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PHYSICO-CHEMICAL, PROXIMATE, MINERAL AND BIOACTIVE COMPOSITION OF *GARCINIA BUCHANANII* BAKER FRUIT FROM UGANDA AND RWANDA

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ABSTRACT

Garcinia buchananii Baker (Family,Cluciaceae/Guttiferae) is an underutilized indigenous fruit tree that produces edible fruits that are used as both food and medicine in tropical Africa. This study evaluated the physical and chemical characteristics of *G. buchananii* fruits collected from Uganda and Rwanda. Ripe fruits were harvested during their peak seasons in Masaka and Bugesera Districts in Uganda and Rwanda, respectively. The fruits were analyzed for physical characteristics including; fruit weight, fruit size (that is length and width), number of seeds per fruit, seed weight, seed dimensions(length, width and breadth); chemical characteristics (pH and titratable acidity), proximate composition (moisture content, protein, fat, dietary fibre, carbohydrates and energy), mineral composition (K, Na, Ca, Mg, Ca, Fe, Zn, Cu), and bioactive components (total phenolic compounds, flavonoids and anthocyanins; and antioxidant activity). Data were statistically analyzed using a student T-test ($p \leq 0.05$). The results indicated that fruit weight and pulp content ranged from 6.3±1.3-9.5±2.8g and 54.1±10.6- 81.1±6.5%, respectively. Titratable acidity of the pulp ranged from 6.1±0.8 to 7.1±0.1 %. Nutritionally, dietary fibre, vitamin C, iron and zinc ranged from 20.0±0.4 -22.6±1.8 g/100g, 32.8±3.2-42.0±3.3 mg/100g, 4.8±0.2 - 6.5±0.8 mg/100g and 1.1±0.0 -2.5±0.1 mg/100g, respectively. The total phenolic compounds and antioxidant activity ranged from 996.7±50.5 - 1147.5±47.4 mg/g GAE (Garlic Acid Equivalent) and 8.0±0.2- 8.4±0.1 mg/100g AAE (Ascorbic Acid Equivalent) as IC50, respectively. There was a significant difference ($p \leq 0.05$) in the physical characteristics (weight, length, width and breadth), nutritional composition and bioactive components of the fruit samples of the two countries. Assessment of the nutrients indicated that the pulp was rich in vitamin C, iron, zinc, copper and dietary fibre. The pulp also contained phenolic compounds with antioxidant activity. The seeds had 6-24% crude oil content with palmitic, stearic, oleic and linoleic as major fatty acids. The total unsaturated fatty acids in the seed oil ranged from 58.4-59.5%. Although this finding showed significant differences ($P \leq 0.05$) in the physical and chemical of *G. buchananii* fruit from Uganda and Rwanda, the nutritional composition and bioactive component information has shown the potential of the fruits for processing into high-value nutraceuticals.

Key words: Chemical, Physical, Proximate, Mineral, Nutritional, Bioactive, *Garcinia buchananii,* Fruit

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INTRODUCTION

The genus Garcinia (family, Cluciaceae/Guttiferae) comprises over 250 species, mostly small to medium-sized fruit trees native to the continent of Africa and Asia **[1].** Three Garcinia species including; *Garcinia livingstonei, G. kola* and *G. buchananii* are native to tropical Africa. Among these species, *Garcinia buchananii* (Baker) is the most common in sub- Saharan African countries.

Garcinia buchananii is an indigenous fruit tree distributed in East, Central and Southern Africa [2]. The species is a small to medium evergreen tree/shrub that grows at an altitude of 480-1800m to a height of approximately 25m tall with a brown to pale grey bark and its leaves are oblong or elliptic, thick and leathery. It produces fleshy edible ripe yellow-orange fruits that are spherical in shape with a pleasant combined sweet and sour taste. The fruits are highly valued for food and medicine [3]. For instance, the fruits are reported to be among the consumed fruits as a food snack in Uganda [4]. A study in Mukono, Uganda, by Nieminen *et al*. [5] identified *G. buchananii* as one of the indigenous fruits with an export potential.

