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Original Research Article

Effect of Provenance on Some Vitamins and Minerals Content of Baobab (*Adansonia digitata*) Fruit Pulp

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Abstract

The effect of provenance on nutritional attributes of the edible pulp of baobab *(Adansonia digitata)* from different districts of Malawi was investigated. Vitamin C was analyzed by the 2, 6-dichlorophenolindophenol titrimetry while vitamin A and minerals were measured by spectrophotometry and Atomic Absorption Spectroscopy, respectively. In general, the pulp contained high levels of vitamin C and minerals, which were significantly influenced ($p \leq 0.05$) by provenance. Baobab fruit pulp from Chikwawa district showed significantly highest ($p \leq 0.05$) vitamin C content (347.67 ± 3.52 mg/100 g) as compared to the rest of the samples. Fruits from Mangochi district showed highest vitamin A content (60.92 ± 1.20 mg/kg). Those from Dedza district had highest contents of calcium (2788 ± 129. 43 mg/kg) and copper (5.02 ± 1.01 mg/kg) while those from Mangochi showed highest contents of potassium (1172 ± 186.22 mg/kg) and zinc (5.18 ± 2.10 mg/kg). Highest sodium content (282.30 ± 13.00 mg/kg) was observed in fruit pulp from Mwanza district. Therefore, the results from this work clearly indicate that provenance influences the level of most nutritional attributes of *A. digitata* fruit pulp. This knowledge is necessary for identification of sites containing nutritious fresh baobab fruits for consumption or quality product development.

Keywords: *Adansonia digitate;* Provenance; District; Fruit pulp; Vitamin A; Vitamin C; Minerals; Malawi.

Introduction

More than 800 million people remain chronically undernourished globally, and the HIV epidemic largely overlaps with populations already experiencing low diet quality and quantity (Ivers *et al.*, 2009). Micronutrient malnutrition affects more than half of the world's population, especially women and pre-school children (Hall *et al.*, 2008). Millions of women and children in south and southeast Asia and sub-Saharan Africa (SSA) are at a greater risk of iron, zinc, and vitamin A deficiencies (FAO and WHO, 2004; Hanson *et al.*, 2011). Food-based approach especially high intake of high quality local and wild fresh fruits, vegetables and derived products may help to improve the situation in these regions.

Forests and homestead farms are important sources of non-timber products including indigenous fruits, which are consumed by communities and also sold to generate income (Saka *et al*., 2007). In SSA, indigenous fruit-bearing trees (IFBTs) are treasured sources of macro- and micro-nutrients, and health-promoting phytochemicals that mitigate some of the physiological effects of malnutrition (Chivandi *et al*., 2015). Indigenous fruits in SSA are heavily underutilized due to the lack of scientific knowledge of their composition and processing. The underutilized fruits have the potential to reduce problems in rural development, hunger, malnutrition, and gender inequality. Thus full exploitation of fresh indigenous fruits including production of wide-range high quality products is essential for food security, health and socio-economic welfare of rural communities (Saka and Msonthi, 1994; Akinnifesi *et al*., 2004; Akinnifesi and Kwesiga, 2006; Ndabikunze *et al*., 2010). Fruit and products from indigenous trees are particularly important during the hunger periods of the year, and also increase rural household income through sales of fresh fruits and processed products (Akinnifesi and Kwesiga, 2006; Ndabikunze *et al*., 2010). Fruits are receiving increasing interest from researchers working on wild edible plant species because of their nutritional value as well as medicinal properties (Lamien-Meda *et al*., 2008).

In sub-Saharan Africa, a large number of children are at risk of vitamin A deficiency, the third greatest public health problem after HIV/AIDS and malaria on the entire African continent (Kwesiga *et al*., 2003; Black *et al*., 2008). Therefore, solving malnutrition in developing nations is a necessity, and requires a range of interconnected approaches, including exploring natural nutritional value of locally available fruits.

