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Recent Advances in Natural Sciences

Journal Homepage: https://flayoophl.com/journals/index.php/rans

Comparative analysis of the nutritive and antinutritive values of the pulps and kernels of Mafida (*Spondias* sp. cf. *S. mombin* L., wild variety) and Mobola plum (*Parinari curatellifolia* Cav.) in Akwanga, north-central Nigeria

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ARTICLE INFO

Article history:
Received: 15 April 2026
Received in revised form: 10 July 2026
Accepted: 11 July 2026
Available online: 19 August 2026

Keywords: Mafida, Mobola plum, Antinutritional factors, Amino acids

DOI:10.61298/rans.2026.4.2.353

ABSTRACT

This study comparatively evaluated the proximate composition, mineral content, antinutritional factors, and amino acid profiles of the pulps and kernels of Mafida and Mobola plum collected in Akwanga Local Government Area, Nasarawa State, Nigeria. Samples were prepared and analysed using standard analytical methods. The kernels of both fruits contained more protein, fat, and metabolic energy than their corresponding pulps. Mafida kernel contained 27.01% crude protein and 18.38% total fat, whereas Mobola plum kernel contained 33.96% crude protein and 22.32% total fat. Mafida pulp had higher moisture, carbohydrate, and crude fibre contents, and Mobola plum pulp had a notably higher carbohydrate content (53.50%) than its kernel. Both fruits contained measurable macro- and trace elements, including Na, K, Ca, Mg, Fe, Zn, and Cu; however, their overall contribution to dietary mineral requirements was limited. Oxalates, phytates, alkaloids, phenolics, and other antinutritional factors occurred at appreciable concentrations, indicating that processing may improve nutritional safety and nutrient bioavailability. All nine essential amino acids were detected, with the kernels generally showing higher total amino acid contents and better protein quality than the pulps. Mafida and Mobola plum kernels therefore have potential as protein- and energy-dense ingredients, but processing and bioavailability studies are required before their use in food formulations can be recommended.

1. INTRODUCTION

Economic instability in Nigeria since early 2024, worsening insecurity, and consequent food scarcity have intensified the search for alternative, underutilized food sources. Native species may escape scientific evaluation because they are not widely known, leaving both their potential benefits and harmful effects poorly characterized. Plant foods can supply macronutrients such as carbohydrates, proteins, and fats, as well as minerals, but they may also contain antinutritional factors (ANFs). At high oral doses, phytates present in cereals, beans, oilseeds, and carrots

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can cause mineral loss through chelation with divalent essential mineral ions [1–3]. Phenolic compounds can decrease amino acid bioavailability by deactivating enzyme active sites and forming complexes with protein substrates [4]. Saponins, which are also found in foods such as carrots, may alter vascular epithelial cells and impair the absorption of vitamins A and E and lipids when consumed in high amounts [1, 2].

Mafida (*Spondias* sp. cf. *S. mombin* L., wild variety), a member of the family Anacardiaceae, is morphologically related to *Spondias* species [5–7]. Indigenous communities in northern Nasarawa State use it for nutritional and medicinal purposes [8]. Mobola plum (*Parinari curatellifolia* Cav.) belongs to the family Chrysobalanaceae and is also known as the hissing tree. It occurs in Akwanga and Lafia Local Government Areas of Nasarawa State, Nigeria, and has also been reported in Malawi [9]. Among the Mada people of Akwanga, aqueous extracts of the bark and roots are used traditionally to treat illnesses, including typhoid fever. The pulp and the palatable kernel, which is enclosed in a hard stone and exposed manually by cracking, are consumed raw.

Appropriate nutrition requires a balance between food consumption and knowledge of food composition and its influence on nutrient bioavailability and assimilation. Although high intakes of some ANFs have well-documented adverse effects, low intakes of certain compounds may have pharmacological benefits in conditions such as diabetes, obesity, and cancer [4, 10]. The preparation method, mitigation strategy, and form of consumption for plant foods containing ANFs should therefore be informed by their chemical composition [1]. Despite increasing interest in underutilized fruits, no integrated evaluation combining amino acid profiling, antinutritional risk assessment, and proximate analysis has been reported for Mafida and Mobola plum. This study therefore aimed to compare the nutritional and antinutritional values of the pulps and kernels of Mafida and Mobola plum. The specific objectives were to determine their (i) proximate composition, (ii) mineral content, (iii) antinutritional factors, and (iv) amino acid composition.