Although the fruits of *G. buchananii* are consumed and commercialized in the Lake Victoria Basin Districts in Uganda and Rwanda [6], scientific information to support its use in food and medicine product development is limited. To enhance value addition and commercialization of *G. buchananii* fruit, documentation of the physical characteristics, proximate and mineral composition and bioactive components of fruit collected from Uganda and Rwanda is essential. With increased interest in healthier foods, nutritional information on *G. buchananii* creates awareness on the value of its fruits in the formulation of products that can be used to manage health condition like cardiovascular diseases (CVD) such as hypertensive heart disease, coronary heart disease, heart failure and stroke; cancer and micronutrient deficiencies.

MATERIALS AND METHODS

Sample collection and preparation

The yellow-orange ripe *G. buchananii* fruits were harvested from six mature healthy trees in Masaka and Bugesera Districts in Uganda and Rwanda, respectively. The fruits were harvested by climbing each tree and picking 60 ripe fruits randomly into a clean cotton bag. The harvested fruit samples were transported in a cool box to the laboratory at the School of Forestry, Environmental and Geographical Sciences, Makerere University, where they were washed with clean tap water to remove dirt and dust. The clean fruits were then stored at -4^{o}C until analyzes were done.

Physical characteristics of the fruits

All the harvested fruits were measured for weight in grams (with an analytical balance) and linear dimensions (length, width and breadth) with a Vernier caliper. Each fruit was then de-pulped with the help of a stainless-steel knife to separate the seeds from the pulp. The number of seeds per fruit were counted and the weight (g) of the pulp measured. The percentage weight of the pulp was determined as (weight of pulp/

weight of fruit)*100. Similarly, the weight and linear dimensions of the seeds (length, width, and breadth) were also measured using the same method.

Chemical characteristics of the fruit pulp
The extracted pulp was blended in a laboratory blender and measured for pH and titratable acidity **[7]**, moisture content by oven method, vitamin C by titrating with 2, 6-dichlorophenol indophenol and β-carotene by extraction with petroleum ether and analysis with an HPLC (Shimadzu class VP 1); column C18 (water spherisirb ODS2, 3 μm 4.6 x 150 mm) using isocratic elution with mobile phase, acetonitrile –methanol - ethyl acetate (0.05%triethylamine) (80:10:10) at flow rate of 2.0 ml/min and pressure of 95kg F/min [8].

Proximate composition of the fruit pulp
The proximate composition of the fruit pulp including; crude protein, dietary fibre, crude fat and total ash as dry matter were determined using standard methods [7]. The total carbohydrates value was determined by difference (100%-crude protein content %-total fat content %-moisture content %). The caloric value was estimated by a conversion factor of four, nine and four for protein, fat and carbohydrates, respectively [9].

Mineral analysis of the fruit pulp
The dry pulp was also measured for mineral contents including; Na, K, Ca, P, Mg, Zn and Fe using the Atomic Absorption Spectrophotometer, model-Shimatzu AA-63000 [8, 9].

Bioactive Components
Qualitative phytochemical screening was conducted on the pulp (30g) using standard methods [10]. The phytochemical ingredients tested included saponins, tannins, reducing compounds, flavonoids, alkaloids, anthracenocides, steroids and triterpenes. Quantitative phytochemical analysis was conducted on the pulp for total phenolic compounds, total flavonoids, total anthocyanins and total antioxidant activity [11].

Physico-chemical characteristics of *G. buchananii* seed oil
The seeds of *G. buchananii* were dried in an oven at 40-50^{o}C for 36 hours, ground into powder (300 g) and extracted with n-hexane (2000 ml) using a Soxhlet apparatus at 40-60^{o}C for 8 hours. The organic solvent was evapourated using a rotary evaporator and the residue was transferred to a dry beaker of known weight and dried in a vacuum oven at 40^{o}C for 40 minutes until all the organic solvent was removed. The vegetable oil yield was determined [12]. The physical and chemical characteristics of *G. buchananii* seed oil such as refractive index, colour, free fatty acid, acid value, iodine value and fatty acid profile as methyl esters were determined using standard methods [7].

Data analysis
The results for the physical and chemical characteristic were analyzed using descriptive statistics and a student T-test ($p \leq 0.05$) for comparing data between Uganda and Rwanda.

