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Original Article

BIOACTIVE COMPOUNDS AND FUNCTIONAL POTENTIAL OF *UAPACA KIRKIANA* (MUELL. ARG.) FRUITS

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ABSTRACT

Consumption of *Uapaca kirkiana* indigenous fruit by the local populace is growing in popularity because of the acclaimed health and functional benefits. The aim of the study was to determine the bioactive compounds and functional properties of the *U. kirkiana* fruit. Besides the fruit's pulp yield, the bioactive phytochemical constituent, physicochemical properties and functional characteristics of the pulp were analysed. The sugar, starch, minerals, and ascorbic acid constituents of the fruit pulp were, respectively determined using the following instruments: brix refractometer, megazyme kit, inductive coupled plasma-optical emission spectrometer and 2,6-dichlorophenolindophenol (DCPIP) titration test. The total phenolic content (TPC), tannin, and flavonoid contents were evaluated using Folin Ciocalteau test, tannin binding test and vanillin test, respectively. The average weight of the *U. kirkiana* fruits harvested from three regions having different climatic conditions ranged from 23.56 to 34.20 g per fruit. The mean pulp weight was from 12.15 g/100 g to 15.09 g/100 g per fruit. The biochemical and functional parameters obtained include total titratable acid (0.3 - 0.48 g/kg), antioxidant activity (34.96 - 36.68%), vitamin C (15.74 - 16.63 mg/100 g), dry matter content (28.81 - 29.38%), pH (4.3 - 4.6) and sugar content (20.29 - 21.87 g/100 g). Fructose was the dominant sugar (10.12-11.0 g/100 g). Preliminary phytochemical screening of the pulp indicated the presence of tannins, flavonoids, amino acids and carbohydrate content. Total phenolic content ranged from 67.0 to 82.5 µg GAE/g. The essential elements constituent evaluation of the pulp revealed that Fe content was 11.3 - 12.2 mg/100 g, K (383.07 - 439.8 mg/100 g), Mg (28.7 - 35.1 mg/100 g), Ca (16.4 - 17.3 mg/100 g), P (13.4 - 15.1 mg/100 g), Na (9.08 - 9.78 mg/100 g), Cu (0.8 - 0.94 mg/100 g) and Zn (0.87 - 0.94 mg/100 g). This study, besides establishing *U. kirkiana* fruit as a good source of micronutrients (Fe, Cu, Zn), reveals that the fruit is also an excellent source of phenolic compounds, vitamin C and sugars, hence use as a dietary supplement may combat some nutritional deficiencies. We, therefore, recommend *U. kirkiana* fruits to be used to produce nutritive functional foods with health benefits such as probiotic jams and as an additive.

Key words: Indigenous fruit, micronutrients, phenolic, pulp, phytochemicals.

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INTRODUCTION

Uapaca kirkiana belongs to the genus *Uapaca* of the family *Euphorbiaceae* and sub-family *Phyllanthaceae* [1, 2]. The *U. kirkiana* plant is an underutilized indigenous fruit tree (IFT) found in the Miombo ecological zone in sub-Saharan Africa. The tree produces fruits, which are oval in shape, yellow-brown, and possess a fleshy skin with juicy pulp [1, 3].

The fruit is of important socio-economic value amongst the rural and urban poor. *Uapaca kirkiana* was found to be the most preferred indigenous fruit tree among consumers and farmers [1]. The fruit was popular because of its sweet taste and nutritional value as well as better market growth prospects [4]. The fruit is a food resource to many rural households especially during times of drought [3, 5]. The underprivileged and vulnerable groups of the society in drier regions of the sub-Saharan Africa are known as intensive consumers of wild fruits. The fruit is noted to be a good source of sugar, protein, and energy for the local consumers [6, 7]. Studies have confirmed that the fruit contains water (58.0-72.6 %), carbohydrates (28.7 %), proteins (0.1-0.5 %), fat (0.3-0.4 %), calories (523 kcal /100 g) and serves as a good source of Fe, Zn, Ca and K [6, 7]. Owing to diverse species of *U. kirkiana*, caused by differences in soil quality and varying environmental conditions, the indigenous plant has wide-range of functional properties as well as rich phytochemicals [6].

Phytochemicals are active biological compounds such as phenolic acids, carotenoids, flavonoids [8] and tannins, which confer health benefits to their consumers such as prevention against inflammation and some cancers [9]. Their protective characteristics are due to the ability to act as free radical scavengers, hydrogen-donating compounds, singlet oxygen quenchers and /or metal chelators [10]. Unfortunately, indigenous knowledge on edible fruits is not yet adequately documented, particularly within Africa, though some attempts have been made in the past to document the uses of certain indigenous fruits [11]. Therefore, to fill this research gap in indigenous knowledge system, the aim of this study was to determine the bioactive compounds and properties of the *U. kirkiana* fruit as a healthy functional food.

