Nutrient composition of some monkey kola (*Cola pachycarpa* K. Schum) accessions in South-Eastern Nigeria

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Abstract

Monkey kola (*Cola parchycarpa* K. Schum) is an underutilized indigenous fruit species in West Africa, valued for its edible fruits of potential nutritional and medicinal benefits. This study was conducted to evaluate the nutrient composition, mineral and vitamin content, phytochemical properties, and genetic variability of 13 accessions collected from collected from various locations across Abia and Imo States in southeastern Nigeria in 2021 and 2022. Standard laboratory procedures were used to determine proximate, mineral, vitamin, and anti-nutritional components using the complete Randomized Design (CRD) with three replicates per accession, while genetic variability parameters such as phenotypic and genotypic coefficients of variation, heritability, and correlation matrices were analyzed. Results revealed significant genotypic differences ($P<0.001$) among the accessions for most of the nutrient trait measured. The fruit pulp exhibited high moisture content (82.76–86.99 %) and carbohydrate levels (7.2312.01 %), with relatively moderate amounts of crude protein (1.77–2.88 %) and low fat (0.27–2.61 %). Mineral content varied among accessions, with potassium (82.97–124.43 mg/100 g), calcium (19.67–29.51 mg/100 g), magnesium (13.79–25.26 mg/100 g), and iron (2.17–4.16 mg/100 g) being the most prominent. Vitamin C content ranged from 2.66–21.47 mg/100 g, while carotene and vitamin E ranged from 1.25–4.77 mg/100 g and 1.83–3.85 mg/100 g, respectively. Anti-nutritional factors such as tannins (0.06–0.30 mg/100 g), oxalate (0.03–0.55 mg/100 g), and saponin (0.02–0.04 mg/100 g) were present at low levels. Broad-sense heritability was high for most nutritional traits including, crude protein (100 %), vitamin C (99.94 %), potassium (99.55 %), and calcium (99.43 %), indicating strong genetic control and breeding potential. The study highlights the high nutritional value and significant genetic variability of *C. parchycarpa*, reinforcing its potential as a candidate for crop improvement and nutritional diversification in sub-Saharan Africa.

Keywords: *Cola parchycarpa*, heritability, minerals, nutrient composition, vitamins.

Introduction

Fruits are an essential component of human and animal diets, providing not only major nutrients such as carbohydrates and proteins, but also vital micronutrients, fiber, and a range of bioactive compounds that support health and prevent diseases (Shiundu, 2002; Sachdeva *et al.*, 2013). In recent years, the importance of underutilized indigenous fruit species has been increasingly recognized for their potential to address nutritional deficiencies, support biodiversity, and contribute to sustainable agricultural systems. One such species is Monkey kola, *Cola parchycarpa*, a member of the Malvaceae family, indigenous to southern Nigeria and parts of Cameroon.

C. parchycarpa produces edible, fleshy fruits consumed by local populations and wild primates alike. While traditionally valued for its taste and local medicinal uses—including treatment of dysentery, headaches, and fatigue (Sanusi *et al.,* 2023; Pamplona-Roger, 2008). It contains considerable levels of carbohydrates, crude protein, vitamins C and E, and essential minerals such as calcium, potassium, and iron (Okwu, 2004; Ene-Obong et al., 2014; Akinmoladun *et al.*, 2019). Furthermore, it exhibits low concentrations of anti-nutritional factors and contains phytochemicals such as flavonoids, tannins, phenols, and saponins, which confer antioxidant and health-promoting properties.

Despite its nutritional and medicinal value, *C. parchycarpa* remains underexploited and largely absent from formal crop improvement programs. In the face of rising food insecurity, particularly in sub-Saharan Africa, there is a compelling need to explore and improve such indigenous fruits to diversify diets and reduce dependence on staple crops. Moreover, selecting and breeding genotypes with superior nutrient profiles offers a viable strategy for enhancing the quality of local food systems (Bouis and Saltzman, 2017). To harness the breeding potential of *C. parchycarpa*, detailed evaluation of its nutritional and phytochemical traits, as well as the genetic variability among existing accessions, is essential. Understanding the extent of variation and the heritability of traits such as proteins, vitamins, and mineral content is critical for the selection of high-performing genotypes and the development of cultivars with enhanced nutritional quality (Allard, 1991; Johnson *et al.*, 1955; Burton, 1952). This study was therefore conducted to evaluate the nutrient, mineral, vitamin, and phytochemical composition of some accessions of *Cola parchycarpa* collected from southeastern Nigeria, and to assess the genetic variability and heritability of these traits.

Materials and Methods

Plant Material Collection and Accession Information

A total of thirteen (13) genetically distinct accessions of Cola parchycarpa were selected for this study. These were collected from various locations across Abia and Imo States in southeastern Nigeria, specifically spanning seven local government areas in Abia State and one in Imo

State. Geographic coordinates (latitude and longitude) were recorded using a handheld GPS device to document the precise origin of each accession. The collection sites, accession codes, and location details are summarized in Table 1.