RESULTS AND DISCUSSION

Physical characteristics

The weight and dimensions (length and width) of *G. buchananii* fruit samples from Uganda and Rwanda in this study were found to be significantly different (p≤0.05), but not for the number of seeds per fruit (Table 1). A study by Gogoi [1] also reported similar results in weights and dimensions for *Garcinia pedunculata, G. cowa, G. xanthochymus* and *G. lanceaefolia* from different locations in India, and their variation was attributed to differences in the growing and climatic conditions. Perhaps this was also reflected in *G. buchananii* from Uganda and Rwanda since samples were collected from different climatic conditions. For instance, fruit samples of *G. buchananii* from Uganda were collected in Masaka district with a bimodal type of rainfall and mild equatorial temperatures [13] and in Rwanda, samples were collected from Bugesera district characterized by very hot climate, rarity of rains and excessively prolonged periods of drought with a higher average daytime temperature [14].

The understanding of the physical characteristics of *G. buchananii* fruit, particularly its weight (mass), pulp content and dimensions (length and width) (Table 1) was necessary. This information is essential in aiding design of postharvest handling and processing technologies, and conducting plant breeding experiments in addition to marketing of *G. buchananii* fruit.

Chemical characteristics

The titratable acidity (6.09-7.12%) for *G. buchananii* obtained in this study was higher than for those of other Garcinia species; *G. pedunculata, G. cowa, G. xanthochymus and G. lanceaefolia* that ranged from 1.5 to 5.7% [1]. These variation in titratable acidity in the fruits of Garcinia can be attributed to the types of acids found in the fruit species. Although titratable acidity values of *G. buchananii* fruit samples from Uganda and Rwanda had no significant difference (p≤0.05), their pH values showed significant difference (Table 2). The results of this study were in contrast to that of Gogoi [1] for fruits samples from different locations, where titratable acidity was found to be significantly different (p≤0.05).

It is clear from the pH (2.65-2.95) of *G. buchananii* fruit samples from Uganda and Rwanda that it has acidic properties since their pH value were <4.0 [15]. The pH and titratable acidity are very important quality parameters for fruits because they indicate their microbiological and physicochemical stability. Acidic pH of *G. buchananii* can be important in extending fruit shelf life and also contributing to its sour taste. According to Ikram *et al.* [16] fruits with sour taste like *G. buchananii* have high antioxidant activity.

Proximate composition

There was a significant difference (p≤0.05) in the proximate composition values of *G. buchananii* fruit samples collected from Uganda and Rwanda (Table 2). The samples from Uganda presented high values for moisture content, total ash, and crude fat while those from Rwanda presented high values for crude protein, dietary fibre, total

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carbohydrates and caloric value. The variation in the proximate composition values of *G. buchananii* fruit samples from Uganda and Rwanda can be attributed to their different agroecological and climatic conditions.

The crude protein content of *G. buchananii* samples (5-7g/100g) in this study was within the range of other indigenous fruits like *Vitellaria paradoxa* C.F.Gaertn (5.6) and *Sclerocarya birrea* (A. Rich.) (4.7) [17]. With the protein Recommended Dietary Allowance (RDA) of 60g per day [18], consumption of 100g of *G. buchananii* pulp can provide 7-11% of protein daily requirement. Proteins are essential in growth and for the repair and replacement of dead and dying cell in addition to providing energy.

The dietary fibre content of *G. buchananii* (20-22 g/100g) in this study (Table 2) was higher than other indigenous fruits like *Adansonia digitata* (16.2g) and *S. birrea* (16.3g), but lower than that of *Vangueria infausta* Burch (39) as reported by Amarteifio & Mosase [15]. With the RDA of 12g per day for dietary fibre [18]; *G. buchananii* fruit pulp can provide 100-200% of the daily requirement. Dietary fibre aids the absorption and re-absorption of cholesterol and bile acid and also has the ability to lower the incidence of constipation, preventing obesity and development of diabetes, as well as reducing chances of developing colon and breast cancer.

Vitamins

The presence of considerable amount of vitamin C and β-carotene in fruits is important for human health and nutrition. In this study, there was a significant difference (≤ 0.05) in the values of vitamin C for *G. buchananii* fruits from Uganda and Rwanda (Table 2). The values of vitamin C (33-42 mg/100g) for *G. buchananii* fruit samples from Uganda in this study was lower than the value of 141 mg/100g reported for another indigenous fruit in the region like *A. digitata* [15]. With the RDA for Vitamin C of 75mg/day for adults, 100g of *G. buchananii* pulp can provide 44-56% of vitamin C daily requirement. Vitamin C has antioxidant properties and may reduce the risk of arteriosclerosis, cardiovascular diseases and cancer due to its ability to quench singlet oxygen and trap peroxyl radicals and acts as a cofactor in collagen synthesis that is essential in wound healing. Vitamin C also facilitates iron bioavailability by forming a chelate with iron.