MATERIALS AND METHODS

Sample collection

Ripe fruits were collected from *U. kirkiana* trees in Gokwe, Bikita and Kazangarare communal areas in Zimbabwe. Gokwe is a semi-arid region located 18.22°S 28.93°E in Agro farming region 3 with a total rainfall of <650 mm per annum. Its soils are regosol (weakly developed) and basaltic vertisols (clayey). Bikita is a dry area located 20.5 S° 31.37° E in Agro farming region 4 with rainfall total of <450 mm per annum. Kazangarare is semi-hot area located 16.30°S 29.56°E with characteristic semi-dry conditions (Figure 1).

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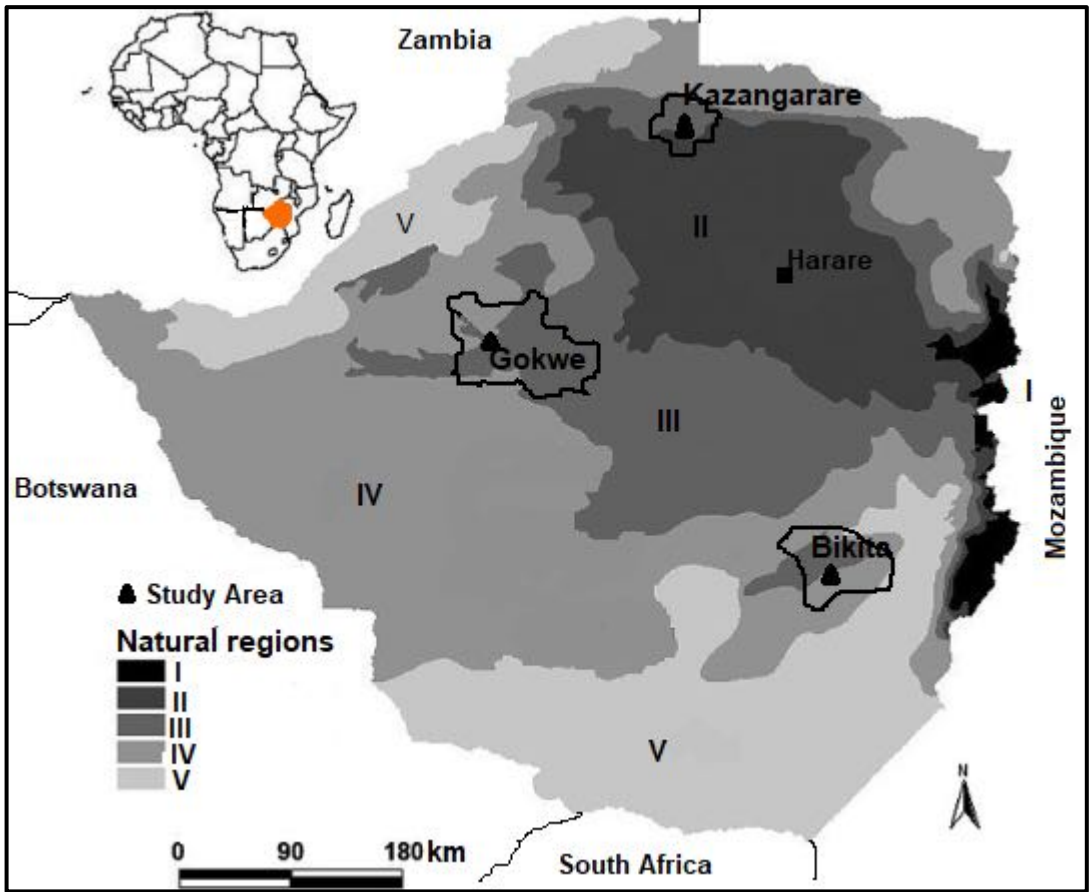

Figure 1: **Map showing sampling area (Bikita, Gokwe, Kazangarare) in Zimbabwe**

Data were collected between December 2017 and February 2018. From each area, the fruit trees were chosen using randomized statistical design. Comparative analysis for the biochemical and functional properties [pH, total soluble solids (TSS), dry matter (DM), sugars, acidity, mineral content, and vitamin C], determination of the fruits' physical attributes (weight, diameter, length, pulp yield), and the phytochemical composition were conducted. Samples of 100 ripe *U. kirkiana* fruits that had fallen from the trees were randomly collected from the ground.