In Malawi, smallholder farmers are aware and appreciate the importance of fruit trees, and it is not surprising to find trees growing on croplands, around the homesteads and in swampy areas (Akinnifesi and Kwesiga, 2006). Indigenous fruits can contribute greatly to the well-being of the rural people since most are rich in sugars, essential vitamins, minerals, vegetable oils, proteins, crude fibre and total carbohydrates necessary for human nutrition (Mojeremane and Tshwenyane, 2004; Saka *et al*., 2007; Ndabikunze *et al*., 2010; Tembo *et al*., 2017). Improved nutrition increases immunity, reduces the effect of HIV and arrests the rapid progression of HIV/AIDS, which affect food production and economic activities of people (Ivers *et al*., 2009). Indigenous fruits, therefore, constitute an important food sources for combating malnutrition due to major deficiencies of vitamins A and C, essential amino acids and minerals such as calcium, iron and zinc in local diets (Thiong'o *et al*., 2000; FAO and WHO, 2004; Chivandi *et al*., 2013; Chivandi *et al*., 2015).

Malawi has a wide range of indigenous fruits including baobab (*Adansonia digitata),* mobola plum *(Parinari curatellifolia),* monkey oranges *(Strychnos cocculoides)* and ber *(Ziziphus mauritiana)* growing in the forests and homestead farms. Baobab fruit is preferred amongst most indigenous fruits because of its multipurpose use, and ease of storage (Chadare *et al*., 2009; Caluwé *et al.*, 2010; Lisao *et al*., 2017; Tembo *et al*., 2017). Throughout Sub-Saharan Africa regions, baobab is becoming increasingly recognised for its high nutrient and polyphenol contents (Coe *et al*., 2013; Parkouda *et al*., 2015; Venter and Witkowski, 2011). Every part of baobab is used where trees are found. The fruit is the most used part of the baobab (Lisao *et al*., 2017). Baobab is used as a source of food and traditional medicine, and is sold (as fresh fruits or processed) for household income. Seeds, leaves and bark are used for the treatment of malaria, tuberculosis, fever, diarrhoea, anaemia, dysentery and toothache while fruits are used for treatment of microbial infections (Caluwé *et al*., 2010; Kaboré *et al*., 2011; Kamatou *et al*., 2011; Shackleton *et al*., 2015). Baobab fruit trees are tolerant to high temperatures and long spans of drought (Osman, 2004). Baobab fruits are large, egg shaped, 15 to 20 cm long with a hard woody outer shell covered with yellowish brown hairs. The fruits are filled with dry white powdery pulp that covers brown seeds. Most of the pulp falls off upon cracking the shell, some get stuck to the seeds and is eaten fresh like sweets (Tembo *et al*., 2017). Baobab is becoming recognised for its high nutritional and medicinal values. The various ethnomedicinal and food uses of *A. digitata* have attracted the interest of several pharmaceutical companies and researchers (Irondi *et al*., 2016). International statutory bodies including the European Commission and United States of America (USA) Food and Drug Administration (FDA) have approved the use of baobab pulp as a novel food and ingredient in certain nutritional products (Chadare *et al*., 2009; Li *et al*., 2017). The pulp is rich in organic acids, pectins, minerals, vitamin B, hydroxycinnamic acid glycosides, iridoid glycosides, phenylethanoid glycosides and procyanidins and it contains seven to ten times higher content of vitamin C than oranges (Kamatou *et al*., 2011; Khakimov *et al.*, 2016; Li *et al*., 2017; Shahat, 2006). Tembo *et al*. (2017) reported that Malawi baobab pulp contains high levels of ascorbic acid, vitamin C, citric acid, malic acid, procyanidin B_2, gallic acid and (-)-epicatechin and show higher total phenol content and antioxidant activity. Higher antioxidant activity is likely due to high total phenol and ascorbic acid content (Besco *et al*., 2007). Thus baobab fruit offers an opportunity for the development of quality novel functional foods which can help to improve nutrition and health status populations as well as promote commercialisation and international trade. Baobab fruit pulp is processed into different products including porridge, juice, alcoholic beverages and dried as food reserves by most rural communities (Tembo, 2008; Caluwé *et al.,* 2010).