There was also a significant difference ($p \leq 0.05$) in the values of β-carotene for *G. buchananii* fruits of Uganda and Rwanda (Table 2). Generally, β-carotene values of *G. buchananii* fruit samples (0.55-0.86 mg/100g) were higher than that of common citrus fruits. In nutrition, ß-carotene is usually expressed as retinol. It is estimated that 1µg of retinol is equivalent to 1µg of Retinol Activity Equivalents (REA) which is also nutritionally equivalent to 12µg of dietary ß-carotene. Therefore, in this study, β-carotene in *G. buchananii* fruit samples is equivalent to 45.8-71.6µg RAE. Based on the findings of this study, *G. buchananii* fruit samples can be regarded as a good source of vitamin A, since it meets the RAE value of 70 or higher as reported in Ekesa *et al.* [19]. With the RDA of 400µg RAE per day for 6 years old children and 700 µg for adult females, 100g of *G. buchananii* pulp can provide 6 and 10 % of their daily requirement, respectively. Increased carotenoid intake is associated with decreased risk of cancer, age-related macular degeneration, cataracts, sunburn-induced skin damage,

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and cardiovascular diseases. The biological role of carotenoids is due to their antioxidant properties in which they are able to bind to the attacking free radicals that usually lead to a number of health conditions [20].

Mineral composition

Fruits and vegetables are major sources of both macro and micro minerals that are essential in the human diet. In this study, there was a significant difference ($p \leq 0.05$) in the mineral values for sodium, magnesium, calcium, zinc, and iron in the pulp of *G. buchananii* fruit samples from Uganda and Rwanda, except for copper (Table 2). The cause of variations in mineral values of *G. buchananii* fruit samples from Uganda and Rwanda was not established, though reasons like soil health and modern agriculture can be attributed to variation.

Specifically, the values obtained for potassium (612-702 mg/100g) for G. *buchananii* fruit samples in this study (Table 2) were comparably higher than that of guava (417 mg/100g), orange (200 mg/100g), apple (90 mg/100g) and banana (358 mg/100g) as reported by Mahapatra *et al*. [21], but lower than that of *Adansonia digitata* L. (1866 mg/100g), *S. birrea* (2183 mg/100g), and *V. infausta* (1683 mg/100g), as reported by Stadlmayr *et al.* [22]. With the RDA of potassium of 2000mg/day [18], 100g of *G. buchananii* fruit can contribute 31-35% of its daily requirement. Potassium is essential in protein synthesis, water balance, normal functioning of nerves and muscles; and absorption of glucose and glycogen while magnesium is required in the synthesis and breakdown of carbohydrates, fats, proteins and synthesis of DNA and RNA [9].

The values obtained for magnesium (41-53 mg/100g) in *G. buchananii* fruit samples in this study (Table 2) were higher than that of other indigenous fruit of the same genus like *G. kola* (15 mg/100g) [23]. With the RDA for magnesium of 320mg/100g [18], 100g of *G. buchananii* fruit pulp can provide 13-16% of its daily requirement. Magnesium is an activator of many enzymes and maintains electrical potential in the nerves [24].

The value for iron (5-7mg/100g) obtained for *G. buchananii* fruit samples in this study (Table 2) were comparable to that of *Adansonia digitata L.* (6 mg/100g) but lower than that of *Balanites aegyptiaca* Del (14 mg/100g) as reported by Stadlmayr *et al.* [22]. With the RDA of 10mg/day for iron [18], 100g of *G. buchananii* fruits can provide 50-65% of its daily requirement. Iron is an essential constituent of hemoglobin, myoglobin, and a number of oxidative enzymes (cytochromes), and plays a significant role in oxygen transport and, thus prevention of anemia [24].

The value of zinc (1.1-2.5 mg/100g) obtained in *G. buchananii* fruit samples in this study (Table 2) were within the range of *B. aegyptiaca* (1.8mg/100g), *A. digitata* (1.4mg/100g) but not *S. birrea*, (0.3mg/100g) as reported by Stadlmayr *et al.* [22]. With the RDA of 15mg/day for zinc [18], 100g of *G. buchananii* can provide 7-17% of its daily requirement. Zinc is a component of many body enzymes and plays an important role in DNA synthesis and replication, cell division/ cell growth and differentiation; normal immune defense functioning of the body and as an antioxidant [24].

