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Proximate composition, physical characteristics and mineral content of fruit, pulp and seeds of *Parinari curatellifolia* (Maula) from Central Malawi

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In this study, proximate composition, physical characteristics and mineral content of fruit, pulp and seeds of *Parinari curatellifolia* (Maula) fruits from Bunda forests in Central Malawi were determined. Proximate composition included crude protein, crude fat and crude fiber, while physical characteristics included mass, length, thickness of whole fruit and kernels and minerals included potassium, magnesium, manganese, copper, zinc, iron and phosphorus. Total carbohydrate contents were also determined. All the results have been presented on dry matter basis. Results on crude protein ranged from 3.9±0.03 to 15.61±0.05% with pulp registering the lowest values (P<0.05) while the highest values were registered in kernels. Results on crude fat revealed that kernels had the highest values (46.05±0.19%) compared to values obtained in pulp or a mixture of pulp and peels while for crude fiber, the highest values (21.39±0.28%) were obtained in whole fruit. Furthermore, results on ash content showed that the highest values (5.71±0.25 %) were obtained in fruit peels while the lowest values (1.58±0.15 %) were registered in whole fruit. Lastly, results on carbohydrate content revealed that the highest values (84.95±0.14%) were obtained in the pulp while the lowest values (34.34±0.21%) were registered in kernels. The findings from this study have shown that there are significant differences in nutrient and mineral composition in the whole fruit, seeds and pulp of *P. curatellifolia* from Central Malawi and therefore these findings can be useful in nutritional planning regarding consumption of the *P. curatellifolia* fruit.

Key words: Maula *(Parinari curatellifolia),* indigenous fruits, kernels, minerals, crude protein, nutrition, Bunda forest.

INTRODUCTION

Global human population is estimated to reach 9.6 billion by 2050 and 10.9 billion by 2100 respectively. On the other hand, it is expected that the population would rise to 8.2 billion by 2050 reaching 9.6 billion by the 21st

century in developing worlds with a 5 times increase in the least developed countries like Malawi (UNPD, 2012).

Sub-Saharan Africa (SSA) population growth, Malawi inclusive, is expected to increase by 1.2% annually by 2050 triggering urbanization and improved individual income (UNPFA, 2008; Thornton, 2010; Théwis and Galiş, 2012). It has previously been reported that SSA has the highest number of food insecure people where 214.1 million people have been reported to be chronically undernourished in 2012 to 2014 with a prevalence of 23.8% (FAO et al., 2014).

Furthermore, it is widely acknowledged that global climate is changing. Global surface temperature has been estimated to increase between 1.8 and 4.08°C by 21st century (IPCC, 2007a, b). In lower latitudes, like in SSA, temperature changes have been projected to be 1 to 2.8°C with crop productivity in tropics and subtropics dropping by 10 to 20% by 2050 (Jones and Thornton, 2003) creating food insecurity because of dependence on rain-fed agriculture (IPCC, 2007a).

Cereal production for a number of crops in SSA would decline by 3.2% spiking prices by more than 4% in 2050 (Gachene et al., 2015; Ringler et al., 2010; Ringler et al., 2011) culminating in declining of cereal demand by 3.6 MMT representing 1.5% decrease by 2050 (Ringler et al., 2010). In SSA, 23.2% of the population, live on calorie-deficient food (FAO et al., 2015) with about 600,000 children expected to suffer from malnutrition by 2050 as a result of climate change (Ringler et al., 2010). Many people in rural and peri-urban populations of southern Africa, face food shortage (FAO, 2000), resulting in food acute malnutrition (Akinnifesi et al., 2004).

In SSA, many authors have previously reported that 4 in 5 rural people are poverty stricken depending on wild fruit harvesting to secure food supply during times of hunger/famine (Loghrust, 1986; Lockett and Grivetti, 2000; Makonda and Gillah, 2007; Msuya et al., 2010). Indigenous fruit trees (IFTs) are food and nutrient sources for SSA people in the form of minerals and vitamins from fruit consumption (Chirwa and Akinnifesi, 2008) while the surplus fruits have been used for sale (Akinnifesi et al., 2004). With respect to Malawi, many people experience severe food shortage in both dry and rainy season (October to February) forcing them to depend on wild products like indigenous fruits (Akinnifesi et al., 2004; Mtupanyama et al., 2008).