Pulp extraction

The edible part of the fruits was obtained by cutting the fruits, removing seeds, mashing, and the crude mixture was sieved through 800 µM to obtain smooth pulp. The fruits were weighed before and after pulping to determine the yield in g kg^{-1}.

Biochemical and functional characteristics

Determination of fruit diameter and length

A hand caliper (Model 151, ZIIU Standart, Blagoevgrad, Bulgaria), was used to measure fruit diameter and length of nine randomly selected fruits [12].

pH measurement

The pH was determined using a digital pH meter (BT-675, BOECO, Hamburg, Germany) [13]. The glass electrode of the pH meter was calibrated using standard buffer solutions (pH 4 and pH 7) prior to pH measurements.

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Total soluble solids (TSS) analysis

The total soluble solids content of the *U. kirkiana* pulp was determined using a bench brix refractometer (MA871, North Carolina, Milwaukee Instruments, USA) according to a standard AOAC method [13].

Dry matter content

Dry matter was determined using the automatic oven drying method by placing the sample in a crucible and incubating at 100 ^{o}C overnight [13].

Glucose, fructose, and sucrose analyses

The glucose, fructose and sucrose contents were determined using a sucrose/D-fructose/D-glucose assay kit (K-SUFRG, Megazyme International, Ireland) and a colorimetric measurement with absorbance at 340 nm using UV-Vis spectrophotometer (Genesys 10S, Thermo Scientific, Waltham, Massachusetts, USA) [14].

Total titratable acidity (TTA)

Approximately 10 g of sample was dissolved in 100 mL distilled water and titrated against 0.1 M NaOH solution. Development of a pink colour was recorded as the endpoint using phenolphthalein as an indicator [13].

Mineral content analysis

Mineral analysis of the fruit pulp was determined using an Inductively Coupled Plasma–Optical Emission Spectrometer (ICP-OES) (Agilent 5100, Agilent Technologies, Santa Clara, California, USA), which allows for simultaneous detection of minerals [13]. The sample was digested using concentrated solutions of nitric acid (HNO_3) and sulphuric acid (H_2SO_4), followed by addition of ultrapure hydrogen peroxide (H_2O_2) to complete digestion. The sample was then fed into the ICP-OES and results were recorded.

Vitamin C (ascorbic acid) assay

The ascorbic acid concentration was determined by the Dichlorophenolindophenol (DCPIP) titration test according to an AOAC method [13]. Dichlorophenolindophenol solution was prepared by dissolving 0.25 g in 500 mL of distilled water. Sodium bicarbonate (0.21 g) was then added to the DCPIP solution and allowed to dissolve. The resulting solution was finally diluted to 1 L with distilled water. Ten grams of the sample was placed into a 100 mL volumetric beaker and mixed with 40 mL of 5 % acetic acid. After 20 minutes, water was added to 100 mL. The resulting solution (with sample) was then titrated against the prepared standard DCPIP.

Qualitative tests

Eighty (80) grams of the fruit pulp were extracted with four solvents (petroleum ether, chloroform, ethanol, and water) using the Soxhlet apparatus. The extract obtained after successive extraction was analysed for tannins, alkaloids, flavonoids, saponins, carbohydrates, proteins, amino acids and fats using qualitative tests.

In testing for tannins, few drops of 5 % ferric chloride solution were added to 2 ml of the extract and the presence of a blue colour indicated a positive test for hydrolysable tannins.

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For alkaloids, 50 mg of extract solution was diluted with 5 ml of distilled water and 2 M HCl was added and filtered. To the filtrate (1 ml), 2 drops of Wagner's reagent were added and formation of yellow or brown precipitate indicated a positive test result. In a flavonoid test, 3 drops of 10 % lead acetate were added to 1 ml extract solution and the formation of yellow precipitate confirmed a positive test. Testing of Saponins was conducted by addition of 5 drops of olive oil to 2 ml of the extract solution and the formation of an emulsion upon shaking confirmed a positive test.

Proteins were analysed by addition of 5 drops of 1 % copper sulphate solution and 2 ml of 10 % NaOH to 2 ml of the extract solution and formation of purple or violet colour indicated a positive test for proteins. In testing for amino acids, 5 drops of millions reagent were added to 1 ml of extract solution and heated for 10 minutes in a water bath, cooled and 1 % sodium nitrite solution was added and the presence of a red colour indicated positive result. Fats and oils were analysed by addition of 5 drops of the extract solution into 1 ml of 1 % copper sulphate solution and 3 drops of 10 % sodium hydroxide. The appearance of a clear blue solution confirmed a positive test result. Carbohydrates were determined using the Molisch's, Barfoed's, and Seliwanoffs tests.