2. MATERIALS AND METHODS

2.1. COLLECTION AND IDENTIFICATION OF SAMPLES

Thirty fresh, ripe Mafida fruits were collected from three trees in Angwon A. A. Kwoto, Akwanga, and from bushland along Andaha Road, Akwanga. Thirty ripe Mobola plum fruits were also collected from two trees in Aricha District, Akwanga Local Government Area. The samples were identified in the Department of Forestry and Conservation, Federal University of Lafia. Voucher numbers were assigned at the Herbarium Laboratory, Department of Plant Science and Biotechnology, Federal University of Lafia, as follows: Mafida (*Spondias* sp. cf. *S. mombin* L., wild variety), FUL/SC/PSB/H. Lab/0080; and Mobola plum (*Parinari curatellifolia* Cav.), FUL/SC/PSB/H. Lab/0081. Mafida was provisionally identified as *Spondias* sp. cf. *S. mombin* L. on the basis of morphological similarity but was not assigned to a confirmed species. The specimen may represent a cryptic species or an undescribed taxon pending further taxonomic investigation. Figures 1 and 2 show ripe Mafida and Mobola plum fruits, respectively.

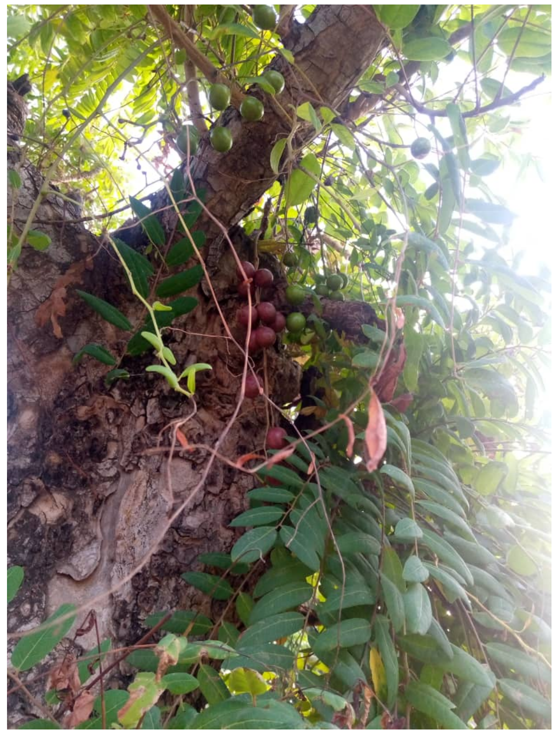

Figure 1. Mafida fruits on a tree in Akwanga town.

Figure 2. A portion of ripe Mobola plum fruits collected from a tree in Aricha District, Akwanga.

2.2. PREPARATION OF SAMPLES

Both fruits were washed with distilled water, and the pulps were separated from the stone seeds and oven-dried separately at 60 °C for 2 days according to Ref. [9]. The dried Mafida pulp was homogenized in an electric blender. The dried Mobola plum pulp was first crushed into smaller granules and then ground into a fine powder in an electric blender. The powders were packed separately in sterile plastic bags, labelled, and stored in a refrigerator at 4 °C [11]. The oven-dried Mafida and Mobola plum kernels were exposed by manually cracking the hard shells with a light hammer. The kernels were milled separately into fine powders and stored in sterile bags in the same manner as the pulps.

2.3. PROXIMATE ANALYSIS

Standard procedures described in Refs. [9, 12, 13] were used to determine moisture, ash, crude fibre, nitrogen, crude protein (nitrogen $\times 6.25$), crude fat, and carbohydrate by difference. The parameters are reported as the mean percentages of duplicate determinations.

2.4. MINERAL CONTENT

An AA320N atomic absorption spectrometer (Shanghai General Analytical Instrument Factory, Shanghai, China) was used to determine the concentrations of Na, K, Ca, Mg, Fe, Cu, and Zn. The means and standard deviations of duplicate determinations are reported in mg/100 g of sample.

2.5. ANTINUTRITIONAL FACTORS

Saponins, tannins, flavonoids, total phenolics, oxalates, alkaloids, phytates, and cyanide were determined using standard analytical procedures described in Refs. [13–19], respectively.

2.6. AMINO ACID ANALYSIS

Amino acid composition was determined by high-performance liquid chromatography using an Applied Biosystems phenylthiohydantoin (PTH) amino acid analyser.

2.6.1. Sample preparation for general amino acid determination

Two parallel hydrolysis procedures were used because tryptophan is destroyed during acid hydrolysis at high temperatures. For the general amino acid determination, approximately 0.1–0.9 g of each defatted sample was hydrolysed with 6 M HCl under vacuum at 110 °C for 24 h. Nitrogen gas was introduced into the glass ampoules before hydrolysis to remove oxygen and minimize oxidation of cystine and methionine. The ampoules were flame-sealed with a Bunsen burner and heated in an oven at 110 °C for 24 h. After cooling, each ampoule was opened and its contents filtered. The filtrate was evaporated to dryness with a rotary evaporator. The residue was dissolved in 5 mL of acetate buffer (pH 2.0), transferred to a plastic specimen bottle, and stored in a freezer. This procedure converts asparagine and glutamine to aspartic acid and glutamic acid, respectively.

The PTH analyser cartridge was loaded with 60 μL of hydrolysate. Norleucine (10 μL) was added to the amino acid standard mixture as an internal standard to correct for variations between the sample and standard mixture. The analyser was used to separate and quantify leucine, lysine, isoleucine, phenylalanine, tryptophan, valine, methionine, proline, arginine, tyrosine, histidine, cystine, alanine, glutamic acid, glycine, threonine, serine, and aspartic acid.