Nutrient content analyses

The nutrient content of the *Cola parchycarpa* accessions was analysed at the biochemistry laboratory of the National Root Crops Research Institute, Umudike, Nigeria. To ensure reliable data, The Completely Randomized Design (CRD) with three (3) replicates per accession was used for the nutrient analysis.

Proximate Composition: The moisture, ash, crude protein, crude fat, crude fiber, and carbohydrate contents of the samples were determined using standard procedures recommended by the Association of Official Analytical Chemists (AOAC, 2019). Moisture content was assessed by oven-drying 5 g of the sample at 105°C until a constant weight was achieved. Ash content was determined through dry ashing in a muffle furnace at 550°C. Crude protein was estimated using the micro-Kjeldahl method by determining total nitrogen and multiplying by a factor of 6.25. Fat content was measured by Soxhlet extraction using petroleum ether as solvent. Crude fiber was analyzed through sequential digestion in dilute acid and alkali. Carbohydrate content was computed as: Carbohydrate (%) = 100−(Moisture + Ash + Fat + Protein + Fiber)

Energy Value: The total caloric value (kcal/100g) was estimated using the Atwater conversion factors: Energy (kcal) = (4×Protein) + (9×Fat) + (4×Carbohydrate)

Mineral Analysis: Mineral element contents including calcium, magnesium, sodium, potassium, iron, zinc, phosphorus, and copper were read using Atomic Absorption Spectrophotometry (AAS) after wet digestion of samples with concentrated nitric acid (HNO_3) and hydrogen peroxide. Flame photometry was used for sodium and potassium. Phosphorus was determined colorimetrically using the vanado-molybdate yellow method.

Vitamin Content Determination: Vitamin content was analyzed by spectrophotometric methods following sample extraction with appropriate solvents: Vitamin C was measured by titration with copper (II) sulfate following EDTA/TCA extraction. Vitamins B_1 (thiamine), B_2 (riboflavin), and B_3 (niacin) were determined using acid digestion, followed by colorimetric or fluorometric measurements. Carotene and vitamin E (tocopherol) were extracted with organic solvents and quantified using UV-Vis spectrophotometry at their respective wavelengths.

Antinutrient analysis: Selected anti-nutritional and bioactive compounds were quantified using the following methods: Tannins were analyzed using the Folin–Denis spectrophotometric method (Pearson, 1976). Saponins and alkaloids were extracted gravimetrically via solvent extraction and precipitation (Haborne, 2000). Phenols and flavonoids were determined by acid hydrolysis followed by spectrophotometric quantification. Oxalate was assessed via titration using standard permanganate solution after digestion. Hydrogen cyanide (HCN) was determined by alkaline titration following liberation through acid hydrolysis.

Results

Proximate composition of *Cola parchycarpa*

The proximate analysis of 13 *C. parchycarpa* accessions showed significant variation across all measured traits in both years (Table 2). In 2021, total solids ranged from 11.41 (AM) to 15.50 % (NT), while in 2022, values ranged from 13.61 (NT) to 17.24 % (OL). The overall grand mean for total solids across accessions in 2022 was 15.28 %. Moisture content remained high across all accessions, with values between 84.71 and 86.99 % in 2021 and 82.76 to 86.64 % in 2022, averaging 84.75 % when both years were pooled togather. Ash content showed moderate variation, ranging from 1.28 to 1.65 % in 2021 and 1.45 to 1.73 % in 2022, with a mean value of 1.59 % when both years were combined. Crude protein content was highest in accession AE (2.88 %) and lowest in accession OL (1.83) and OD (1.77 %). Carbohydrate content, the dominant nutrient fraction, ranged from 7.23 (UO and UB) to 12.01 % (OL and UM), averaging 10.43 % in 2022. Crude fibre and fat contents remained low across all accessions, ranging from 0.46–0.82 and 0.27–2.61 %, respectively

Mineral composition

Mineral profiling showed that *C. parchycarpa* is rich in essential macro- and micronutrients (Table 3). In 2022, potassium was the most abundant mineral, with levels ranging from 105.46 to 124.43 mg/100g for OB and UM, respectively and a grand mean of 115.00 mg/100g. Calcium levels varied from 19.67 to 29.51 mg/100g OL and UB, respectively, with an average of 24.35 mg/100g. Magnesium content ranged between 17.25 mg/100g (OL) and 25.26 mg/100g (OB), while iron content varied from 2.17 mg/100g (UO) to 4.16 mg/100g (ND). Zinc levels spanned from 1.14 mg/100g (UH) to 2.42 mg/100g (OH), and copper ranged from 0.21 mg/100g (ND) to 0.45 mg/100g (AE).

Vitamin content

The vitamin content demonstrated significant diversity across all accessions (Table 4). Vitamin C content was most dominant among the vitamins and ranging from 2.66 to 21.47 mg/100 g for OH and ND, respectively in 2022, with a grand mean of 17.21 mg/100 g. Carotene content ranged from 1.25 to 1.84 mg/100 g for UB and UM, respectively. Vitamin E content varied between 1.83 mg/100 g for NT and 3.34 mg/100 g for OH. Vitamin B_1 ranged from 0.85 mg/100 g (OB) and 1.18 mg/100 g (UO). Similar patterns of variability were observed for vitamin B_2 (0.67–0.93 mg/100g). Vitamin B_3 was similar among all accessions.