Bioassay of bioactive phytochemicals

Extraction of polyphenols

The fruit pulp was dried in a cabinet solar drier using direct sun light at 40-60 ºC. The pulp was placed in trays and left for 8 hours, allowing heat to build up in the cabinet. The pulp was checked for moisture until it had reached <15% and the dried pulp milled into a powder (FZ102, Retsch, Pudong, Shanghai). Sun dried fruit pulp (2 g) was ground and placed in 50 mL Eppendof plastic tubes on ice. Extract prepared in the solvent (50 % methanol in distilled water, 1:1 v/v, 10 mL) was subjected to ultrasonication for 15 min. Using a bench centrifuge, the tubes were centrifuged (MLC-3000, Thermo Fisher Scientific, Waltham, MA USA) for 10 min at 1610 x g. After separation, the supernatant was collected, filtered, and analysed.

Total phenolic compounds measurement

Total phenolic compounds were determined using a method adapted from Makkar [15] and Harbone [16]. A sample (50 µL) was diluted to 1 L using distilled water. Then, 1 N Folin-C reagent (500 µL) and sodium carbonate solution (2.5 mL) were added. The mixture was incubated for 40 min at 25 º C and the absorbance measured at 725 nm using a Spectronic- Genesys spectrophotometer (Genesys 5, Thermo Fisher Scientific, Waltham, Massachusetts, USA) against a methanol blank. A standard curve of gallic acid plotted between the concentrations of 2.5–50 µg was used to determine the total phenolic content (Figure 2). The total phenolic content of the fruit pulp was expressed in µg of gallic acid equivalence (GAE)/g dry weight (DW).

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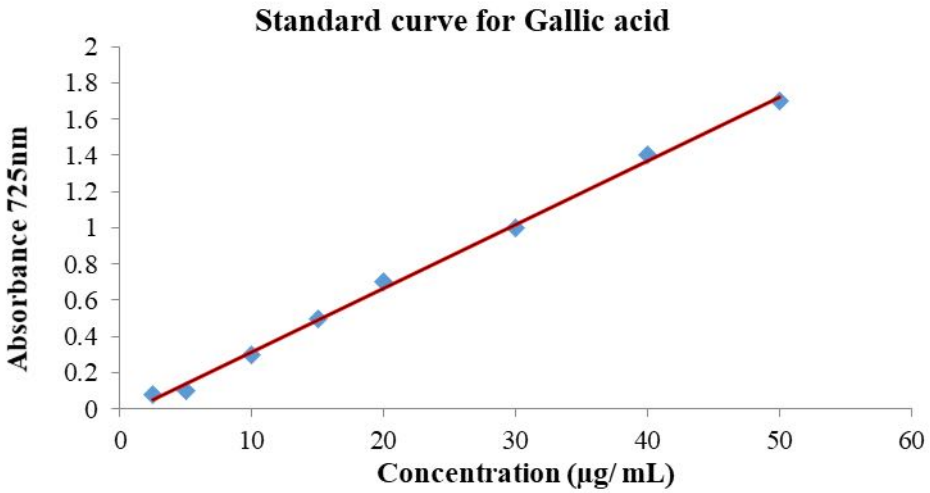

Figure 2: Standard curve of Gallic acid for Total phenolic content assay

Tannin binding assay

Tannins were determined following the method adapted from Makkar [15]. One gram of polyvinylpolypyrrolidone (PVPL) was dissolved in 1 mL distilled water and 1 mL sample was added to this mixture. The mixture was then vortexed and incubated for 15 min at 4 ºC, following which it was centrifuged (Microyn Digital Bench-top Centrifuge) at 1107 x *g* and the total content of phenolic compounds in the supernatant was determined by measuring the absorbance at 725 nm using a Spectronic- Genesys spectrophotometer (Genesys 5, Thermo Fisher Scientific, Waltham, Massachusetts, USA). The tannin content was calculated as follows:

Tannin content (mg / g) = Total content of phenolic compounds before binding with PVPL - Total content of phenolic compounds after binding with PVPL.