2.6.2. Sample preparation for tryptophan

Tryptophan was analysed separately using equivalent amounts of the defatted samples employed for the general amino acid determination. The samples were hydrolysed with 4.2 M sodium hydroxide, evaporated in a rotary evaporator, and loaded into the Applied Biosystems PTH amino acid analyser.

2.6.3. Derivation of concentration from peak parameters

Each sample was analysed in duplicate. Phenyl isothiocyanate was used to generate PTH derivatives of the amino acids. Peak height (N_{H}) and peak width at half-height ($W_{\mathrm{H}/2}$) were used for quantification. Concentration was calculated as

$$\text{Concentration} = N_{\mathrm{H}}\, W_{\mathrm{H}/2}\, S_{\mathrm{std}}\, C, \tag{1}$$

where

$$S_{\mathrm{std}} = NE_{\mathrm{std}} \times M_{\mathrm{r}} \times \mu_{\mathrm{AA,std}}, \tag{2}$$

and, using D for dilution, m_{s} for sample mass (g), and V_{L} for volume loaded,

$$C = \frac{16D}{m_{\mathrm{s}}\, N(\%)\, V_{\mathrm{L}}} \div [N_{\mathrm{H}}\, W(\mathrm{nLeu})]\,. \tag{3}$$

2.7. DETERMINATION OF ISOELECTRIC POINT, DIETARY PROTEIN QUALITY, AND PREDICTED PROTEIN EFFICIENCY RATIO

The isoelectric point (pI), dietary protein quality, and predicted protein efficiency ratio (P-PER) were calculated using the equations employed in Ref. [2]. The isoelectric point of an amino acid mixture was calculated as

$$\mathrm{pI}_m = \sum_{i=1}^{n} \mathrm{pI}_i X_i, \tag{4}$$

where pI_m is the isoelectric point of the amino acid mixture, pI_i is the isoelectric point of the ith amino acid, and X_i is its mass or mole fraction. Dietary protein quality was evaluated from the amino acid score (AAS):

$$\mathrm{AAS} = \frac{\text{test-sample amino acid content}}{\text{reference-protein amino acid content}} \times 100. \tag{5}$$

The P-PER was calculated as

$$\text{P-PER} = -0.468 + 0.45(\mathrm{Leu}) - 0.105(\mathrm{Tyr}). \tag{6}$$

2.8. STATISTICAL ANALYSIS

In this descriptive study, the coefficient of variation (CV) was used to assess the relative variability of each parameter around its mean, and percentage difference was used to compare nutrient levels between each pulp and its corresponding kernel. Metabolic energy and fatty acid content were calculated according to Ref. [20]. Fatty acid content was calculated as the product of total fat and 0.8. Metabolic energy was calculated as

$$\begin{aligned}\text{Energy} = {} & (\text{protein} \times 17) + (\text{fat} \times 37) \\ & + (\text{carbohydrate} \times 17).\end{aligned} \tag{7}$$

3. RESULTS AND DISCUSSION

3.1. PROXIMATE COMPOSITION

Tables 1 and 2 present the proximate compositions of the Mafida and Mobola plum pulps and kernels. In Mafida, total fat and fatty acids were the most variable parameters (CV = 47.21% and 47.23%, respectively). These components were major contributors to the higher energy content of the kernel (1599 kJ/100 g). Crude protein (CV = 26.48%) and carbohydrate (CV = 22.51%) also varied appreciably. The larger proportion of protein in the kernel and carbohydrate in the pulp indicates that the kernel is the better protein source, whereas the pulp is the better carbohydrate source. Kernels often contain more protein, while fruit

Table 1. Proximate composition of Mafida pulp and kernel (%)[a].

Analysis	Pulp	Kernel	Mean	SD	CV (%)
Crude protein	18.49	27.01	22.75	6.03	26.48
Total fat	9.18	18.38	13.78	6.51	47.21
Ash content	6.12	5.025	5.57	0.77	13.89
Crude fibre	25.79	19.73	22.76	4.29	18.83
Moisture	3.10	2.79	2.95	0.22	7.44
Carbohydrate	37.32	27.07	32.20	7.25	22.51
Fatty acids	7.34	14.70	11.02	5.20	47.23
Energy (kJ/100 g)	1288	1599	1444	220.1	15.25

[a]Values are means of duplicate determinations. Carbohydrate = 100 − (moisture + ash + crude fibre + crude fat + crude protein). Calculated metabolic energy (kJ/100 g) = (protein × 17) + (fat × 37) + (carbohydrate × 17). Calculated fatty acid = 0.8 × crude fat. SD, standard deviation; CV, coefficient of variation.

Table 2. Proximate composition of Mobola plum pulp and kernel (%)[a].