Phytochemical Content

The phytochemical screening revealed the presence of bioactive compounds, including tannins, oxalates, hydrogen cyanide (HCN), alkanols, phenols, phytates, saponins, and flavonoids (Table 5). In 2022, tannin levels ranged from 0.06 mg/100g (UB and UO) to 0.30 mg/100g (UH), with a mean of 0.09 mg/100g. Oxalate was only detected in 2021. it ranged from 0.03 mg/100g for OH and UH and 0.55 mg/100g for UO. HCN content values ranged from 0.01 mg/100g (OR, OB, OH, UO, UB, UM, OL, AM and UH) – 0.06 mg/100g (NT and ND). Phenol content varied from 0.06 mg GAE/g (AE and OD) to 0.54 mg GAE/g (OH), with a mean of 0.89 mg GAE/g in 2022. Saponin content ranged from 0.02 to 0.04 mg/100g.

Genetic component analysis

Genetic variability parameters for the nutritional and phytochemical traits of the *C. parchycarpa* accessions are presented in Table 6. Broad sense heritability estimates ranged from 72.91 to 100 %. Crude protein recorded the highest heritability (100 %), followed closely by vitamin C (99.94 %), potassium (99.55 %), calcium (99.43 %), and total solids (98.61 %). Other traits with high heritability values included magnesium (99.21 %), vitamin B_1 (98.94 %), vitamin E (98.92 %), iron (98.35 %), ash content (98.31 %), vitamin B_2 (97.77 %), and crude fibre (97.66 %). The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were closely matched for most traits. For example, crude protein showed both GCV and PCV values of 18.84 %, while vitamin C had GCV and PCV of 49.12 % and 49.14 %, respectively. Potassium recorded GCV and PCV values of 9.13 and 9.15 %, respectively while calcium showed 12.10 and 12.14 %, respectively. Traits such as oxalate, crude fat, and hydrogen cyanide (HCN) recorded relatively lower heritability values with 86.79, 88.14, and 72.91 %, respectively. The highest environmental coefficient of variation (ECV) was observed in oxalate (24.53 %), followed by crude fat (13.62 %) and HCN (7.73 %), whereas the lowest ECV values were recorded for vitamin B1 (0.25 %), crude protein (0.27 %), and magnesium (0.29 %).

Correlation Analysis

The correlation matrix for the nutritional and phytochemical traits revealed several significant relationships among the measured parameters (Table 7). Crude protein showed strong positive and significant correlations with vitamin C (r = 0.82), potassium (r = 0.67), and vitamin E (r = 0.64). Total solids also exhibited strong positive associations with calcium (r = 0.75), magnesium (r = 0.69), and ash content (r = 0.68). Potassium was significantly and positively correlated with calcium (r = 0.71), vitamin C (r = 0.60), and crude protein (r = 0.67). Calcium also showed positive correlations with iron (r = 0.58), magnesium (r = 0.62), and total solids (r = 0.75). Vitamin C was positively correlated with ash (r = 0.65), phenol content (r = 0.57), and vitamin B_1 (r = 0.49). Among the phytochemical traits, phenol content exhibited a moderate positive correlation with flavonoid content (r = 0.52). Flavonoids also correlated positively with vitamin B_2 (r = 0.41), while crude fibre showed moderate positive associations with carotene (r = 0.55) and vitamin B_1 (r = 0.50). Crude fat had a slight negative correlation with moisture content (r = –0.29), while oxalate showed weak or non-significant associations with most traits.

Discussion

This study provided a comprehensive assessment of the nutritional, mineral, vitamin, and phytochemical composition of some accessions of *C. parchycarpa*, alongside an analysis of their genetic variability and heritability. The findings underscore the considerable diversity within the species, highlighting its potential for genetic improvement and utilization as food and nutritional security programs in sub-Saharan Africa. Carbohydrate levels of the fruit is an indication that it can serve as a modest energy source. More importantly, the moderate crude protein content (1.77–2.88 %) in several accessions—especially AE and UM implies its potential for dietary protein supplementation, which is critical of protein-deficient diets typical of rural African communities. The low fat content (<2.61%) suggests its suitability for low-calorie diets, while the dietary fiber content provided potential benefits in the management of metabolic disorders such as diabetes and hypertension. These findings aligned with earlier reports on monkey kola's suitability for health-conscious diets and its relevance in preventing non-communicable diseases (Ogbu and Umeokechukwu 2014; Ene-Obong *et al.*, 2014).

The mineral composition showed that *C. parchycarpa* is a rich source of essential micronutrients, particularly potassium, calcium, and magnesium. These minerals play vital roles in electrolyte balance, bone health, and enzymatic functions. The presence of iron and zinc, albeit in moderate concentrations, is important for addressing micronutrient deficiencies such as anemia and impaired immune function, which are prevalent in developing regions (FAO, 2021; Bouis and Saltzman, 2017).