The composition of plant edible parts is affected by several factors such as tree age, soil type, genotype, phenotype, agronomic practices, provenance and post-harvest handling (Assogbadjo and Chadare, 2012; Assogbadjo *et al*., 2012; Caluwé *et al*., 2010; Chadare *et al*., 2009; Lee and Kader, 2000; Mahmood *et al*., 2012; Ngobese *et al*., 2017; Nitcheu Ngemakwe *et al*., 2017; Shoko *et al*., 2014; Simons and Leakey, 2004; Tembo, 2008; Thiong'o *et al*., 2000; Zhao *et al*., 2017).

Although indigenous fruit trees are widely used by humans in southern Africa, little information is available on regional genetic variation in these species, knowledge essential for their proper use and conservation (Kadu *et al*., 2006; Smedt *et al*., 2011). Information on the influence of provenance on physicochemical characteristics of baobab fruits of Malawi can hardly be found. This study was, therefore, undertaken to investigate the effect of provenance on levels of vitamin A, vitamin C and selected minerals of *Adansonia digitata* fruit pulp from different geographical locations of the country.

Materials and Methods

Chemicals and reagents

Analar and chemically pure grades of reagents were used. Acetic acid, ascorbic acid, nitric acid, sodium hydroxide, methylene blue and absolute ethanol were purchased from Saarchem (South Africa); methanol, dichloromethane and sodium potassium tartrate tetrahydrate were from Merch (UK). Metaphosphoric acid, copper sulphate pentahydrate and 2, 6-dichlorophenolindophenol dye were from Associated Chemical Enterprise (South Africa); zinc acetate, pH 4 and 7 buffer tablets, and potassium hydrogen phthalate were from BDH chemicals (UK); retinoic acid and magnesium carbonate were from Sigma (St. Louse, USA). Aqueous solutions were prepared using de-ionised and distilled water prepared using a Permutit portable MK 8A de-ioniser and MILLIPORE water distiller, respectively.

Study areas, and baobab fruit sampling

Fresh fruits of baobab were collected from baobab trees at their harvesting stage (fully ripe and sun dried) from five districts of Malawi namely; Chikwawa, Dedza, Mangochi, Mwanza and Salima. Chikwawa is in the southern region of Malawi with mostly clay soils and is located on 16.03°S and 34.78° E., The district receives very erratic rains which range between 1.81 and 126mm per month, highest levels being in January. Chikwawa is usually hot with monthly average temperatures ranging from 21.5°C to 29°C. However some days may be as hot as 39°C especially in October and November. Dedza is in central region of Malawi located on 14.32°S and 34.27°E, and has mostly clay to loamy soils. The district receives monthly rainfalls ranging from 0.82 and 82.35mm; wettest months are between January and April. Dedza is fairly cool, with monthly temperatures ranging from 13.6°C to 20.6°C; November is the hottest month. Mangochi is in southern region of Malawi, located on 14.43°S and 35.25°E. The district has sandy soils along Lake Malawi shore, and clay loam soils inland. Mangochi receives most rains between January (45.5mm) and April (86.75mm). Monthly temperatures vary from 19.3°C to 26.3°C; hottest months are between October and December. Mwanza is in southern region of Malawi, located on 15.62°S and 34.52°E. The district has mostly clay soils and receives monthly rainfall ranging from 4.63mm to 161.38mm. Monthly temperatures range from 19.1°C to 26.4°C, with October has being hottest month of the year. Salima is in southern region of Malawi located between 13.73° S and 34.6° E. The district has sandy soils along Lake Malawi shore, and clay soils inland (where samples were collected). Salima receives most monthly rains (21.30mm to 98.43 mm) between December and April. Monthly temperatures range from 21.2°C to 28.0°C with November as the hottest.