Analysis	Pulp	Kernel	Mean	SD	CV (%)
Crude protein	6.57	33.96	20.27	19.37	95.75
Total fat	8.68	22.32	15.50	9.65	62.23
Ash content	5.235	3.345	4.29	1.34	31.15
Crude fibre	15.25	24.33	19.79	6.42	32.44
Moisture	10.77	1.445	6.11	6.59	107.96
Carbohydrate	53.50	14.61	34.01	27.50	80.75
Fatty acids	6.944	17.86	12.40	7.72	62.24
Energy (kJ/100 g)	1342	1651	1497	218.5	14.60

[a]Values are means of duplicate determinations. SD, standard deviation; CV, coefficient of variation.

pulps commonly contain more carbohydrate, particularly sugars [21, 22]. Protein is stored in kernels to support embryonic development and growth [21, 22], whereas the high sugar concentration of pulp attracts animals that disperse seeds [23].

Mobola plum kernel contained substantially more crude protein, total fat, crude fibre, and fatty acids than the pulp, making it more nutrient-dense (Table 2). Its higher energy content (1651 kJ/100 g) was attributable to the higher protein and fat contents. Moisture was the most variable parameter (CV = 107.96%). The low moisture content of the kernel may favour preservation and long-term storage, whereas the pulp provides more water. The large variation in carbohydrate content (CV = 80.75%) and the higher pulp value indicate that the pulp is the richer carbohydrate source.

Proteins perform essential roles in enzymatic reactions, hormonal functions, fluid balance, and molecular transport [24]. The crude protein contents of Mafida pulp and kernel were higher than reported values for *Spondias mombin* pulp (0.86–3.06%) [12, 25], shea butter pulp (5.23%) and kernel (9.30%) [26], and carrot (9.39%) and cucumber (14.39%) [2]. They were comparable to the values reported for Sodom apple fruit (19.55%) and leaves (20.91%) [11] and Mobola plum seeds (33.1%) [27], but lower than the values reported for *Clarias gariepinus* (48.83%) and *Tilapia quineesis* (67.82%) [20]. The Mobola plum pulp protein content was higher than reported values for *S. mombin* pulp (0.86–3.06%) [12, 25] and gingerbread plum (1.95%) [28]. The Mobola plum kernel value exceeded those reported for Mobola plum seeds (33.1%) [27], Sodom apple leaves and fruit [11], shea butter kernel and pulp [26], and carrot and cucumber [2].

Fats and lipids are essential nutrients involved in body development and protection. They supply mono- and polyunsaturated fatty acids, omega-3 fatty acids, cholesterol, and phospholipids and contribute to blood-pressure regulation, cell-membrane structure, and hormone formation [24]. The total fat content of Mafida kernel was higher than values reported for Mobola plum seed (5.15%) [27], *T. guineensis* (14.83%) [20], and gingerbread plum (11.0%) [28], but lower than values reported for *C. gariepinus* (26.11%) [20] and shea butter kernel (45.66%) [26]. The Mobola plum kernel fat content (22.32%) was higher than values reported for gingerbread plum (11.0%) [28], shea butter pulp (10.95%) [26], and *T. guineensis* (14.83%) [20], but lower than values reported for *C. gariepinus* (26.11%) [20] and shea butter kernel (45.62%) [26].

3.2. MINERAL CONTENT

Tables 3 and 4 present the selected essential minerals in Mafida and Mobola plum. The macroelements were Mg, Na, K, and Ca, and the trace elements were Fe, Zn, and Cu. In Mafida, Zn was the most variable mineral (CV = 41.6%) and was more concentrated in the kernel, whereas the other elements had CV values below 30%. Mg was the most concentrated mineral and occurred at almost equivalent concentrations in the pulp and kernel (CV = 0.610%). Na had the lowest concentration and was the least variable parameter (CV = 0.33%).

In Mobola plum, Mg was the most variable element (CV = 94.70%) and was more concentrated in the pulp. Magnesium is important for cell growth and repair, protein metabolism, and wound healing [28]. Except for Cu (CV = 74.50%), Zn (CV = 34.50%), and Mg, the minerals had CV values below 28%. All minerals except Na were more concentrated in the Mobola plum pulp. Copper is required in trace amounts for red blood cell formation, bone maintenance, wound healing, and antioxidant functions [24]. Calcium was the least variable element (CV = 1.31%). K was the most concentrated element in the pulp, whereas Na was the most concentrated in the kernel. Sodium contributes to fluid balance, nutrient absorption, and nerve impulse transmission. Potassium supports platelet function, nerve transmission, muscle function, and energy metabolism [24]. The Na/K ratios of Mafida pulp and kernel were 1.05 and 0.97, respectively, and those of Mobola plum pulp and kernel were 0.934 and 1.03, respectively. On the basis of the proposed acceptable ratio of less than 1 [20], Mafida kernel and Mobola plum pulp may be more favourable for cardiovascular health.