Antioxidant activity

The radical scavenging activity was determined using a previous method, [13], which was modified as follows. The methanolic solution of 2.2-diphenyl-1-picrylhydrazyl (DPPH) (1.5 mL, 1 mM) was mixed with 0.1 g sample and incubated at 25 °C for 25 min. The sample was mixed at five equal time intervals during the incubation period. The absorbance was determined at 517 nm on a Spectronic Genesys Spectrophotometer (Genesys 5, Thermo Fisher Scientific, Waltham, Massachusetts, USA) after calibration with methanol. Ascorbic acid (0.1 M) was used as a reference control. The scavenging activity was expressed as the percentage decrease in absorbance with time using the following equation:

$$\text{DPPH radical scavenging activity} = \frac{\text{Ab}_{\text{control}} - \text{Ab}_{\text{sample}}}{\text{Ab}_{\text{control}}} \times 100$$

where $\text{Ab}_{\text{control}}$ = Absorbance of control and $\text{Ab}_{\text{sample}}$ = Absorbance of sample

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Flavonoid content

Flavonoid content was determined using the vanillin assay [13], where, 5 µL *U. kirkiana* pulp sample was measured and distilled water was added to make 1 mL in a test tube. The total flavonoids (proanthocyanidins) content was calculated from a calibration curve, and the result was expressed as catechin equivalent per g dry weight.

Statistical Analysis

The results of functional and physicochemical properties were expressed as the mean ± standard deviation (SD), and all experiments were conducted in triplicates. The least significant differences (LSD) test was used to determine significant difference at $p < 0.05$ using XLSTAT statistical computer package (Version 2015.04.36025).

RESULTS AND DISCUSSION

Fruit physical qualities

The results of *U. kirkiana* physical qualities are presented in Table 1 showing fruit fresh weight, length, diameter, and pulp yield. The physical properties of the fruits were significantly different ($P < 0.05$) among the three study areas. Kazangarare fruits were far better in all the physical properties, followed by Gokwe fruits that had better fresh weight, fruit diameter and pulp diameter. The variation in the fruit weight is attributed to environmental factors such as temperature and soil moisture as reported by Dai *et al*. [17]. Generally, variability in fruit features are ascribed to climatic, edaphic, genetic and cultural factors [18]. The higher fruit length observed in Kazangarare area could be explained by genetic characteristics of fruits in that area, when compared to other locations. A fruit length of 31.2 cm was observed in Gokwe, which showed a significant difference ($p < 0.05$) with observations by Katsvanga *et al*. [12]. A significant variation on fresh weight was observed, with Gokwe and Bikita recording lowest fresh weight (Table 1). The study also noted a lower fresh weight of 26.4 g in Gokwe and it was statistically significant in all three areas. Similarly, fruit pulp weight from the three study locations (Bikita, Gokwe and Kazangarare) were 12.2, 14.3 and 15.09 g/100 g, respectively (Table 1). Pulp weight recorded in Zimbabwe were lower than the pulp yield of 28.3 g/100 g in *U. kirkiana* fruits obtained in Tanzania as reported by Ndabikunze [6]. The Tanzanian fruits were pulped using a mechanical fruit pulping machine as compared to a manual process used in Zimbabwe, hence the low pulp weights/ yield observed in this work.

Biochemical and functional properties

The biochemical and functional properties of the fruit pulp are presented in Table 2. The TTA (0.3 - 0.48 g/kg) and pH (4.3 - 4.6) values in the three areas were significantly different ($P < 0.001$ and $P < 0.01$, respectively). Values were in agreement with TTA (4.67) and pH (0.5 g/kg) reported by Ndabikunze *et al.* [6], which are the indicators of the organoleptic quality of the fruit [19]. The TTA can be related to the presence of organic acids, such as malic and citric that are present in most ripe fruits [20]. Vertuani *et al.* [21] reported the presence of organic acids (citric, malic, tartaric, succinic) and ascorbic acid in fruit pulps. A positive relationship between water supply, TTA and organic acid content in ripe fruits was reported by Thakur & Singh [22].

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The sugar content (20.-21.87 g/100 g) as shown in Table 2 was significantly different in the three areas (P< 0.01) and approximately 45 % of the variation in pulp was attributed to TSS. The pulp TSS content was higher than the value of 16.9 g/100 g reported by Ndabikunze *et al*. [6] on the *U. kirkiana* fruit study. The brix measurement is a ratio (weight by weight) of water to sugar (TSS) in the food material. Brix is mainly determined in fruit pulps as an indicator of the nutritional potential of the fruit. Katsvanga *et al*. [12] noted that fruits from areas that experience humid conditions with warm nights often have higher TSS levels and lower fruit acidity, which explained the trend observed in this study. The TSS could be attributed to the intensity of solar radiation received in the area during the ripening stage, during which the conversion of starch to sucrose, and the reduction of sugars occur [23, 24]. This is correlated with the high sugar content. The vitamin C content ranged from 15.74 to 16.6 mg/100 g (Table 2). Vitamin C analysis was important because it is essential for immune response and health [25].