These fruits are consumed in different forms and some are used as medicines by the rural marginalized communities (Benhura et al., 2012). Indigenous fruits, like *Parinari curatellifolia* fruit extracts are used as cardiac tonic and for the treatment of heart diseases like hypertension whereas the leaf extracts treat body inflammation and anemia (Peni et al., 2010). Despite being significant in people lives, wild edible fruits have been underutilized with little attention in investigating their various potentials (Salih and Yahia, 2015). In view of increasing food insecurity from the effects of growing human population and climate change, new and nonconventional sources of food from indigenous fruit trees (IFTs) should be explored. Therefore research intensification in exploration of the significance of underutilized crops like fruits from IFTs is of paramount importance.

P. curatellifolia, locally known as Maula, is an IFT that grows in Sub-Saharan Africa, Malawi inclusive. *P. curatellifolia* grows naturally in Bunda forest and belongs to the *Chrysobalanceae* family (Oladimeji and Bello, 2011). It bears greenish with grey spots (Benhura et al., 2013) ovoid in shape fruits of 3-5 cm long and 2.4-4 cm in diameter (FAO, 1982). The fruits contain woody seed stones containing kernels which have high oil content and the kernels are eaten raw in the form of nuts (Saka and Msonthi, 1994; Katende et al., 1995; Benhura et al., 2012). The kernels have been reported to contain high levels of nutrients like crude protein, 33.1±0.12%, carbohydrates, 52.38±0.01% (Oladimeji and Bello, 2011), and crude fat, 37.75 % (Orwa et al., 2009).

Efforts have been made to explore the uses, growth, domestication and commercialization of wild fruit trees (IFTs) in SSA countries, Malawi inclusive, including that of *P. curatellifolia* (Mtupanyama et al., 2008; Kwesiga et al., 2000; Akinnifesi et al., 2004, 2006, and 2007). However, limited information exists on the nutritional value of these indigenous fruits in Malawi (Saka and Msonthi, 1994). The significance of foods for human consumption is based on their nutrients, energy and mineral contents. Against this background of having limited information on nutritional value of indigenous fruits such as *P. curatellifolia,* this current study was carried out with the aim of characterizing the physical properties and nutritional value, in terms of proximate, mineral and chemical composition of Maula fruits, with respect to the fruit, pulp and seeds, from Bunda Forest in Central Malawi.

MATERIALS AND METHODS

Sample collection and preparation

Ripe Maula *(Parinari curatellifolia)* fruits were collected from Bunda Forest which is under Lilongwe University of Agriculture and Natural Resources, Bunda campus, in Lilongwe district in Central Malawi in the months of September and October. The fruits were washed using distilled water and the peels and mixture of pulp and peels and pulp were manually removed (Figure 1) from the woody seed stone and were partially sundried for 24 h. The fruits were sundried at 37°C on a stainless metal sheet which was placed on a concrete floor to prevent dust accumulation (Brennand, 1994; Ahmed, 2013). The fruits were finally dried in the forced air laboratory oven at 60°C to avoid cooking them for 2 days (Wijewardana et al., 2016) (Figure 1). The woody seed stones were sundried for 5 weeks for seed kernel collection. The seed kernels were removed from the woody seed stone by crushing the stones with a hard stone as shown in Figure 2. Some fruits were sundried for 14 days and crushed together with kernels before finally being dried in the oven for 48 h at 60°C (Ahmed, 2013) (Figure 2). The dried whole fruits, pulp,

Figure 1. A: *Parinari curatellifolia* fruits, B: Peels, C: peeled fruits, D: fruit stones.