Vitamin analysis showed considerable variation among accessions. Notably, vitamin C content, demonstrating the fruit's potential as an antioxidant-rich dietary component. Similarly, high levels of carotene and vitamin E enhance its role in preventing oxidative stress-related disorders (Winklhofer-Roob *et al.*, 2003). The considerable inter-accession variation in vitamin B-complex levels (B_1, B_2 and B_3) further supports the fruit's capacity to contribute to neurological and metabolic health (Calderon-Ospina and Nava-Mesa, 2019). The variation in micronutrient and vitamin content across accessions offers a basis for targeted selection of nutritionally superior genotypes for use in breeding programs aimed at developing biofortified or health-enhancing fruit cultivars.

The presence of beneficial phytochemicals such as phenols, flavonoids, saponins, and tannins across accessions indicates potential use of *C. parchycarpa* as a functional food or source of nutraceuticals. These compounds are known for their anti-inflammatory, antimicrobial, and antioxidant activities. The low levels of anti-nutritional factors such as oxalates and hydrogen cyanide further support the fruit's safety for consumption and industrial processing. Significantly higher phenol content in certain accessions (e.g., OH) suggests these genotypes may offer greater health benefits and could be prioritized in breeding programs for functional fruit development.

The wide range of heritability observed among the *C. parchycarpa* accessions demonstrated the presence of substantial genetic variability for the studied traits. High heritability estimates, particularly for crude protein, vitamin C, potassium, calcium, and total solids, suggested that these traits are predominantly controlled by additive gene effects and are thus amenable to improvement through direct phenotypic selection. Similar results have been reported by Nwofia and Ojimelukwe (2012).

The minimal differences between genotypic and phenotypic coefficients of variation (GCV and PCV) in traits such as crude protein, vitamin C, potassium, and calcium further confirmed the limited influence of environmental factors. This reinforces the reliability of these traits as selection indices in breeding programs. For instance, the matching GCV and PCV values observed for crude protein indicated that observed variability is entirely genetic, enhancing its value as a key trait for improvement. On the other hand, traits such as oxalate and crude fat showed wider disparities between GCV and PCV values, coupled with higher environmental coefficients of variation. This implied stronger environmental influence and suggested that improvement of these traits may require evaluation under more controlled or multi-environmental conditions. The relatively lower heritability of hydrogen cyanide also highlighted the need for careful environmental management in breeding efforts targeting anti-nutritional factors.

The correlation analysis revealed important relationships that can inform indirect selection strategies. The strong and positive correlation between crude protein and vitamin C is an indication of the feasibility of improving both traits simultaneously, thereby enhancing both the macronutrient and antioxidant profile of selected genotypes. Similar positive associations between potassium and calcium, as well as between calcium and magnesium, supported the selection of accessions with multiple micronutrient advantages, which is critical in addressing mineral deficiencies prevalent in low-resource diets (FAO, 2021; Bouis and Saltzman, 2017).

Positive associations between total solids and ash, calcium, and magnesium further indicated that accessions with higher dry matter content also tend to accumulate more minerals. These interrelationships could be leveraged in breeding programs to develop nutrient-dense fruit varieties without compromising yield components.

Conclusion

The combination of high heritability, strong positive trait correlations, and clear genetic variability among accessions is an indication that *C. parchycarpa* possesses significant potential for genetic enhancement. These findings support its integration into formal breeding programs aimed at improving the nutritional quality and functional value of indigenous fruits for food and nutrition security in sub-Saharan Africa.

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Table 1: *Cola parchycarpa*accessions and area of collection

S/N	Accession No	Town	LGA	State	Latitude	Longitude
1	NT	Ntiga	Isiala Ngwa north	Abia	5°24'11.0"N	7°25'11.5"E
2	OR	Orie Ugba	Umuahia North	Abia	5° 31' 33" N	7° 30' 10" E
3	ND	Ndoru	Ikwuano	Abia	5° 26′ 13″ N	7° 33′ 56″ E
4	OB	Obegu	Ugwunagbo	Abia	4° 59′ 4.1″ N	7° 19′ 32.82″ E
5	OH	Ohuhu	Umuahia North	Abia	5° 35' 59.99" N	7° 31' 59.99" E
6	UO	Umuosu	Isiala-Ngwa South	Abia	5° 23' 45" N	7° 28' 45" E
7	UB	Ubani	Umuahia North	Abia	5° 35' 57" N	7° 30' 6" E
8	UM	Umuikea	Isiala ngwa south	Abia	5°21'44.7"N	7°23'59.9"E
9	OL	Olokoro	Umuahia South	Abia	5° 28' 7.83"N	7° 29' 46.43"E
10	AM	Ahiazu mbaise	Ahiazu mbaise	Imo	5°32′49″N	7°16′13″E
11	OD	Obuda	Aba South	Abia	5° 5' 27" N	7° 20' 52" E
12	AE	Ahiaeke	Umuahia North	Abia	5° 30' 37" N	7° 31' 44" E
13	UH	Umuahia	Umuahia North	Abia	5° 31′ 60″ N	7° 28′ 60″ E