Fruit samples were handled and pre-processed as described by Tembo *et al*. (2017) with minor modifications. Briefly, twenty (20) fruit trees containing sufficient fresh fruits were identified from each site and ten (10) fruits per tree were collected for the study. A total of two hundred (200) fresh fruits from each provenance were kept separately in sack cloth and transported at ambient conditions to the University of Malawi, Chancellor College chemistry laboratory for pre-treatment, processing and subsequent analysis. Only undamaged fruits with no signs of infection such as discolouration or rotting were selected for the study. The fruits were cracked, and the pulp (which is in the form of a powder) was separated from the hard shell and seeds using a mortar and pestle with light pounding not to crush the seeds. Pulp powder was sieved to one size (1mm) using Endecotts sieve shaker and kept in air tight plastic containers at dry ambient conditions (23-27°C) until extraction and parameter determination.

Determination of moisture content

The moisture content was determined using the hot oven method in order to express results on dry matter (DM) basis. Accurately weighed pulp samples (5g) were enclosed in an oven (Model: B5S 88H 113, ELE International Limited, Hertfordshire, England) set at 110ºC until constant weight was obtained. The dried samples were cooled in a desiccator for 90 min, and reweighed.

Determination of total soluble solids

The total soluble solids (TSS) in fruit pulp were determined, in triplicate, using a hand-held PR-32 Refractometer (ATAGO, Tokyo, Japan). Fresh pulp was placed on the refractometer sensitive port and TSS estimated as % Brix.

Determination of acidity and pH

Total acidity and pH were determined as described in AOAC (AOAC, 2005). For acidity, fruit pulp (4g) was homogenised in hot de-ionised water (75°C) for 2 min using the Phillips blender. The homogenate was left to cool and kept in the refrigerator until determination. Potassium hydrogen phthalate solution (0.10M, 10mL) was titrated against sodium hydroxide (0.10M) using phenolphthalein indicator (5 drops) and the actual concentration of sodium hydroxide calculated. Refrigerated samples were equilibrated at room temperature and an aliquot (10mL) was titrated in triplicate against standardised sodium hydroxide solution using phenolphthalein indicator (5 drops). Fruit pulp acidity was expressed as a percentage.

The pH of fruit pulp was determined in triplicate as follows: to fruit pulp (4g), de-ionised water (150 mL), which was previously boiled and cooled to room temperature was added. The contents were homogenised for 1 min and the resultant mixture was transferred into a beaker (200mL). The pH was measured using a 744 Metrohm pH meter (Metrohm, Switzerland).

Extraction and analysis of ascorbic acid (Vitamin C)

Extraction of ascorbic acid, also known as vitamin C, was undertaken as described in AOAC (2005). Baobab fruit pulp (2g) was homogenised in metaphosphoric acid + acetic acid solvent system (0.38M HPO_3 +1.38M HOAc, 100mL) for 120 seconds at medium speed, and allowed to stand in a refrigerator at 5°C for 30 minutes for the supernatant to settle before filtration and determination (Tembo, 2008). Ascorbic acid was determined by the visual titrimetric method using the 2, 6-dichlorophenolindophenol (DCIP) dye. The dye was initially standardised by titrating it against ascorbic acid standard (1mg/mL; 2mL) in a solvent system (5mL) before use. The supernatant was filtered using Whatman No.1 paper to ensure clear filtrate. The filtrate (10mL) was transferred into a well-rinsed and dried conical flask, and titrated against standardised DCIP until the end point (pink colouration). A blank determination was done for each set of samples. The results were expressed as mg/100g dry weight.