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The value of copper (0.15-0.23 mg/100g) in *G. buchananii* fruit samples in this study (Table 2) were lower than that of *A. digitata* (1.6 mg/100g) as reported by Stadlmayr *et al.* [22]. With the RDA for copper of 0.9mg/100g per day [18], 100g of *G. buchananii* fruit pulp can provide 17-26% of its daily requirement. Copper is a cofactor in cellular metabolism and copper-dependent enzymes which catalyze reactions in the body that involve molecular oxygen species [24].

Bioactive components

According to the World Health Organization, bioactive components and antioxidant activity of fruits are indicators of their contribution to health. The pulp of *G. buchananii* in this study was found to contain phytochemicals like; flavonoids, alkaloids, saponins, tannins, coumarins, sterols and reducing compounds (Table 3).

Flavonoids are low molecular weight compounds with 15 carbon atoms widely distributed in fruits and known to provide a wide range of health benefits including anticancer, protection against coronary heart diseases, anti-inflammatory, antitumor and antimicrobial activities, besides improving in insulin sensitivity [25]. Tannins (complex phenolic compounds of high molecular weight) and anthocyanins (a subgroup of highly soluble flavonoids) can both inhibit the growth of selected cancer tumor cells [26]. Alkaloids (containing a heterocyclic nitrogen atom) can be good in the treatment of cough, asthma and hay fever [27], have antihypertensive [28], anti-cancer, antioxidant, anti-mutagenic, antimicrobial and anti-inflammatory activities [29]. Saponins are glycosides containing either a steroid or triterpenoid aglycone with haemolytic, molluscicidal, anti-inflammatory, antimicrobial, and antitumor activity [30]. Essential oils are complex mixtures of different terpenes with antimicrobial, anticancer, anti-inflammatory and antinociceptive activities [31].

There is growing interest in natural antioxidants in fruits and vegetables due to their nutraceutical potential against chronic degenerative diseases [32]. Analysis of antioxidant compounds in this study showed a significant difference ($P \leq 0.05$) in total phenolic compounds and total flavonoids, but not for total anthocyanins and total antioxidant activity in *G. buchananii* pulp samples of Uganda and Rwanda (Table 4). The variation in the antioxidant compounds may be attributed to tree growing conditions like soil fertility, climate and agricultural practices [33].

Specifically, the total phenolic compounds (807-1147 mg/100g) obtained in this study (Table 5) were remarkably higher than that of other domesticated fruits like an orange (75 mg/100g) and papaya (28 mg/100g) [34]. Since total phenolic compounds correlates well with antioxidant activity, the anti-oxidant activity of *G. buchananii* pulp (8.0-8.4) in this study was found to be lower than that of papaya (3.5) and seedless guava (2.1) [34].

Physico-chemical characteristics seed oil

Although seeds of *G. buchananii* are usually discarded after eating the pulp, it was important to establish their potential as a source of vegetable oil for food, fuel, cosmetic and nutraceutical applications. In this study, the seeds of *G. buchananii*

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provided vegetable oil yield that ranged from 16.0-28.7% (Table 5). This value was within the range for cotton seed (15-24%), soya bean (17-24%), and olive fruit (20-25%) as reported by Chougui *et al.* [35], but lower than *V. paradoxa* (40-60%) as reported by Okullo *et al.* [12]. This indicates that seeds of *G. buchananii* can be a potential source for vegetable oil for domestic and industrial applications once its chemical composition has been evaluated.

The extracted seed oil of *G. buchananii* showed a yellow-green colour, semi-solid texture at room temperature and a refractive index that ranged from 1.482-1.485 (Table 5). The yellow green colour of *G. buchananii* seed oil was different from that of an olive oil and sun flower oil that are yellow. The presence of either yellow or green colour in any oil can be attributed to the presence of carotenoids. The refractive index of the oil obtained in this study was slightly higher than the specifications in the Codex Alimentarius standard 2010-1999 (1.447-1.477) for common vegetable oils (1.464-1.478).