Table 2a – Proximate composition of 13 *Cola parchycarpa*

2021							
Accessions	Total solids (%)	Moisture content (%)	Ash content (%)	Crude protein (%)	Crude fibre (%)	Fat content (%)	Carbohydrate content (%)
NT	15.50	84.97	1.53	2.28	0.55	0.27	10.92
OR	15.48	84.97	1.47	1.91	0.51	0.33	11.38
ND	15.21	86.79	1.47	2.26	0.49	0.35	8.65
OB	13.01	86.99	1.28	2.04	0.57	0.39	8.74
OH	13.85	86.15	1.34	1.92	0.76	0.29	9.54
UO	11.45	86.95	1.48	1.93	0.47	0.35	7.23
UB	14.47	85.56	1.64	2.19	0.55	0.33	7.23
UM	15.33	84.71	1.65	2.42	0.63	0.41	10.17
OL	14.72	85.28	1.31	1.83	0.73	0.50	10.36
AM	11.41	85.59	1.34	1.89	0.47	0.41	7.45
OD	14.46	85.54	1.53	2.30	0.61	0.28	9.95
AE	14.25	85.75	1.36	1.86	0.49	0.41	10.14
UH	13.28	86.72	1.35	1.93	0.46	0.28	9.29
MEAN	13.88	86.03	1.44	2.06	0.56	0.35	9.51
LSD$_{(0.05)}$	0.56***	1.32***	0.03***	0.05***	0.02***	0.03***	0.55***

Table 2b – Proximate composition of 13 *Cola parchycarpa*

				2022			
Accessions	Total solids (%)	Moisture content (%)	Ash content (%)	Crude protein (%)	Crude fibre (%)	Fat content (%)	Carbohydrate content (%)
NT	13.61	86.39	1.45	1.93	0.71	0.48	9.04
OR	16.35	86.64	1.48	1.87	0.74	2.61	11.66
ND	14.62	85.38	1.66	1.85	0.71	0.29	10.12
OB	15.26	84.74	1.54	1.93	0.64	0.35	10.79
OH	15.28	84.72	1.64	2.14	0.69	0.51	10.29
UO	15.35	84.65	1.73	2.31	0.77	0.41	10.13
UB	16.41	83.59	1.47	1.84	0.66	0.53	11.90
UM	14.39	85.47	1.57	2.27	0.81	0.51	12.01
OL	17.24	82.76	1.73	2.16	0.82	0.51	12.01
AM	14.57	85.45	1.55	2.16	0.73	0.46	9.66
OD	15.66	84.34	1.52	1.77	0.69	0.46	11.22
AE	14.18	85.82	1.61	2.88	0.66	0.37	9.66
UH	15.24	84.76	1.67	2.51	0.77	0.56	9.73
MEAN	15.24	84.75	1.59	2.05	0.72	0.61	10.43
$LSD_{(0.05)}$	0.17***	0.16***	0.02***	0.33***	0.02***	ns	0.18***

Note: cm = centimetre, ns = not significant, * =significant at 5%, ** = significant at 1% and *** = significant at 0.01%, Gm = grand mean, mg = milligrams, g = grams, W = Week

Table 3: Mineral composition of 13 *Cola parchycarpa*

2021

Accessions	Ca (mg/100g)	Na (mg/100g)	Mg (mg/100g)	Fe (mg/100g)	Zn (mg/100g)	K (mg/100g)	P (mg/100g)
NT	24.99	54.38	16.82	3.89	2.17	95.34	30.93
OR	21.45	49.26	14.82	2.49	1.75	89.27	24.59
ND	26.98	50.92	15.75	4.16	2.44	94.45	35.47
OB	22.81	52.54	17.95	3.93	1.89	88.82	29.31
OH	27.01	67.94	19.22	3.73	1.91	87.19	31.49
UO	21.71	48.88	19.54	2.87	1.75	86.33	23.72
UB	19.79	29.27	13.79	2.66	1.49	85.90	28.16
UM	23.93	53.14	18.67	3.77	1.75	92.89	33.39
OL	20.84	52.95	14.77	2.35	1.58	84.32	26.25
AM	25.50	47.16	14.43	2.77	1.91	89.88	24.49
OD	24.37	52.49	16.40	3.85	2.37	82.97	32.51
AE	23.94	48.29	15.42	2.86	1.86	87.11	27.19
UH	26.81	57.17	18.47	2.67	2.18	85.59	28.34
MEAN	23.86	51.17	16.35	3.23	1.93	88.47	28.91
LSD$_{(0.05)}$	0.80***	80.35***	0.42***	0.12***	0.07***	1.09***	1.09***