Figure 2. A: Removing kernels from the stones, B: kernels in the container, C: Kernels.

mixture of pulp and peels and peels were ground through a 1 mm sieve using a Thomas-WILEY model 4 Laboratory Mill before analyzing the chemical properties. The ground samples were used in the analysis for proximate composition; dry matter (DM), ash, crude protein (CP), crude fat and crude fiber (CF) using Association of Official Analytical Chemists (AOAC, 1996) methods.

Physical characteristics determination

The fruits and kernels were evaluated for their physical characteristics as described by Benhura et al. (2013) where 20 fruits and kernels were randomly selected, thoroughly cleaned and weighed on JP-2000 electronic balance to the nearest 0.01 g. The 20 fruits and kernels were weighed each at a time with its stone and peels weighed too. The physical characteristics of the seeds and kernels in terms of length (long axis) and thickness (short axis) were evaluated by using Mitutoyo vernier caliper.

Proximate composition

The analysis of dry matter, mineral ash, crude protein, crude fat, crude fiber and calculation of carbohydrate content in the samples were carried out using methods described in Association of Official Methods of Chemical Analysts (AOAC 1990), AOAC, (1996) and AOAC, (2005) respectively.

Dry matter using oven method

Dry matter (DM) was determined by drying the samples in a laboratory drying oven at 105°C for 5 h. The crucibles were thoroughly washed, dried in the oven, cooled in a desiccator and weighed. 2.5 g of the sample was weighed into the crucible and dried to constant weight. The sample dry matter in percentage was calculated as the fraction of the dried weight to that of the original one multiplied by 100 (AOAC, 1996; AOAC, 1990).

Ash using muffle furnace

Ash content was determined by igniting 2.5 g of the samples weighed in a porcelain crucible in the muffle furnace at 550°C for 2 h. The amount of ash content in percentage was calculated as shown below:

$$\%Ash = [(W_a-W_t)/ (W_0-W_t)] \times 100 \text{ (AOAC, 1990)}.$$

Where:

W_0 is weight of crucible and sample before igniting the sample, W_a is weight of crucible and ash and W_t is weight of crucible only.

Crude fat

Crude fat was analyzed by extracting 2.5 g of the sample weighed in the porous extraction thimble by using petroleum ether in a soxhlet apparatus for 16 h. The soxhlet apparatus was equipped with a water cooled condenser fitted on to the weighed 250 ml flat bottomed quick fit flask containing petroleum ether as a fat solvent. The solvent was boiled at 40°C continuously to extract the fat from the sample. The mixture of fat and solvent was collected in the flask and the solvent was evaporated at 40°C in a vacuum rotary evaporator. Thereafter, the flask was dried and re-weighed and crude fat content was calculated as a percentage of the dry weight of the sample as shown below:

$$\% \text{ Crude fat} = [(A-B) / C] \times 100 \text{ (AOAC, 1996)}.$$

Where A = weight of flask + oil, B = weight of flask only, C = weight of dry sample.

Crude fiber

Crude fiber was determined by boiling 1.5 g of the samples in 200

ml of weak Sulphuric acid (1.25%) and Sodium Hydroxide (1.25%), with few drops of anti-foaming agents being added, for 30 min respectively. The residues were filtered and washed three times with hot water and then washed with 95% ethanol and dried at 105°C for 5 h to constant weight. The dried residues were ignited in a muffle furnace at 550°C for 2 h. The crude fiber, in grams, was calculated as the difference between the weight of the residues and ash and converted as a fraction of the sample weight in percentages as shown in the equation below:

$$\% \text{ Crude fiber} = [(\text{Loss of weight on ignition} / \text{sample weight})] \times 100 \text{ (AOAC, 1990)}$$

Crude protein using Kjeldahl method

Crude protein (CP) content of the samples was analyzed by using micro- Kjeldahl method, and the N content was converted to CP by multiplying by 6.25. The method involves digestion of the samples in concentrated (98 %) sulphuric acid with selenium tablet as a catalyst, distillation of the digests into weak acids (4 % boric acid) and titration of the distillates with 0.1 M Hydrochloric (HCl) acid (AOAC, 1990).

Carbohydrates

Carbohydrates content was calculated by difference using the following formula; 100 % - (CP % + CF % + crude fat % + Ash %) as described in AOAC (2005).