Vitamin C was significantly ($p < 0.05$) affected by the area of fruit collection. Fruits obtained from Bikita were 5% better in Vitamin C than fruits collected in Gokwe and Kazangarare. Processing conditions have an effect on vitamin C because of high sensitivity to heat and at temperatures above 70 °C it tends to leach out into the surrounding solution [25]. However, the drying conditions of the pulp were between 40 and 60ºC in the drier and it did not affect the vitamin C content of the fruit. The observed vitamin C content is lower when compared to the reported 128.3 mg/100 g for *U. kirkiana*, *Sclerocarya birrea* (Anacardiaceae) and 141.3 mg/100 g for *Adansonia digitata* (Malvaceae) [5, 6]. The low vitamin C content in the fruit pulp is still significant because of the antioxidant benefit. A previous study indicated that vitamin C at low concentrations or in the presence of metal ions such as iron and copper is beneficial as an antioxidant [26]. The iron and copper contents of the fruit are shown in Table 3. The presence of these metals and vitamin C in the fruit pulp give the fruit an antioxidant property. Lee and Kader [27] reported that vitamin C content in fruits is influenced by many factors such as genotype differences, climatic conditions, maturity index, harvesting method, and postharvest handling practices.

In this study, the dry matter content (DM) of the pulp was not affected by location of the fruit tree. However, Muchuweti, Ndhlala, & Kasiyamhuri [28] reported a difference of 0.125 mg/g in DM content between the sampled ripe *U. kirkiana* fruits. The results of antioxidant activity of the fruit using DPPH ranged from 35 to 36.7 % as shown in Table 2. It has been established that the hydroxyl groups of phenolic compounds facilitate radical scavenging ability, hence polyphenolics act as strong antioxidants [29]. Therefore, the observed low antioxidant content (36 %) of the *U. kirkiana* fruit pulp could be attributed to the low presence of the phenolic compounds in the pulp. This can be supported by the total phenolic content of 67.0 - 82.5 µg GAE/g noted in the fruits. However, according to Ndlala *et al.* [30], *U. kirkiana* fruit peels exhibited higher antioxidant activity of 43 %. This explains that the antioxidant activity is different in each part of the whole fruit. Thus, there is need to assay other parts of fruit such as the seed for antioxidant activity.

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Mineral composition

The mineral content results of the sampled *U. kirkiana* fruits are presented in Table 3. Mineral content results for Fe (11.25 - 12.16 mg/100 g), Mg (28.72 - 35.13 mg/100 g)), Na (9.08 - 9.78 mg/100 g) and P (13.42 -15.06 mg/100 g)) were significantly different ($P<0.05$) in all the fruit samples. This meant that mineral content was different even though the fruits are of the same species. The results suggest that differences in tree to tree variation and ecological conditions of the sample area (Bikita, Gokwe, and Kazangarare) had an effect on mineral composition in the fruit. Phosphorus, Na and Fe accounted for approximately 73 %, 50 % and 3 % variations, respectively. There is need to use molecular analysis on genetic variations in the fruit tree that might cause the variability in the mineral contents. The Fe and Zn values are higher than the mean values reported by Ndabikunze *et al*. [6], but are in agreement with the values recorded by Stadlmayr *et al*. [7] on the same fruit. The *U. kirkiana* fruit pulp has comparable iron content to the recommended daily allowance (RDA) values of 12-19 mg/100 g [31] and is a good Fe and Zn source when compared to other indigenous fruits such as *A. digitata* (Malvaceae); 0.10 mg/100 g for iron and 0.14 mg/100 g for Zn; *V. infausta* (Rubiaceae); 0.09 mg/100 g for Fe and 0.02 mg/100 g for Zn [6]. Iron and Zn deficiencies are a major problem in Sub-Saharan Africa, especially in rural Zimbabwe [31]. These deficiencies are often referred to as hidden hunger because they are less visible than macronutrients deficiencies [32]. Iron is essential in the synthesis of haemoglobin and myoglobin [33] and zinc plays a vital role in gene regulation and apoptosis [34].

Glucose, sucrose, and fructose content

The glucose, sucrose and fructose contents are indicated in Table 4. Fructose content (10.12- 11.0 g/100 g) was relatively higher and the variation among the three sugars could be attributed to differences in the maturity index of the fruit as the sugar content often varies according to the ripening stage [35]. Furthermore, during ripening, sugars (glucose) accumulate rapidly through the process of gluconeogenesis [36]. It is also known that fruits from water stress areas tend to accumulate sugars and organic acids in plant tissues. This was supported by Gautier *et al.* [37], who noted that temperature and solar radiation have a huge influence on the sugar accumulation in the fruit. The authors also recorded that within the 26 to 30 ºC range, the TSS increases during ripening stage due to changes in carbohydrate biosynthesis and increased transpiration rate.