2022

Accessions	Ca (mg/100g)	Na (mg/100g)	Mg (mg/100g)	Fe (mg/100g)	Zn (mg/100g)	K (mg/100g)	Cu (mg/100g)
NT	25.72	42.41	19.45	2.64	1.72	115.48	0.26
OR	20.55	41.71	21.22	2.57	1.15	114.81	0.22
ND	21.64	38.07	20.65	3.31	1.17	109.27	0.21
OB	28.96	36.83	25.26	2.86	1.83	105.46	0.41
OH	28.48	42.72	23.72	3.17	2.42	121.38	0.41
UO	23.56	49.04	20.76	2.17	1.44	119.78	0.25
UB	29.51	42.42	20.46	2.46	1.39	115.79	0.27
UM	24.77	46.79	19.00	2.32	1.19	124.43	0.29
OL	19.67	42.78	17.25	3.21	1.83	116.77	0.24
AM	23.66	40.47	19.75	2.81	1.22	108.88	0.30
OD	24.74	39.37	20.46	2.75	1.25	115.53	0.32
AE	23.57	45.27	19.75	2.17	1.22	108.88	0.45
UH	21.57	45.27	19.72	2.17	1.14	118.51	0.33
MEAN	24.35	42.18	20.57	2.70	1.41	115.00	0.30
LSD$_{(0.05)}$	0.33***	0.53***	0.59***	0.05***	0.02***	0.74***	0.02***

Note: cm = centimetre, ns = not significant, * =significant at 5%, ** = significant at 1% and *** = significant at 0.01%, Gm = grand mean, mg = milligrams, g = grams, W = Week

Table 4: Vitamins compositions of 13 *Cola parchycarpa*

2021

Accessions	B1 (mg/100g)	B2 (mg/100g)	B3 (mg/100g)	Carotene (mg/100g)	E (mg/100g)	C (mg/100g)
NT	1.57	1.13	1.14	4.43	3.26	12.49
OR	1.57	1.17	1.28	3.83	3.17	10.61
ND	1.45	1.08	1.19	3.90	3.17	9.82
OB	1.24	0.89	0.95	4.09	2.79	10.70
OH	1.53	1.25	1.13	3.79	2.89	10.72
UO	1.24	0.91	1.04	3.57	2.87	10.66
UB	1.27	0.93	1.05	4.77	3.85	12.46
UM	1.43	1.21	1.44	4.64	3.17	11.76
OL	1.26	1.06	1.28	3.38	2.76	10.57
AM	1.27	0.87	1.06	4.15	2.46	9.33
OD	1.61	1.36	0.93	3.27	2.46	9.33
AE	1.31	1.06	1.25	4.27	2.71	11.66
UH	1.49	0.87	1.08	3.63	2.86	9.74
MEAN	1.38	1.06	1.16	3.97	2.98	10.66
LSD$_{(0.05)}$	0.05***	0.04***	0.06***	0.25***	0.07***	0.10***

2022

Accessions	B1 (mg/100g)	B2 (mg/100g)	B3 (mg/100g)	Carotene (mg/100g)	E (mg/100g)	C (mg/100g)
NT	1.06	0.75	1.13	1.29	1.83	19.51
OR	1.05	0.71	1.13	1.35	1.88	19.58
ND	0.91	0.71	1.35	1.27	1.83	21.47
OB	0.85	0.67	1.24	1.29	2.17	19.79
OH	0.93	0.74	1.10	1.64	3.34	2.66
UO	1.18	0.93	1.89	1.61	2.28	20.41
UB	1.15	0.81	1.07	1.25	1.91	19.14
UM	1.14	0.88	1.27	1.84	2.21	3.16
OL	1.17	0.83	1.25	1.56	2.17	19.65
AM	1.08	0.69	1.10	1.33	1.93	18.66
OD	1.08	0.69	1.10	1.33	1.93	18.66
AE	0.93	0.81	1.25	1.27	2.77	20.72
UH	1.14	0.76	1.34	1.49	2.62	20.31
MEAN	1.05	0.77	1.19	1.42	2.22	17.21
LSD$_{(0.05)}$	0.02***	0.02***	ns	0.03***	0.33***	0.44***

Note: cm = centimetre, ns = not significant, * =significant at 5%, ** = significant at 1% and *** = significant at 0.01%, Gm = grand mean, mg = milligrams, g = grams, W = Week

Table 5 – Averages of Phytochemical composition of 13 *Cola parchycarpa*

2021

Accessions	Tanin (mg/100g)	Oxalate (mg/100g)	HCN (mg/100g)	Alkanol (mg/100g)	Phenol (mg GAE/g)	Phytate (mg/100g)	Saponin (mg/100g)
NT	0.09	0.06	0.06	0.04	0.23	0.07	0.03
OR	0.08	0.04	0.03	0.03	0.19	0.08	0.03
ND	0.09	0.06	0.06	0.04	0.35	0.06	0.04
OB	0.14	0.05	0.05	0.03	0.25	0.04	0.03
OH	0.07	0.03	0.03	0.04	0.21	0.06	0.03
UO	0.08	0.55	0.03	0.03	0.19	0.05	0.04
UB	0.07	0.05	0.03	0.03	0.17	0.04	0.02
UM	0.07	0.04	0.03	0.03	0.16	0.15	0.02
OL	0.08	0.06	0.03	0.03	0.28	0.05	0.03
AM	0.06	0.04	0.03	0.03	0.29	0.05	0.03
OD	0.08	0.04	0.05	0.04	0.23	0.05	0.03
AE	0.09	0.05	0.05	0.02	0.27	0.06	0.03
UH	0.07	0.03	0.03	0.02	0.25	0.08	0.02
MEAN	0.08	0.05	0.04	0.03	0.02	0.06	0.03
LSD$_{(0.05)}$	0.015***	0.002***	0.002***	0.009***	0.024***	0.002***	0.002***