Determination of mineral composition

1.0 g of each sample was weighed in porcelain crucibles which were ignited in a muffle furnace at 550°C to constant weight. The ash was dissolved in 3 ml of 3 M Hydrochloric (HCl) acid, transferred to 100 ml volumetric flask and diluted to the 100 ml mark (AOAC, 2005). 0.75 ml of the diluted digested samples were placed in 20 to 25 ml glass vials and diluted with 9 ml of distilled water. Standards were prepared by adding 0.0 ml, 0.1 ml, 0.2 ml, 0.3 ml, 0.4 ml and 0.5 ml into 20 to 25 ml vials and diluted with 9 ml of distilled water. 2.0 ml of phosphovanadomolybdate /molybdate reagent (solution) was added in each vial and absorbance was measured after 1 h of color development (AOAC, 2005). Phosphorus was determined by a DR 5000 WAGTECH projects ultra-violet visible spectrophotometer at 860 nm wavelength. Potassium (K) was analyzed using Flame Photometer while magnesium, iron, manganese, copper and zinc were analyzed using PG990 atomic absorption spectrophotometer (AAS) (AOAC, 2005).

Statistical analysis

Data from the laboratory chemical analyses were done in triplicates and the mean value of each chemical parameter was calculated using Microsoft excel. The data was statistically analyzed by using analysis of variance (ANOVA) in Microsoft Excel ToolPak. T-test two-sample with unequal variances was used to compare mean values and significance was accepted at P≤ 0.05 level.

RESULTS AND DISCUSSION

Physical characteristics of *P.curatellifolia* seeds and kernels

Results on the physical characteristics of *P. curatellifolia* fruit are presented in Tables 1 and 2 respectively. The ripe fresh fruit weighed on average 22.69±0.69 g and this observation was in agreement with findings reported by Benhura et al. (2013) in Zimbabwe who found an average weight of 23.0±3.0 g for Waterfalls samples. The mean proportions of pulp and pulp and stone as a fraction of fruit were 46.75±0.9 and 90.09±0.50% respectively. However, the pulp proportion obtained in this study was lower than 51.1, 48.9 and 50.1% for *P. curatellifolia* fruit obtained from Amby, Waterfalls and Acadia in Zimbabwe respectively as reported by Benhura et al. (2013). *P. curatellifolia* kernel from this study weighed 352.8±11.4 mg and was 6.38±0.16 mm long with a thickness of 3.66±0.13 mm. The kernels from this study weighed less than 14000±3000, 21000±4000 and 23000±3000 mg for *P. curatellifolia* kernels when compared with kernels from Amby, Waterfalls and Acadia in Zimbabwe respectively (Benhura et al., 2013). Similarly, the kernels from this study were shorter than 22±3, 30±6 and 30±6 mm for *P. curatellifolia* kernels from Amby, Waterfalls and Acadia in Zimbabwe (Benhura et al., 2013). These differences could probably be attributed to the differences in ecological zones from where the fruit was grown (Tables 1 and 2).

Proximate composition

Results on proximate composition of *P. curatellifolia* fruits and its different parts in percentages are shown in Table 3.

Dry matter composition

Results on dry matter composition revealed that there were significant differences for the different fruit parts. Dry matter composition ranged from 88.66±0.15 to 99.31±0.04% for pulp and peels, and fruit respectively. Maula fruits registered higher dry matter values than (P>0.05) kernels, peels, pulp and (P<0.05) pulp and peels respectively.

Crude protein composition

Crude protein content ranged from 3.90±0.03 to 15.61±0.05% for pulp and kernel respectively. Crude protein content in pulp was the lowest (P<0.05) compared to the mixture of pulp and peels, kernels and (P>0.05) peels. The high crude protein value in the mixture of pulp and peels compared to that registered in the pulp could be attributed to the peels which are known to contribute

Table 1. Physical Characteristics of *Parinari curatellifolia* fruit**.**

Parameter	Value (Mean ± SE)
Mass of fruit (g)	22.69±0.69
Pulp + stone fraction (as % of fruit)	90.09 ±0.50
Pulp fraction (as % of fruit)	46.75±0.90
Pulp + peel fraction (as % of fruit)	56.67±0.77
Mean peel fraction (as % of fruit), n=20	9.91±0.50
Mean stone fraction (as % of fruit), n=20	43.33±0.77
Mean fruit length (mm), n=20	38.30±0.48
Mean fruit thickness (mm), n=20	30.84±0.56

Mean ± SE= mean ± standard error, n=20.

