93.79	90.18	3.61	2.58	1.17	2.33	87.05	84.09	356.27	2.42	0.30	2.67
VI	4.89	95.11	92.65	2.46	1.76	0.81	2.13	78.96	87.94	367.61	2.79	0.24	2.11
Overall mean	**6.75**	**93.25**	**90.21**	**3.03**	**2.19**	**0.88**	**2.04**	**81.83**	**85.11**	**356.51**	**2.49**	**0.25**	**2.31**

MC = Flour moisture content (%), DM = dry matter (%), OM = organic matter (%), AS = ash content (%), FB = crude fiber content (%), FT = crude fat (%), CP = crude protein (%), ST = starch (%), CHO = carbohydrate (%), TE = total energy (kcal/100 g DM), CN = cyanide (mg/100 g), TN = tannin (mg/100 g), and SP = saponin (mg/100 g).

4. Conclusion

Among the tested accessions, G8 and G18 are the best accessions for long-term root storage and eating quality because of their high dry matter and organic matter levels. The highest starch concentration is recorded in G11 and G46, showing that these accessions might be used for making a variety of commercial products such as starch, alcohol, and glucose. Accessions G9, G29, and G51 had lower cyanide values in the dry weight base than other accessions, indicating that they are appropriate for the food industry.

Along with the medium to high heritability, GCV and genetic advance as a percent of the mean value are shown for ash, crude fiber, crude, cyanide, tannin, and saponin. Thus, these characters can be used as good criteria for the future cassava nutritional composition improvement program. Accessions from cluster mean III have high dry matter, organic matter, crude protein, starch, carbohydrate, total energy, and low antinutritional factors. This is an indication that accessions belonging to cluster mean III could be used as an initial population for further study in biochemical composition improvement. In conclusion, the present study showed the presence of high biochemical variability among the tested accessions and could be used to select accessions with a desirable biochemical composition in future breeding work.

Data Availability

The data sets used to support the findings of this study are available at the hands of the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

BB carried out the fieldwork and laboratory work, performed the statistical analysis, and drafted the manuscript. The rest of the authors coordinated the study, supervised fieldwork, and laboratory work, and contributed to the write-up of the manuscript. All authors have read and approved the final manuscript for submission.

Acknowledgments

The authors would like to thank Jimma and Wolita Sodo Universities for financing the research work. The authors are also pleased to acknowledge Jimma Hawassa Agricultural Research Centers and International Institute for Tropical Agriculture for providing planting materials used for the study. Jimma University and Wolita Sodo University financed all the research work.

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