Extraction and analysis of provitamin A

Provitamin A carotenoid (β-carotene) in the baobab fruit pulp was determined according to a method described in AOAC (2005) with some modification. Fruit pulp (2g) was transferred into dried centrifuge tubes (50mL) and magnesium carbonate (1g) was added. Dichloromethane (8mL), methanol (2mL), and distilled water (12mL) were added in turn with a 30 s vortexing separation after each addition. The resultant mixture was centrifuged using a CENTRA CL2 Centrifuge (Thermo Electron Corporation, Milford, USA) for 4 min at 1000 rpm. Three layers were formed: organic (bottom), insoluble fibre (middle) and aqueous on top. The two top layers were decanted carefully, and the organic layer (5mL) containing carotenoids diluted to 50mL mark in a brown volumetric flask with dichloromethane. The solutions were kept in the dark at ambient temperature of around 25°C for 15 min to equilibrate before analysis. The absorbance of samples and blank were measured at 325nm using a UV/Vis Spectrophotometer (JENWAY 6405, Essex, London, UK). A calibration curve with retinoic acid (RA) concentration ranging from 0 to 150mg/ L and high linearity ($R^2 \geq 0.999$) was used for quantification. Vitamin A was expressed as milligram retinoic acid equivalent per kilogram (mg RAE/kg) dry weight.

Extraction and determination of reducing sugars

Reducing sugars were extracted and analysed according to the method described in Pearson (1981). Fresh baobab pulp (4g) was homogenised in hot de-ionised water (75°C, 150mL) using a Phillips blender for 40 s at low speed followed by 60 s homogenisation at high speed separated by 20 s rest. The supernatant (150mL) was transferred into a volumetric flask (250mL) to which Fehling's solution (5mL) was added. The mixture was shaken and left to cool. The solution was diluted to the mark and allowed to settle for 30 min. The supernatant was filtered using a Buchner flask and kept in a refrigerator until analysis. An aliquot of Fehling's solution (5mL) was transferred into a conical flask (250mL) to which de-ionised water (15mL) and standard invert sugar (14mL) was added. The mixture was placed on a hot plate and at the onset of boiling, methylene blue (5 drops) was added and invert sugar titration started until blue colour disappeared leaving a red colouration. The sample (20mL), initially equilibrated to room temperature was mixed with standardised Fehling's solution (25mL) in a volumetric flask, and the resultant solution treated as for the standard. The concentration of reducing sugars was expressed as a percentage.

Extraction and determination of minerals (Ca, Cu, Fe, K, Mg, Na and Zn)

Extraction and determination of minerals were undertaken as described in AOAC (AOAC, 2005). An accurately weighed fruit pulp (1g), in a dish was transferred in an oven (B5S 88H 113, 110ºC) for 12 hours, and the dried material ashed in a Muffle furnace (Gallenkamp, Loughbrough, UK) for 2 hours at 500ºC. The white ash was cooled and de-ionised water (10 drops) and nitric acid (5.85M, 4 drops) added. Excess acid was evaporated in the oven (110ºC) for 30 min and returned in a furnace for additional 1 hour. The samples were cooled, dissolved in hydrochloric acid (5.09M, 10mL) and diluted to 50mL with de-ionised water in a volumetric flask. The absorbance of standard solutions and blank for each mineral were determined using atomic absorption spectrophotometer (AAS) (200A, BUCK Scientific, Norwalk, USA). The absorbance of sample solutions was read immediately after each standard measurement. The concentration of minerals was calculated from the standard calibration plot and results expressed as mg/kg dry weight.

Statistical analysis

Analysis of variance (ANOVA) using Tukey's test ($p \leq 0.05$) was performed to evaluate the significance of differences amongst means of triplicate determinations using IBM SPSS statistical software version 22.

Results and Dscussion

Physicochemical characteristics of baobab pulp

Physicochemical parameters including pH, acidity, dry matter content, reducing sugars and total soluble solids influence stability of micronutrients such as vitamins, sensory as well as microbiological quality of fruits and derived products (Fennema, 1996; Tembo *et al*., 2017). Results for vitamins and selected physicochemical characteristics of baobab pulp are shown in Table 1. The data show the influence of provenance on observed parameters. Significant differences ($p \leq 0.05$) in reducing sugars and titratable acidity were observed among baobab fruit pulp from different provenances. Variations in these parameters may be due to differences in soil properties (Assogbadjo *et al*., 2012; Chadare *et al*., 2009; Ibrahima *et al*., 2013). On the other hand, the pH and total soluble solids were not significantly ($p > 0.05$) different with provenance. The pH results in this study were in the range reported by Saka *et al*. (2007) in composite baobab. The acidic nature and a lower pH of baobab pulp are likely attributed to higher levels of organic acids including ascorbic, dehydroascorbic, citric, malic, tartaric acid and amino acids (Caluwé *et al*., 2010; Tembo *et al*., 2017). Caluwé *et al.* (2010) also reported that baobab pulp is particularly rich in valine, tryptophan and phenylalanine and tyrosine. High levels of organic acids may help to preserve quality attributes of baobab pulp and derived products.