Phytochemicals

Phenolic compounds (phenolic acids, flavonoids, tannins) presence in fruits and vegetables exhibit many health benefits such as antioxidant action, antibacterial, antifungal, and immunosuppressant activities. Studies by Ndlala *et al.* [30], revealed that some indigenous fruits such as *Ximenia caffra* (Olacaceae) and Artobotrys *brachypetalus* (Annonaceae) are better sources of phenolic compounds. These fruits produce about ten times more phenolics than some exotic tropical fruits like apple and grape. The results of preliminary qualitative phytochemical screening of the *Uapaca kirkiana* fruit pulp are shown in Table 5. The results indicate low presence of tannins and flavonoids in the sun-dried fruit pulp. The presence of alkaloids, saponins, proteins and fats were not observed. Results of the tannin assay on the ripe sun-dried fruit pulps recorded concentrations ranging from 14 to 18 µg/g. The tannin concentrations had no significant differences in all the samples from the three study areas. Tannins are water-soluble phenolic

compounds with the ability to combine with proteins, cellulose, gelatin and pectin to form an insoluble complex [38]. Tannins usually are located in the vacuoles of plant cells and, contribute to the dry weight of plants. Fruits often contain hydrolysable tannins. Tannins produce an astringent taste when they react with proteins. During ripening, tannins are polymerised as the acetaldehyde is converted into sugars or consumed during respiration [38]. This explains the low tannin concentration observed in the *U. kirkiana* fruits. The results agree with a similar investigation by Muchuweti *et al.* [28] that recorded a tannin concentration of 18.0 µg/g in ripe sun-dried *U. kirkiana* fruit pulp. The study also showed that the fruit embryo produced more tannin concentration of 46 µg/g from a dry mass of the sun-dried fruit sample, while the seed coat yielded the lowest (13.3 µg/g). There is a perception that some of the tannins and other flavonoids in plant materials are lost [28], or experience certain chemical transformations to other phytochemical metabolites during fruit ripening as well as in the course of sun-drying of the fruit prior to analysis. This assertion is supported by Kennedy [39], which demonstrated evidence of decrease in the grape seed extractable flavan-3-ol polyphenols and the low molecular weight tannins during the ripening of the grape fruit. The flavonoid content of the *U. kirkiana* fruit pulp ranged from 4.0 to 4.9 µg/g and the flavonoid show no significant difference in all samples. The results agree with the outcome of Muchuweti *et al*. [28] that reported a flavonoid content of about 4 µg/g DM in ripe sun-dried *U. kirkiana* fruit pulp. However, a high yield of 13 µg/g DM in the unripe (embryo) sun-dried fruit pulp was recorded. Gallotannin concentration showed a significance difference in samples from all areas. The mean gallotannins concentrations were not significantly different in all the study areas. Muchuweti *et al*. [28] reported a 6.7 µg/g DM gallotannin level in ripe fruit pulp. Gallotannins are known to have bioactivity such as anticancer, antioxidant, anti-inflammatory, anti-hyperglycaemic, lipid-lowering and antimicrobial action [40]. The presence of these polyphenols in the fruit pulp plays an important technological role of being determinants of antioxidant activity.

The TPC of *U. kirkiana* fruit pulp ranged from 67.0-82.5 µg GAE/g Dry Weight (Table 6). Phenolic compounds contain hydroxyl groups, which are hydrogen donors and react with nitrogen and oxygen of organic radicals. This reaction delays the oxidation of organic radicals when stable radicals are formed [41]. Owing to their antioxidative characteristic, phenolic compounds are helpful against cardiovascular, and neurodegenerative illness, diabetes, mutagenesis, and carcinogenesis [42, 43].

CONCLUSION

The study shows that *U. kirkiana* fruit has good physicochemical and biochemical functional properties. The pulp yield and the TSS values of the fruit are high. The investigation established the fruit as a good source of micronutrients especially iron, hence the high record of its consumption by the local populace as a dietary supplement could help to combat iron deficiency. The study also showed that the fruit possesses good amounts of bioactive phenolic compounds as well as vitamin C. These strong antioxidant compounds are purported to have a positive impact on human health. Therefore, we recommend that the *U. kirkiana* fruit be considered for production of nutritive functional foods. Comprehensive bioassay and toxicity analyses should be conducted to establish the fruit's full nutritive value.