2022

Accessions	Tanin (mg/100g)	HCN (mg/100g)	Alkanol (mg/100g)	Phenol (mg GAE/g)	Saponin (mg/100g)	Flavoniod (mg/100g)
NT	0.08	0.01	0.04	0.23	0.03	0.03
OR	0.08	0.02	0.02	0.13	0.02	0.02
ND	0.08	0.01	0.02	0.21	0.02	0.02
OB	0.07	0.02	0.03	0.18	0.02	0.03
OH	0.07	0.02	0.04	0.54	0.03	0.03
UO	0.06	0.01	0.01	0.16	0.02	0.02
UB	0.06	0.01	0.01	0.16	0.02	0.02
UM	0.08	0.02	0.03	0.26	0.02	0.03
OL	0.07	0.02	0.03	0.13	0.02	0.02
AM	0.08	0.02	0.02	0.15	0.02	0.02
OD	0.08	0.01	0.02	0.06	0.02	0.02
AE	0.08	0.01	0.02	0.06	0.03	0.02
UH	0.30	0.02	0.04	0.16	0.03	0.02
MEAN	0.09	0.02	0.03	0.19	0.02	0.03
LSD$_{(0.05)}$	ns	0.001***	0.001***	Ns	0.002***	ns

Note:cm = centimetre, ns = not significant, * =significant at 5%, ** = significant at 1% and *** = significant at 0.01%, Gm = grand mean., mg = milligrams, g = grams, W = Week

Table 6 - Genetic component analyses for Proximate, Minerals, Vitamins and Phytochemicals of 13 accessions of *Cola parchycarpa*

Attributes	Grand Mean (X)	VP	VG	Ve	h^2B (%)	PCV	GCV	PCV-GCV	ECV
Total solids (%)	14.56	1.435	1.415	0.020	98.606	8.227	8.170	0.058	0.971
Moisture content (%)	85.39	1.167	1.062	0.105	91.000	1.265	1.207	0.058	0.379
Ash content (%)	1.51	0.013	0.013	0.000	100.000	7.631	7.631	0.000	0.000
Crude protein (%)	2.05	0.045	0.045	0.000	100.000	10.369	10.369	0.000	0.000
Crude fibre (%)	0.64	0.007	0.007	0.000	100.000	12.732	12.732	0.000	0.000
Fat content (%)	0.48	0.185	0.032	0.153	17.117	89.347	36.965	52.382	81.342
Carbohydrate content (%)	9.97	1.247	1.227	0.020	98.396	11.196	11.105	0.090	1.418
Ca (mg/100g)	24.10	7.913	7.868	0.045	99.431	11.672	11.639	0.033	0.880
Na(mg/100g)	46.68	41.213	37.375	3.838	90.687	13.754	13.098	0.656	4.197
Mg (mg/100g)	20.57	3.638	3.608	0.030	99.175	9.271	9.233	0.038	0.842
Fe (mg/100g)	2.96	0.280	0.278	0.002	99.405	17.858	17.805	0.053	1.378
Zn (mg/100g)	1.67	0.113	0.043	0.070	38.235	20.188	12.483	7.705	15.866
K (mg/100g)	101.73	22.650	22.548	0.102	99.551	4.678	4.668	0.011	0.313
P (mg/100g)	28.91	13.577	13.577	0.000	100.000	12.745	12.745	0.000	0.000
Cu (mg/100g)	0.30	0.003	0.003	0.000	100.000	19.086	19.086	0.000	0.000
B1 (mg/100g)	1.22	0.015	0.015	0.000	100.000	10.064	10.064	0.000	0.000
B2 (mg/100g)	0.91	0.017	0.017	0.000	100.000	14.129	14.129	0.000	0.000
B3 (mg/100g)	1.18	0.018	0.012	0.007	63.636	11.510	9.182	2.328	6.941
Carotene (mg/100g)	2.70	0.125	0.125	0.000	100.000	13.108	13.108	0.000	0.000
E (mg/100g)	2.60	30.213	30.205	0.008	99.972	211.534	211.504	0.029	3.513
C (mg/100g)	13.93	20.943	20.932	0.012	99.944	32.843	32.834	0.009	0.775
Oxalate (mg/100g)	0.04	1.203	0.700	0.503	58.172	2551.083	1945.721	605.362	1649.907
Saponin (mg/100g)	0.03	2.912	0.005	2.907	0.172	6615.083	274.126	6340.957	6609.401

Note: VP= Phenotypic variance, VG= genotypic variance, Ve= environmental variance, h2 B (%) =heritabili

Table 7 - Correlation matrix of Proximate, Minerals, Vitamins and Phytochemicals of 13 accessions of *Cola parchycarpa*