Table 1. Some physicochemical properties of baobab pulp from five difference provenances.

Sample Provenance	Vitamin A (mg/kg)	Vitamin C (mg/100g)	Reducing Sugar (%)	Acidity (%)	pH	TSS (%)
Chikwawa	35.83 ± 6.59^{c}	347.70 ± 3.52^{a}	11.27 ± 0.02^{a}	2.58 ± 0.16^{b}	3.19 ± 0.01^{b}	21.80 ± 2.36^{b}
Dedza	31.08 ± 1.72^{d}	259.70 ± 0.00^{c}	8.75 ± 0.11^{d}	2.20 ± 0.03^{d}	3.25 ± 0.01^{b}	32.50 ± 0.00^{a}
Mangochi	60.92 ± 0.25^{a}	239.30 ± 0.00^{d}	10.18 ± 0.03^{b}	2.86 ± 0.00^{a}	3.14 ± 0.01^{b}	32.03 ± 0.64^{a}
Mwanza	54.71 ± 2.72^{b}	317.00 ± 3.52^{b}	10.22 ± 0.20^{b}	2.40 ± 0.00^{c}	3.16 ± 0.01^{b}	30.63 ± 2.03^{a}
Salima	29.86 ± 0.42^{d}	233.10 ± 16.25^{d}	9.01 ± 0.09^{c}	2.68 ± 0.08^{b}	3.43 ± 0.01^{a}	31.87 ± 0.51^{a}

Abbreviations: DM = dry matter; TSS = total soluble solids. Values are means of three independent samples ± SD.
Mean values within a column with different superscript letters indicate significant differences (Tukey's test $p \leq 0.05$).

Vitamin A content

Vitamin A deficiency (VAD) is one of the most common and devastating micro-nutrient deficiencies in the world, and is especially common in tropical developing nations (Jones *et al*., 2013). Dietary sources of vitamin A include meat, dairy products, fruits and vegetables. For this reason, baobab fruit pulp was screened for the presence of vitamin A and influence of provenance on levels was also evaluated.

Results for vitamin A content in baobab fruit pulp from the five provenances are presented in Table 1. All samples showed reasonable amounts. The level of vitamin A in all samples was much higher when compared to the recommended daily allowance for humans of all age groups (FAO *et al*., 2004). However, significant ($p \leq 0.05$) variation in vitamin A concentration was observed amongst most provenances. Fruits from Mangochi district showed highest vitamin A of all, while Salima showed the least. Although baobab fruit samples from Dedza showed higher levels of vitamin A than Salima, levels were not significantly different ($p > 0.05$). A possible suggestion could be similarity in soil characteristics and rainfall pattern between these provenances.

Thus fruit samples from Mangochi could be used to process vitamin A rich products or as additive and enrich this micronutrient in derived foods. Such products would likely reduce vitamin A deficiency in vulnerable groups including under-five children and pregnant women especially in rural low-income communities. This could be a cheaper approach of meeting the recommended daily allowance of vitamin A for the resource-poor. It is worthy reminding that at least 250 million pre-school children worldwide are vitamin A deficient, with the majority of this figure coming from developing countries (FAO *et al*., 2004; Hanson *et al*., 2011; Jones *et al*., 2013).