3.3. ANTINUTRITIONAL FACTORS

Tables 5 and 6 show that Mafida and Mobola plum pulps and kernels contained several antinutritional factors at different concentrations. Except for oxalate, the antinutritional factors in Mafida kernel were less concentrated than those in the pulp. Similarly, Mobola plum kernel had lower concentrations than the pulp, except for saponins and total phenolics. This pattern contrasts with findings for shea (*Vitellaria paradoxa*), in which antinutritional factors were more concentrated in the kernel [26].

Flavonoids were the most variable antinutritional factor in Mafida (CV = 128.56%) and were more concentrated in the pulp (525 mg/100 g). Saponins were the next most variable factor (CV = 124.78%) and were also more concentrated in the pulp

Table 3. Mineral content of Mafida pulp and kernel (mg/100 g)[a].

Analysis	Pulp	Kernel	Mean	SD	CV (%)
Sodium	0.0858 ± 0.0152	0.0862 ± 0.0152	0.0860	0.0003	0.33
Potassium	0.0815 ± 0.0144	0.0890 ± 0.0157	0.085	0.0046	5.35
Calcium	0.0803 ± 0.0016	0.0940 ± 0.0023	0.087	0.0097	11.12
Magnesium	0.1154 ± 0.0199	0.1164 ± 0.0020	0.116	0.0007	0.610
Iron	0.0094 ± 0.0006	0.0123 ± 0.0011	0.011	0.0021	18.90
Zinc	0.0048 ± 0.0002	0.0088 ± 0.0005	0.007	0.0028	41.6
Copper	0.0056 ± 0.0010	0.0086 ± 0.0015	0.007	0.0021	29.90
Na/K	1.05	0.97	1.01	0.057	5.610

[a]Values are means of duplicate determinations ± standard deviations. SD, standard deviation; CV, coefficient of variation.

Table 4. Mineral content of Mobola plum pulp and kernel (mg/100 g)[a].

Analysis	Pulp	Kernel	Mean	SD	CV (%)
Sodium	0.1667 ± 0.0175	0.1717 ± 0.0152	0.169	0.0035	2.09
Potassium	0.1784 ± 0.0158	0.1664 ± 0.0147	0.172	0.0085	4.93
Calcium	0.1148 ± 0.0203	0.1127 ± 0.0199	0.113	0.0015	1.31
Magnesium	0.1188 ± 0.0204	0.0235 ± 0.0197	0.071	0.0674	94.70
Iron	0.0137 ± 0.0011	0.0093 ± 0.0008	0.012	0.0031	27.00
Zinc	0.0135 ± 0.0000	0.0082 ± 0.0002	0.011	0.0038	34.50
Copper	0.0084 ± 0.0015	0.0026 ± 0.0005	0.006	0.004	74.50
Na/K	0.934	1.03	0.98	0.068	6.92

[a]Values are means of duplicate determinations ± standard deviations. SD, standard deviation; CV, coefficient of variation.

Table 5. Antinutritional factors in Mafida pulp and kernel (mg/100 g.)[a]

Parameter	Pulp	Kernel	Mean	SD	CV (%)
Saponins	240.0	15.00	127.50	159.10	124.78
Tannins	9.73	1.525	5.63	5.80	103.10
Flavonoids	525.0	25.00	275.00	353.55	128.56
Total phenolics	835.0	670.0	752.50	116.67	15.50
Oxalate	2895	4175	3535	905.0	25.60
Alkaloids	155.0	109.0	132.0	32.53	24.64
Phytates	170.69	46.55	108.62	87.78	80.81
Cyanide	1.035	0.512	0.774	0.370	47.81

[a]Values are means of duplicate determinations. SD, standard deviation; CV, coefficient of variation.

Table 6. Antinutritional factors in Mobola plum pulp and kernel (mg/100 g)[a]

Parameter	Pulp	Kernel	Mean	SD	CV (%)
Saponins	110.0	240.0	175.0	91.92	52.53
Tannins	5.265	1.265	3.27	2.83	86.63
Flavonoids	1505	515.0	1010	700.04	69.31
Total phenolics	250.0	330.0	290.0	56.57	19.51
Oxalate	6960	3205	5083	2655	52.24
Alkaloids	166	155	160.5	7.78	4.85
Phytates	190.14	50.30	120.22	98.88	82.25
Cyanide	0.535	0.615	0.575	0.0566	9.84

[a]Values are means of duplicate determinations. SD, standard deviation; CV, coefficient of variation.

Table 7. Amino acid composition of Mafida pulp and kernel (g/100 g crude protein (cp)).