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Table 1: *Uapaca kirkiana* fruit physical parameters

Study site	Fresh weight (g)	Fruit length (mm)	Fruit diameter (mm)	Pulp yield (g/100 g)
Bikita	23.6 ± 1.13[a]	31.5 ± 0.46[a]	30.7 ± 0.46[a]	12.2 ± 0.16[c]
Gokwe	26.4 ± 0.67[b]	31.2 ± 0.31[a]	34.2 ± 0.32[b]	14.3 ± 0.36[b]
Kazangarare	34.2 ± 2.11[c]	50.2 ± 1.16[b]	47.1 ± 2.03[c]	15.1 ± 0.27[a]

Means ± standard deviations are reported. Means within the same row with same letter are not significantly different at P<0.05

Table 2: Biochemical and functional properties of *Uapaca kirkiana* fruit pulp

Functional Property	Sampling Areas		
	Bikita	Kazangarare	Gokwe
pH	4.66 ± 0.01[a]	4.35 ± 0.11[b]	4.42 ± 0.09[b]
Sugar (g/100g)	21.0 ± 0.87[b]	21.9 ± 1.03[a]	20.3 ± 0.52[b]
Dry Matter (%)	28.8 ± 0.62[a]	29.4 ± 0.94[a]	29.2 ± 0.58[a]
Vitamin C (mg/100g)	16.6 ± 0.67[a]	15.7 ± 0.57[b]	16.0 ± 0.69[ab]
Antioxidant Activity (%)	36.7 ± 0.46[a]	35 ± 0.86[b]	36.1 ± 0.76[a]
TTA (g/kg)	0.48 ± 0.04[a]	0.30 ± 0.07[b]	0.34 ± 0.05[b]

Means ± standard deviations are reported. Means within the same row with same letter are not significantly different at P<0.05

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Table 3: Mineral composition of *Uapaca kirkiana* fruit pulp /100 g edible portion

Mineral	Location		
	Bikita	Gokwe	Kazangarare
Ca (mg)	16.9 ± 0.38^{ab}	16.4 ± 0.95^{b}	17.3 ± 0.36^{a}
Fe (mg)	12.1 ± 0.41^{a}	11.3 ± 0.52^{b}	12.2 ± 0.54^{a}
Zn (mg)	0.87 ± 0.17^{a}	0.88 ± 0.11^{a}	0.94 ± 0.13^{a}
Mg (mg)	35.0 ± 1.56^{a}	35.1 ± 0.87^{a}	28.7 ± 9.70^{b}
Na (mg)	9.6 ± 0.33^{a}	9.78 ± 0.26^{a}	9.08 ± 0.33^{b}
P (mg)	15.1 ± 0.18^{a}	14.2 ± 0.54^{b}	13.4 ± 0.49^{c}
K (mg)	383.1 ± 4.22^{a}	390.5 ± 4.35^{a}	439.8 ± 162.32^{a}
Cu (mg)	0.94 ± 0.11^{a}	0.88 ± 0.07^{ab}	0.8 ± 0.8^{b}

Mean± standard deviations are reported. Means within the same row with same letter are not significantly different at P<0.05

Table 4: Sugar content of *Uapaca kirkiana* fruit pulp

Location	Glucose (g /100 g)	Sucrose (g /100 g)	Fructose (g /100 g)
Bikita	4.64 ± 0.23^{a}	7.08 ± 0.16^{a}	10.1 ± 0.24^{a}
Gokwe	4.35 ± 0.47^{a}	7.62 ± 0.45^{b}	11.0 ± 0.35^{b}
Kazangarare	4.60 ± 0.20^{a}	7.10 ± 0.26^{a}	10.9 ± 0.21^{b}

Mean± standard deviations are reported. Means within the same column with same letter are not significantly different at P<0.05

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Table 5: Qualitative test of *Uapaca kirkiana* fruit pulp

		Solvents				
TEST	**Control**	**Petroleum ether**	**Chloroform**	**Ethanol**	**Water**	**Methanol**
Tannins	++++	-	-	-	-	+
Alkaloids	++++	-	-	-	-	-
Flavonoids	++++	-	-	-	-	+
Saponins	++	-	-	-	-	-
Carbohydrates: Molisch's	++++	-	-	+	++	+++
Barfoed's	+++	-	-	+	++	++
Fehling's	+++	-	-	+	-	+++
Seliwanoffs	++++	+	++	+++	++	++++
Proteins	+++	-	-	-	-	-
Amino acids	+++	-	-	-	-	+
Oils & Fats	++++	-	-	-	-	-

Table 6: Total phenolic content of *Uapaca kirkiana* fruit pulp

Location	**TPC (µg GAE / g)**
Kazangarare	74.5 ± 0.01^{a}
Gokwe	67.0 ± 0.01^{b}
Bikita	82.5 ± 0.01^{c}

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