Limited studies have investigated vitamin A in baobab pulp for comparison with present findings. Our findings are in contrast with those reported by Assogbadjo *et al*. (2012) in Benin. No significant differences were reported in vitamin A concentration of baobab pulp from three different provenances (Assogbadjo *et al*., 2012). In a separate study from the same country (Benin), although a significant amount of vitamin A was reported in baobab leaves, fruit pulp did not show presence of vitamin A (Chadare *et al*., 2009). It is possible that vitamin A in the pulp was below detection limit of the method employed or samples tested had overstayed leading to its loss or degradation.

Vitamin C content

Results for vitamin C content in the baobab pulp from the five different climatic zones/provenances are presented in Table 1. The results showed very high levels of vitamin C in baobab pulp compared to commonly consumed fruits including oranges, mangoes and apples. Vitamin C is a well-known antioxidant (Iqbal *et al*., 2004; Del Pino-Garcia *et al*., 2012; Ngobese *et al*., 2017), thus baobab fruits can be blended with commonly consumed fruit products to improve quality in terms of antioxidant capacity and associated benefits to consumers (nutritional and health) (Walingo, 2005; Gabriel et al., 2015). From the results of analysis of variance it was noted that there were significant ($p \leq 0.05$) differences in vitamin C concentrations among provenances. Baobab fruit pulp from Chikwawa provenance showed highest vitamin C concentration of all. The lowest level of vitamin C was obtained in baobab fruit pulp from Salima provenance. Chikwawa experiences higher temperatures and light intensity than other provenances, conditions which may influence sugar synthesis, glucose being the precursor of vitamin C. This is consistent with the high and significant ($p < 0.05$) levels of reducing sugars observed in baobab pulp from Chikwawa. The presence of high levels of vitamin C in samples from Chikwawa means that encouraging consumption of fresh baobab fruits or derived products from this provenance can easily enhance reduction of vitamin C deficiency symptoms such as scurvy which is more prevalent in the rural most communities. Further, the local fruit processors may blend baobab fruit pulp from Chikwawa with other priority indigenous fruits of Malawi such as mobala plums (*Parinari curatellifolia*), monkey oranges (*Strychnos cocculoides*) or mangoes (*Mangifera indica*) in order to improve vitamin C content. This may likely improve nutritional quality and extend shelf life of resultant juice by preventing quality loss caused by auto-oxidation such as browning common in fruit juices with lower levels of ascorbic acid and other organic acids. The pharmaceutical industry may extract and manufacture vitamin C tablets from such rich but cheaper natural resource. Thus vitamin C tablets can be available at relatively affordable price especially to those in need of vitamin C supplements.

Other studies also reported significant variation in average vitamin C concentration between and within wild fruit provenances (Chadare et al., 2009; Assogbadjo and Chadare, 2012; Fang et al., 2017). Assogbadjo and Chadare (2012) reported a very wide variation in vitamin C content for the three baobab provenances studied in Benin. Thus vitamin C content for Dedza provenance (259.70mg/100g) was similar to a lower vitamin C value obtained by Assogbadjo and Chadare (2012). Similarly, Ibrahima *et al*. (2013) reported a wide variability in vitamin C content in six baobab species from Madagascar and Côte d'Ivoire. Therefore, results obtained from this study were consistent with findings reported by others.

Mineral contents

Baobab pulp is rich in essential minerals including calcium (Ca), copper (Cu), iron (Fe), potassium (Fe), magnesium (Mg), sodium (Na) and zinc (Zn) (Table 2). From the results of analysis of variance, it was noted that there were significant ($p \leq 0.05$) differences among provenances for mineral content (Table 2). For instance, the levels of Ca, Cu, K, Na and Zn were significantly (p

≤ 0.05) different amongst all provenances. Dedza and Chikwawa showed highest and lowest levels of Ca respectively. For copper, Mangochi provenance had the highest level while Dedza provenance had the least. The levels of iron and magnesium were not significantly different ($p > 0.05$) amongst all provenances. For potassium, Mangochi and Mwanza provenances showed highest and lowest levels respectively of all. Highest level of sodium was obtained in baobab pulp from Mwanza while that of zinc was observed in samples from Mangochi.