Amino acid	Pulp	Kernel	Mean	SD	CV (%)
Leucine (Leu)[e]	5.26	7.74	6.50	1.754	26.98
Lysine (Lys)[e]	1.95	4.13	3.04	1.542	50.71
Isoleucine (Ile)[e]	3.36	3.35	3.36	0.007	0.21
Phenylalanine (Phe)[e]	4.485	3.545	4.02	0.665	16.55
Tryptophan (Trp)[e]	0.88	1.26	1.07	0.269	25.11
Valine (Val)[e]	3.56	3.01	3.29	0.389	11.84
Methionine (Met)[e]	1.415	1.28	1.35	0.096	7.09
Proline (Pro)	4.925	4.005	4.47	0.651	14.57
Arginine (Arg)	2.365	8.51	5.44	4.375	79.93
Tyrosine (Tyr)	2.665	2.32	2.49	0.244	9.79
Histidine (His)[e]	2.24	2.375	2.31	0.096	4.14
Cystine (Cys)	1.24	1.36	1.30	0.085	6.54
Alanine (Ala)	5.085	4.435	4.76	0.460	9.66
Glutamic acid (Glu)	6.78	12.52	9.65	3.98	41.27
Glycine (Gly)	3.27	4.225	3.75	0.675	18.02
Threonine (Thr)[e]	2.365	3.09	2.73	0.513	18.80
Serine (Ser)	3.165	4.21	3.69	0.739	20.04
Aspartic acid (Asp)	6.59	8.30	7.45	1.209	16.24
Isoelectric point	3.49	4.30	3.90	0.57	14.70
P-PER	1.64	2.80	2.22	0.821	36.98
Leu/Ile	1.57	2.31	1.94	0.523	26.96

[e]Essential amino acid. P-PER, predicted protein efficiency ratio; SD, standard deviation; CV, coefficient of variation.

(240 mg/100 g). Total phenolics were the least variable parameter (CV = 15.50%). In Mobola plum, tannins were the most variable parameter (CV = 86.63%) and were more concentrated in the pulp (5.265 mg/100 g), followed by phytates (CV = 82.25%), which were also more concentrated in the pulp (190.14 mg/100 g). Alkaloids were the least variable parameter (CV = 4.85%), followed by total phenolics (CV = 19.51%). The potentially pharmacologically beneficial antinutritional compounds in the

Table 8. Amino acid composition of Mobola plum pulp and kernel (g/100 g crude protein (cp)).

Amino acid	Pulp	Kernel	Mean	SD	CV (%)
Leucine (Leu)[e]	4.20	5.475	4.84	0.902	18.64
Lysine (Lys)[e]	4.125	3.16	3.64	0.683	18.73
Isoleucine (Ile)[e]	2.325	3.015	2.67	0.488	18.27
Phenylalanine (Phe)[e]	1.00	3.015	2.01	1.425	70.97
Tryptophan (Trp)[e]	4.355	4.13	4.24	0.159	3.75
Valine (Val)[e]	2.11	0.84	1.48	0.898	60.88
Methionine (Met)[e]	3.105	2.75	2.93	0.251	8.57
Proline (Pro)	2.32	1.30	1.81	0.721	39.85
Arginine (Arg)	1.20	3.505	2.35	1.630	69.28
Tyrosine (Tyr)	1.71	6.50	4.11	3.387	82.51
Histidine (His)[e]	0.67	3.10	1.89	1.718	91.15
Cystine (Cys)	2.41	2.18	2.30	0.163	7.09
Alanine (Ala)	4.545	3.185	3.865	0.962	24.88
Glutamic acid (Glu)	4.545	3.675	4.11	0.615	14.97
Glycine (Gly)	2.36	5.11	3.74	1.945	52.06
Threonine (Thr)[e]	3.21	2.79	3.00	0.293	9.79
Serine (Ser)	2.71	3.82	3.26	0.785	24.08
Aspartic acid (Asp)	7.09	5.58	6.33	1.068	16.87
Isoelectric point	5.33	4.64	4.99	0.49	9.79
P-PER	1.26	1.33	1.30	0.050	3.82
Leu/Ile	1.81	1.82	1.82	0.007	0.39

[e]Essential amino acid. P-PER, predicted protein efficiency ratio; SD, standard deviation; CV, coefficient of variation.

Table 9. Concentrations of amino acid groups in Mafida pulp and kernel (g/100 g crude protein).

Amino acid description	Pulp	Kernel	Mean	SD	CV (%)
Total amino acids (TAA)	61.61	79.67	70.64	12.78	18.10
Total non-essential amino acids (TNEAA)	31.18	45.88	38.53	10.39	26.95
% TNEAA	50.30	57.58	53.94	5.148	9.54
Total essential amino acids (TEAA), with histidine	30.44	33.79	32.11	2.365	7.37
TEAA, without histidine	28.20	29.74	28.97	1.089	3.76
% TEAA, with histidine	49.40	42.41	45.91	4.944	10.78
Essential aliphatic amino acids (EAAA)	14.545	17.19	15.87	1.87	11.80
Essential aromatic amino acids (EArAA)	6.805	7.18	6.99	0.27	3.90
Total neutral amino acids (TNAA)	41.33	43.83	42.58	1.77	4.20
% TNAA	67.08	55.01	61.05	8.54	13.98
Total acidic amino acids (TAAA)	13.37	20.82	17.10	5.27	30.80
% TAAA	21.70	26.13	23.92	3.13	13.10
Total basic amino acids (TBAA)	6.555	15.115	10.84	6.00	55.90
% TBAA	10.64	18.98	14.81	4.17	39.80
Total sulphur amino acids (TSAA)	2.655	2.64	2.648	0.011	0.42
% cystine in TSAA	46.70	51.52	49.11	3.41	6.94

SD, standard deviation; CV, coefficient of variation.