Table 2. Physical characteristics of *Parinari curatellifolia* kernel.

Parameter	Value (Mean ± SE)
Mass of kernel (mg)	352.8±11.4
Mean kernel fraction (as % of fruit), n=20	1.59±0.08
Mean kernel fraction (as % of stone), n=20	3.69±0.19
Mean kernel length (mm), n=20	16.78±0.40
Mean kernel width (mm) , n=20	6.38±0.16
Mean ernel thickness (mm), n=20	3.66±0.13

Mean ± SE= mean ± standard error, n=20.

the extra crude protein to the pulp (Benhura et al., 2012). The crude protein content in pulp was higher than 3.4 and 3.0 respectively as compared to the values reported by other researchers in Tanzania and Malawi (Ndabikunze et al., 2006; Saka and Msothi, 1994). The findings in this study have revealed that pulp, peels and mixture of pulp and peels are poor sources of proteins for humans. Crude protein content in the kernel was 15.61±0.05% which is lower than the value of 33.10±0.12% (Oladimeji and Bello, 2011) and 27.10 (Ndabikunze et al., 2006) for research conducted in Nigeria and Tanzania. Crude protein value of 15.61±0.05% for the kernels was lower than 24.70% for raw *Arachis hypogeae* seeds as reported by other researchers for studies conducted in Nigeria (Ayoola et al., 2012). These findings have shown that *P. curatellifolia* kernels are good sources of proteins for human nutrition.

Crude fat composition

Results on crude fat content showed that the range was from 2.02±0.47 to 46.05±0.19% for pulp and kernels respectively. Crude fat content in fruit was the lowest (P<0.05) and kernels had the highest (P<0.05) crude fat contents. Crude fat content in pulp was 3.99±0.08% which was higher (P<0.05) than 2.07±0.23 and 3.70±0.05% for the mixture of pulp and peels and peels only respectively. The values for crude fat were 0.9 and

1.5 higher than the values previously reported by other researchers (Ndabikunze et al., 2006; Saka and Msothi, 1994). Interestingly, crude fat values in kernels were high by different values as compared to values reported by other researchers: 1.77 (Ogungbenle and Atere, 2014) and 5.11±0.10% (Oladimeji and Bello, 2011) but lower than 47.00% (Ndabikunze et al., 2006) as reported for studies conducted in Nigeria and Tanzania. Crude fat value of 46.05±0.47 for *P. curatellifolia* kernel was higher than 39.10% (Kumar et al., 2013) but similar to 47.00±0.03 (Atasie et al., 2009) for groundnuts (*Arachis hypogaea*) as reported in other studies done in India and Nigeria respectively. The high crude fat and crude protein contents in kernels have shown that the kernels are potential sources of energy and essential amino acids and could therefore be used both as food for humans and feed for animals. The *P. curatellifolia* kernels flour could be used as an alternative of groundnut (*Arachis hypogaea*) flour in preparation of traditional vegetable soup by the less privileged rural communities.

Ash composition

Ash content was found to be the highest (P<0.05) in peels compared to that of kernels, fruit, pulp, mixture of pulp and peels respectively. However, ash content in pulp was equal (P>0.05) to that of kernels and mixture of pulp and peels. The ash content in the pulp was 2.46±0.09% which was low compared to the value of 3.9% reported