	MC	TS	ASH	CP	CF	FAT	CHO	Pmg/100g	Camg/100g	Namg/100g	Mgmg/100g	Femg/100g	Znmg/100g	Kmg/100g	B1mg/100g	B2mg/100g
MC		-0.846**	-0.447**	-0.305	-0.333*	0.081	-0.808**	-0.188	0.302	-0.01	-0.06	-0.01	0.166	-0.056	-0.232	-0.556**
TS		-	0.413**	0.370*	0.400*	-0.096	0.970**	0.329*	-0.205	0.03	0.111	0.077	-0.092	0.128	0.352*	0.614**
ASH			-	0.761**	-0.071	-0.279	0.264	0.327*	-0.25	-0.423**	-0.114	0.188	-0.042	0.261	0.258	0.342*
CP				-	0.054	-0.289	0.183	0.756**	0.127	-0.126	0.256	0.684**	0.372*	0.464**	0.530**	0.421**
CF					-	0.179	0.340*	0.29	-0.068	0.389*	0.343*	0.186	-0.258	-0.217	0.215	0.540**
FAT						-	-0.118	-0.286	-0.383*	-0.168	-0.337*	-0.313	-0.528**	-0.058	-0.657**	-0.22
CHO							-	0.193	-0.199	0.05	0.061	-0.053	-0.1	0.043	0.305	0.557**
Pmg/100g								-	0.517**	0.227	0.537**	0.835**	0.584**	0.403*	0.695**	0.528**
Camg/100g									-	0.587**	0.567**	0.514**	0.751**	0.345*	0.651**	0.173
Namg/100g										-	0.692**	0.341*	0.358*	0.054	0.470**	0.351*
Mgmg/100g											-	0.578**	0.352*	0.115	0.575**	0.298
Femg/100g												-	0.620**	0.504**	0.586**	0.428**
Znmg/100g													-	0.275	0.722**	0.276
Kmg/100g														-	0.166	0.054
B1mg/100g															-	0.648**
B2mg/100g																-

Note: VP = Phenotypic variance, VG = genotypic variance, Ve = environmental variance, h2 B (%) = heritability in a broad sense, PCV = Correlation of phenotypic variance, GCV = Correlation of genotypic variance, ECV =Environmental correlation of variance, mg = milligrams, g = grams, W = Week

targeted selection of nutritionally superior genotypes for use in breeding programs aimed at developing biofortified or health-enhancing fruit cultivars.

The presence of beneficial phytochemicals such as phenols, flavonoids, saponins, and tannins across accessions indicates potential use of *C. parchycarpa* as a functional food or source of nutraceuticals. These compounds are known for their anti-inflammatory, antimicrobial, and antioxidant activities. The low levels of anti-nutritional factors such as oxalates and hydrogen cyanide further support the fruit's safety for consumption and industrial processing. Significantly higher phenol content in certain accessions (e.g., OH) suggests these genotypes may offer greater health benefits and could be prioritized in breeding programs for functional fruit development.

The wide range of heritability observed among the *C. parchycarpa* accessions demonstrated the presence of substantial genetic variability for the studied traits. High heritability estimates, particularly for crude protein, vitamin C, potassium, calcium, and total solids, suggested that these traits are predominantly controlled by additive gene effects and are thus amenable to improvement through direct phenotypic selection. Similar results have been reported by Nwofia and Ojimelukwe (2012).

The minimal differences between genotypic and phenotypic coefficients of variation (GCV and PCV) in traits such as crude protein, vitamin C, potassium, and calcium further confirmed the limited influence of environmental factors. This reinforces the reliability of these traits as selection indices in breeding programs. For instance, the matching GCV and PCV values observed for crude protein indicated that observed variability is entirely genetic, enhancing its value as a key trait for improvement. On the other hand, traits such as oxalate and crude fat showed wider disparities between GCV and PCV values, coupled with higher environmental coefficients of variation. This implied stronger environmental influence and suggested that improvement of these traits may require evaluation under more controlled or multi-environmental conditions. The relatively lower heritability of hydrogen cyanide also highlighted the need for careful environmental management in breeding efforts targeting anti-nutritional factors.

The correlation analysis revealed important relationships that can inform indirect selection strategies. The strong and positive correlation between crude protein and vitamin C is an indication of the feasibility of improving both traits simultaneously, thereby enhancing both the macronutrient and antioxidant profile of selected genotypes. Similar positive associations between potassium and calcium, as well as between calcium and magnesium, supported the selection of accessions with multiple micronutrient advantages, which is critical in addressing mineral deficiencies prevalent in low-resource diets (FAO, 2021; Bouis and Saltzman, 2017).

Positive associations between total solids and ash, calcium, and magnesium further indicated that accessions with higher dry matter content also tend to accumulate more minerals. These interrelationships could be leveraged in breeding programs to develop nutrient-dense fruit varieties without compromising yield components.

Conclusion

The combination of high heritability, strong positive trait correlations, and clear genetic variability among accessions is an indication that *C. parchycarpa* possesses significant potential for genetic enhancement. These findings support its integration into formal breeding programs aimed at improving the nutritional quality and functional value of indigenous fruits for food and nutrition security in sub-Saharan Africa.

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