Table 10. Concentrations of amino acid groups in Mobola plum pulp and kernel (g/100 g crude protein).

Amino acid description	Pulp	Kernel	Mean	SD	CV (%)
Total amino acids (TAA)	53.98	63.13	58.55	6.46	11.00
Total non-essential amino acids (TNEAA)	26.56	36.65	31.61	7.13	22.60
% TNEAA	49.20	57.67	53.44	5.99	11.21
Total essential amino acids (TEAA), with histidine	27.42	29.58	28.50	1.53	5.36
TEAA, without histidine	26.75	26.48	26.62	0.191	0.72
% TEAA, with histidine	50.79	46.86	48.83	2.78	5.69
Essential aliphatic amino acids (EAAA)	11.84	12.12	11.98	0.198	1.65
Essential aromatic amino acids (EArAA)	6.025	10.25	8.14	2.99	36.70
Total neutral amino acids (TNAA)	36.33	44.11	40.22	5.50	13.70
% TNAA	67.30	69.88	68.59	1.824	2.66
Total acidic amino acids (TAAA)	11.63	9.25	10.44	1.68	16.10
% TAAA	21.55	14.56	18.06	4.94	27.38
Total basic amino acids (TBAA)	6.00	9.77	7.89	2.67	33.90
% TBAA	11.12	15.48	13.30	3.08	23.18
Total sulphur amino acids (TSAA)	5.515	4.93	5.22	0.41	7.90
% cystine in TSAA	43.70	44.21	43.96	0.36	0.84

SD, standard deviation; CV, coefficient of variation.

Table 11. Amino acid scores of Mafida pulp and kernel based on the FAO/WHO provisional pattern.

EAA	PAAESP (g/100 g protein)	Mafida pulp		Mafida kernel	
		EAAC	AAS	EAAC	AAS
Ile	4.0	3.36	0.84	3.35	0.838
Leu	7.0	5.26	0.75	7.74	1.11
Lys	5.5	1.95	0.35	4.13	0.75
Met + Cys (TSAA)	3.5	2.655	0.76	2.64	0.75
Phe + Tyr	6.0	7.15	1.19	5.87	0.98
Thr	4.0	2.37	0.59	3.09	0.77
Trp	1.0	0.88	0.88	1.26	1.26
Val	5.0	3.56	0.71	3.0	0.60
Total	36	27.19	6.07	31.08	7.06

EAA, essential amino acid; PAAESP, provisional amino acid (egg) scoring pattern; EAAC, essential amino acid composition; AAS, amino acid score.

Table 12. Amino acid scores of Mobola plum pulp and kernel based on the FAO/WHO provisional pattern.

EAA	PAAESP (g/100 g protein)	Mobola plum pulp		Mobola plum kernel	
		EAAC	AAS	EAAC	AAS
Ile	4.0	2.33	0.58	3.02	0.76
Leu	7.0	4.20	0.60	5.48	0.78
Lys	5.5	4.13	0.75	3.16	0.57
Met + Cys (TSAA)	3.5	5.52	1.58	4.93	1.41
Phe + Tyr	6.0	2.71	0.45	9.52	1.59
Thr	4.0	3.21	0.81	2.79	0.70
Trp	1.0	4.36	4.36	4.13	4.13
Val	5.0	2.11	0.42	0.84	0.168
Total	36	23.57	9.55	33.20	10.11

EAA, essential amino acid; PAAESP, provisional amino acid (egg) scoring pattern; EAAC, essential amino acid composition; AAS, amino acid score.

pulps of Mafida and Mobola plum compared favourably with those reported for the edible plant *Jatropha tanjorensis*, including tannins; the flavonoid concentrations in both pulps and kernels were also higher [10]. Alkaloids and cyanide were detected in all samples. However, these data do not support a direct safety conclusion because no validated toxicological limits were identified for the total alkaloid and cyanide fractions in these fruits.

3.4. AMINO ACID COMPOSITION AND PROTEIN QUALITY

Tables 7 and 8 present the amino acid contents of the Mafida and Mobola plum pulps and kernels. Eighteen amino acids were quantified, including nine essential amino acids, in all four samples. In Mafida, lysine was the most variable essential amino acid (CV = 50.71%) and was more concentrated in the kernel (4.13 g/100 g). Lysine contributes to bone formation and retention, hormone production, and the reduction of serum triglycerides [20]. Isoleucine was the least variable essential amino acid (CV = 0.21%). In Mobola plum, phenylalanine was the most variable essential amino acid (CV = 70.97%), whereas tryptophan was the least variable (CV = 3.75%).