Table 2. Some mineral composition of baobab pulp from five provenances

Sample Provenance	Ca	Cu	Fe	K	Mg	Na	Zn
Chikwawa	1956.00 ± 517.74^{d}	2.48 ± 0.96^{d}	19.60 ± 5.38^{a}	979 ± 217^{c}	20.30 ± 4.55^{a}	166.90 ± 32.33^{e}	3.36 ± 0.15^{c}
Dedza	2786.07 ± 129.43^{a}	5.02 ± 1.01^{a}	15.30 ± 1.77^{a}	766 ± 84^{d}	10.40 ± 1.26^{a}	172.30 ± 6.16^{d}	2.37 ± 0.03^{d}
Mangochi	1964.50 ± 246.37^{e}	1.68 ± 0.20^{e}	22.90 ± 0.03^{a}	1172 ± 186^{a}	26.20 ± 3.48^{a}	252.90 ± 45.98^{b}	5.18 ± 2.10^{a}
Mwanza	2269.84 ± 58.97^{b}	4.14 ± 0.64^{b}	17.60 ± 2.86^{a}	530 ± 52^{e}	21.20 ± 1.39^{a}	282.30 ± 13.00^{a}	2.02 ± 0.26^{e}
Salima	1978.49 ± 253.37^{c}	3.58 ± 0.34^{c}	16.40 ± 5.67^{a}	1142 ± 93^{b}	33.60 ± 4.68^{a}	248.20 ± 13.00^{c}	3.40 ± 0.23^{b}

Values are means of three independent samples ± SD. Mean values within a column with different superscript letters indicate significant differences (Tukey's test, $p \leq 0.05$).

The level of minerals in baobab parts including pulp varies widely in literature. For instance, Assogbadjo *et al.* (2012) reported higher values for iron, magnesium and zinc in baobab pulp from Benin than levels obtained in this study. On the other hand, the values of calcium and potassium reported by Assogbadjo *et al*. (2012) are much lower. Similarly, Ibrahima *et al*. (2013) reported higher values of calcium, magnesium and iron in all baobab species from Madagascar and the African mainland than values obtained in the present study; levels of copper are similar.

Like other micronutrients, the variation in levels of minerals (Ca, Cu, K, Na, and Zn) with provenance may be highly ascribed to variation in physicochemical characteristics of the soil and species (Assogbadjo *et al*., 2012; Ibrahima *et al*., 2013). Variation in levels of main minerals (Ca, Cu, Fe, Mg and Zn) with several factors including provenance was also observed in twelve herbs from Japan, thirty-seven different food items from Pakistan and six wild berries cultivars from Portugal and thirty one eggplant varieties from Spain (Prohens and Mun, 2008; Iram *et al*., 2016; Llorent-martínez *et al*., 2017; Mehraj *et al*., 2017). Thus findings from the present study are consistent with published data elsewhere. Superior provenances can be selected and exploited for production of quality indigenous products that can readily improve nutritional status of rural communities especially in developing countries of the southern African region. (Nitcheu Ngemakwe *et al*., 2017).

Minerals are absolutely essential to human health, and without them vitamins have no function to perform (Tembo, 2008). Thus, fruit processors may blend baobab pulp containing high levels of important minerals (calcium, copper and iron) with pulp containing high level of vitamin C to achieve final products including baobab juice which are rich and important sources of these micronutrients. In this way, baobab fruit can contribute to the improvement of nutrition security.

Conclusion

The present study has shown that baobab fruit pulps from Malawi contain some good amounts of various micronutrients which vary with geographical zone from which the fruit is obtained. It has also identified rich provenances for specific micronutrients thereby filling an important gap on the variation of nutritional attributes (vitamins and minerals) with provenance. As such, it is important to have a clear understanding of a specific nutrient of interest and associated provenance when selecting baobab fruit pulp for various purposes including micronutrients supplementation. These findings are useful for consumption and production of quality baobab products that can help to improve health status of the resource-poor and promote commercialisation.

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