Table 3. Proximate composition of *Parinari curatellifolia.*

Sample	DM % (Mean±SE)	Ash % (Mean±SE)	CP % (Mean±SE)	Crude fat % (Mean±SE)	CF % (Mean±SE)	NFE % (Mean±SE)
P. Fruit	99.31±0.04[a]	1.58±0.15[a]	ND	2.02±0.47[a]	21.39±0.28[a]	ND
Pulp	90.6± 0.4[a]	2.46±0.09[b]	3.90±0.03[a]	3.99±0.08[b]	4.71±0.06[b]	84.95±0.14[a]
Pulp + Peels	88.66±0.15[b]	2.85±0.06[b]	5.14±0.10[b]	2.07±0.23[a]	6.25±0.11[c]	83.70±0.28[b]
Peels	95.59±0.03[a]	5.71±0. 25[c]	4.17±0.03[c]	3.70±0.05[b]	19.44±0.13[d]	66.97±0.35[c]
Kernels	99.27±0.04[a]	2.43±0.02[b]	15.61±0.05[d]	46.05±0.19[c]	1.58±0.04[e]	34.34±0.21[d]

Mean ± SE= mean ± standard error. For each parameter, means with same superscript were not significantly different (P>0.05). ND= not determined.

by Ndabikunze et al. (2006) in Tanzania but was higher than 1.8% (Saka and Msothi, 1994) as reported in Malawi. However, ash content in kernels was found to be 2.43±0.02% which was lower than the value of 2.65±0.21% reported in Nigeria by Oladimeji and Bello (2011). The ash content in kernels was lower than 4.55% (Kumar et al., 2013) but higher than 1.48% (Ayoola et al., 2012) for *A. hypogaea* as reported by other authors for studies previously conducted in India and Nigeria respectively.

Crude fiber

The crude fiber content ranged from 1.58±0.04 to 21.39±0.28% for kernels / nuts and whole fruit respectively. The kernel had the lowest (P<0.05) crude fiber content followed by pulp (4.71±0.06%), mixture of pulp and peels (6.25±0.11%) and peels (19.44±0.13%) respectively. The crude fiber content in the pulp was lower than 5.4 and 5.5% as reported in Tanzania and Malawi respectively (Ndabikunze et al., 2006; Saka and Msonthi, 1994). However, crude fiber content in kernels was lower than 5.45 and 1.6±0.1% as compared to the values reported in Nigeria by other researchers (Ogungbenle and Atere, 2014; Oladimeji and Bello, 2011). On the other hand, the crude fiber values for the kernels were lower than 3.7±0.3% (Atasie et al., 2009) and 2.91% (Kumar et al., 2013) for raw groundnuts seeds as reported in Nigeria and India respectively.

Carbohydrate composition

Results on carbohydrate content showed that the range was from 34.34±0.21 to 84.95±0.14% for kernels and pulp respectively. Pulp registered the highest (P<0.05) carbohydrate content compared to the mixture of pulp and peels, peels and kernels. Carbohydrate content in pulp was higher than 21.40±0.30, 27.50±0.50 and 28.90±0.40% respectively as compared to the values obtained for samples collected from Cranborne, Greendale and Prospect in a related study in Zimbabwe (Benhura et al., 2012). However, carbohydrate content for pulp from this study was comparable to the value of 88.20% reported in Malawi (Saka and Msonthi, 1994). The kernel carbohydrate content of 34.34±0.21% was lower than 52.38±0.01% (Oladimeji and Bello, 2011) but higher than 26.00% (Ndabikunze et al., 2006) in comparisons to values obtained in related studies in Nigeria and Tanzania respectively. Furthermore, the carbohydrates content for the kernels obtained in this study was higher than 17.41 (Ayoola et al., 2012) and 25.30% (Kumar et al., 2013) for *A. hypogaea* observed in other studies in Nigeria and India respectively. The high carbohydrate contents in pulp have demonstrated that the pulp could be a potential source of energy for consumers in Malawi.