Leucine was the most abundant essential amino acid in Mafida pulp and kernel (5.26 and 7.74 g/100 g, respectively). The pulp value exceeded those reported for carrot (3.59 g/100 g) [2], shea butter pulp (4.12 g/100 g) and kernel (2.86 g/100 g) [26], pepper (5.08 g/100 g), onion (4.09 g/100 g), and tomato (3.24 g/100 g) [29]. The kernel value also exceeded the values for those foods but was lower than that reported for garlic (8.13 g/100 g) [29].

Tryptophan was the most abundant essential amino acid in Mobola plum pulp (4.355 g/100 g), whereas leucine was the most abundant in the kernel (5.475 g/100 g). The pulp tryptophan value exceeded those reported for carrot (0.37 g/100 g), cucumber (0.73 g/100 g) [2], shea butter pulp (0.75 g/100 g), and shea butter kernel (0.50 g/100 g) [26]. Tryptophan is required for protein synthesis and is a precursor of serotonin and melatonin [30]. The leucine content of Mobola plum kernel was higher than values reported for carrot, cucumber [2], tomato, onion, and pepper [29], but lower than values reported for garlic [29], *C. gariepinus*, and *T. guineensis* [20]. Leucine contributes to cell repair and muscle growth and may affect blood-glucose responses through pancreatic activity [31]. The Leu/Ile ratios of Mafida pulp and kernel were 1.57 and 2.31, respectively, and those of Mobola plum pulp and kernel were 1.81 and 1.82, respectively. These values were comparable to the low ratios reported for carrot and cucumber (1.19 and 2.32, respectively) [2]. A balanced Leu/Ile ratio has been associated with hypoglycaemic properties [31].

Tables 9 and 10 summarize the amino acid groups. Mafida pulp and kernel had higher total amino acid (TAA) contents than the corresponding Mobola plum samples. All nine essential amino acids and nine non-essential amino acids were detected. Both kernels had higher TAA and total essential amino acid values than their corresponding pulps. Leucine was the most abundant essential amino acid in the Mafida and Mobola plum samples and was more concentrated in both kernels. The total acidic amino acid values were greater than the total basic amino acid values in Mafida pulp and kernel and in Mobola plum pulp, indicating acidic protein profiles. Mobola plum kernel had a slightly basic profile because its total basic amino acid value exceeded its total acidic amino acid value.

Tables 11 and 12 present the amino acid scores based on the FAO/WHO/UNU provisional scoring pattern [32]. Mafida kernel had a higher summed amino acid score than the pulp. Lysine, threonine, and valine were the first, second, and third limiting amino acids in the pulp, respectively. Valine, lysine, and total sulphur amino acids were the first, second, and third limiting amino acids in the kernel. Except for phenylalanine plus tyrosine in the pulp and leucine and tryptophan in the kernel, the essential amino acid levels in both Mafida samples were below the provisional pattern. Diets based substantially on Mafida pulp or kernel would therefore require complementary sources of the limiting amino acids. Mafida pulp could supplement phenylalanine plus tyrosine, whereas the kernel could supplement tryptophan and leucine.

Mobola plum kernel also had a higher summed amino acid score than the pulp. Valine, phenylalanine plus tyrosine, and isoleucine were the first, second, and third limiting amino acids in the pulp, respectively. Valine, lysine, and threonine were the first, second, and third limiting amino acids in the kernel. Except for total sulphur amino acids and tryptophan in both samples and phenylalanine plus tyrosine in the kernel, the essential amino acid compositions were below the provisional pattern. Diets based substantially on these samples would therefore require complementary sources of the limiting amino acids.

4. CONCLUSION

Mafida and Mobola plum kernels were nutritionally richer than their pulps in crude protein, total fat, and energy. The kernels may therefore be more suitable for protein- and fat-rich dietary supplementation, whereas the pulps may serve as supplementary sources of crude fibre and carbohydrate in high-energy, high-fibre food concentrates. The overall mineral contents of both Mafida and Mobola plum pulps and kernels were relatively low and may contribute minimally to the recommended dietary intake of essential minerals. Both fruits, particularly their kernels, contained all nine essential amino acids, and the kernels compared favourably with the pulps in total amino acid content. A 100 g portion of either kernel could contribute substantially to the daily protein intake of school-aged children. Processing and bioavailability studies remain necessary before the samples are recommended for food formulation.

DATA AVAILABILITY

The data supporting the findings of this study are derived from ongoing thesis research and are not publicly available at this stage. Access may be considered upon reasonable request and institutional approval.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

FUNDING

This research was financially supported through a Tertiary Education Trust Fund (TETFund) intervention administered by the College of Education Akwanga.

ACKNOWLEDGMENT

The authors acknowledge Dr Titus Ojobe of Priority Laboratory Services, Rukuba Road, Jos, and the Central Laboratory of Abubakar Tafawa Balewa University, Bauchi, for their contributions.

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