Mineral composition

Results on different minerals obtained in *P. curatellifolia* fruit, pulp, mixture of pulp and peels, peels and kernels, in mg 100 g^{-1}, are presented in Table 4. Potassium content ranged from 680.20±4.88 to 736.24±6.29 for kernels and peels respectively. Potassium content in pulp was 712.65±12.02 which was higher (P<0.05) than 710.86±10.51 but lower (P>0.05) than 736.24±6.29 for mixture of pulp and peels and peels respectively. However, potassium content in pulp, mixture of pulp and peels and peels were higher (P<0.05) than that of kernels. The potassium content in pulp was higher than 22.3 (Ndabikunze et al., 2006), 103.68 (Saka and Msonthi, 1994) and 15±1.0% (Benhura et al., 2013) as reported in Tanzania and Zimbabwe. Potassium content in kernels was higher than 459 from a related study in Nigeria (Ogungbenle and Atere, 2014).

Iron content ranged from 295.49±0.68 to 403.81±4.34 for pulp and peels respectively. Peels had the highest (P>0.05) iron content compared to the mixture of pulp and peels which was high (P<0.05) compared to that of pulp and kernels respectively. Pulp iron content was higher than 103.0 (Saka and Msonthi, 1994) but lower than 700±200, 500±100, 800±200 (Benhura et al., 2013) reported in studies conducted in Malawi and Zimbabwe respectively. Iron content in the kernels was high compared to 13.2 obtained in a related study conducted

Table 4. Mineral composition of *P. curatellifolia* (mg100 g^{-1} DM).

Sample	K (Mean±SE)	Mg (Mean±SE)	Mn (Mean±SE)	Cu (Mean±SE)	Zn (Mean±SE)	Fe (Mean±SE)	P (Mean±SE)
P. Fruit	ND	ND	ND	ND	ND	ND	ND
Pulp	712.65±12.02[a]	213.06±8.25[a]	24.27±0.58[a]	6.26±0.00[a]	17.57±0.67[a]	295.49±0.68[a]	405.23 ± 2.17[a]
Pulp + Peels	710.86±10.51[a]	216.08±13.61[a]	31.53±0.00[a]	112.74±0.54[b]	17.85±0.58[a]	398.78±0.56[b]	370.57±10.47[b]
Peels	736.24±6.29[b]	200.01±7.64[b]	29.33±0.27[b]	70.23±0.61[c]	37.57±1.07[b]	403.81±4.34[b]	382.56±4.54[b]
Kernel	680.20±4.88[c]	222.45±2.72[c]	45.79±1.77[c]	12.59±0.76[d]	42.1±0.58[c]	357.02±3.65[c]	540.67±4.87[c]

Mean ± SE= mean ± standard error. For each parameter, means with same superscript were not significantly different (P>0.05). ND= not determined.

in Nigeria (Ogungbenle and Atere, 2014).

Phosphorus content ranged from 370.57±10.47 to 405.23±2.17 for mixture of pulp and peels and kernels respectively. Phosphorus in kernels was the highest (P<0.05) compared to pulp, mixture of pulp and peels and peels respectively. Phosphorus content in pulp was higher than 200±0.0 (Benhura et al., 2013) and 339 (Saka and Msonthi, 1994) from other studies conducted in Zimbabwe and Malawi respectively. *P. curatellifolia* kernels had high phosphorus content compared to 180 (Ndabikunze et al., 2006) and 196 (Ogungbenle and Atere, 2014) obtained from related studies conducted in Tanzania and Nigeria. Furthermore, phosphorus content for the kernels was higher than 340.2 for *A. hypogaea* as observed in India (Kumar et al., 2013) (Tables 3 and 4).

Conclusion

Results from the study have shown that *P. curatellifolia* fruits from Malawi contain essential nutrients and minerals which are essential for the nutritional well-being of less privileged communities in Malawi. The results have also revealed that there are differences in nutrient and mineral composition in different parts of the *P. curatellifolia* fruit. The high carbohydrate content in the pulp present in *P. curatellifolia* have demonstrated that *P. curatellifolia* fruit is a potential source of energy which can benefit consumers from low resource communities in Malawi. It is therefore highly recommended that people should be encouraged to consume *P. curatellifolia* fruits to get good nutrition. It is further recommended that future studies should use *P. curatellifolia* from different regions in Malawi to find out to what extent the nutrient and mineral composition can be influenced by the differences in ecological zones.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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