The chemical characteristics of *G. buchananii* seed oil in this study including the acid value and free fatty acid values (Table 5) were found to be within the Codex Alimentarius permitted maximum 10 mgKOH/g value for vegetable oils. This indicates that *G. buchananii* seed oil meets international standards for edible vegetable oils.

The iodine value of *G. buchananii* seed oil (46 g I_2/100g) in this study (Table 5) was found to be lower than that of olive oil (75-9 I_2/100)g. [36], but higher than that of castor, coconut and palm kernel oils with values that ranged from 11.2 - 33.3 I_2/100g [37]. Since iodine value indicates the degree of un-saturation of oil, it is clear that *G. buchananii* seed oil has high level of saturated fat and it can be described as semi drying oil suitable for production of shoe polish and varnishes [38].

Analysis of the fatty acid profile of *G. buchananii* seed oil showed presence of palmitic, stearic, oleic and linoleic as major fatty acids (Table 5). The dominant fatty acids were found to be oleic acid (57-58%) and stearic acid (29-34) with significant differences ($P \leq 0.05$) observed between Uganda and Rwanda samples. The variation in the fatty acid profile of G. *buchananii* seed oil of Uganda and Rwanda can be attributed to the different climatic conditions of the samples.

The current percentage value of oleic fatty acid of *G. buchananii* seed oil obtained in this study (Table 5) was comparable to that of shea butter oil (55-60%) as reported by Okullo *et al.* [12], but lower than that of olive oil (65-83%) [36]. Oleic acid and linoleic acid are unsaturated fatty acids known to reduce cholesterol in the body [39], thus making *G. buchananii* seed oil an alternative source of healthy edible oil. Oleic acid to linoleic acid ratio is a useful indicator of an oil product stability, shelf-life index and nutritional potential. Exceptionally high ratio of oleic to linoleic acid (34.6-42.1) in this study suggests that *G. buchananii* seed oil has increased shelf life at room temperature (25^o C).

In this study, saturated fatty acids (SFA) in *G. buchananii* seed oil ranged from 36-42%, making it to have a butter like fat properties at room temperature similar to that of shea butter or coconut oil. Saturated fatty acids are linked to increase in serum cholesterol in the human blood and it has been associated with cardiovascular diseases. However, the unsaturated fatty acids (UFA) of *G. buchananii* that ranged from 58-60% was lower than that of peanut oil with a value of 78% [40]. The level of mono unsaturated fatty acids (MUFA) of *G. buchananii* seed oil (56.7-58.1%) were remarkably high, though the value was lower than that of olive oil (65-83%) [36]. Polyunsaturated/Saturated (P/S) ratio of oil is also very important because a high value is regarded favourably for the reduction of serum cholesterol and prevention of heart diseases. In this study, the P/S ratio for *G. buchananii* seed oil (0.04) was much lower than that of hemp (7.3) and walnut (6.5-7.3) seed oils reported to prevent cardiovascular diseases) [40]

CONCLUSION

The physical and chemical characteristics of *G. buchananii* fruit samples of Uganda and Rwanda show differences in sizes and weight, but the documented information can aid scientists to design appropriate postharvest handling and processing technologies for the fruits. Furthermore, *G. buchananii* fruit pulp was found to be rich in iron, zinc, copper, dietary fibre and phenolic antioxidant compounds in both countries. This information is essential in the formulation and production of healthier food and medicinal products like jam, juice, wine, edible oil and nutraceuticals. The study has also established that oil obtained from its seeds has chemical properties (like its fatty acids) that can be recommended for further studies on its application in the food and cosmetic industry.

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Table 1: Phenotypic characteristics of *G. buchananii* fruits and seeds from Uganda and Rwanda

Measurement variable		Uganda	Rwanda
Fruit weight (g)	Mean	9.5±2.8[b]	6.3±1.3[a]
	Minimum	2.3	3.4
	Maximum	16.9	9.3
Fruit length (cm)	Mean	2.5±0.3[b]	2.2±0.2[a]
	Minimum	1.5	1.1
	Maximum	3.2	2.8
Fruit width (cm)	Mean	2.4±0.3[b]	2.1±0.2[a]
	Minimum	1.6	1.8
	Maximum	3.1	2.7
Pulp weight (%)	Mean	81.1±6.5[b]	54.1±10.6[a]
	Minimum	62.6	20.6
	Maximum	93.6	74.6
Number of seeds per fruit	Mean	2.2±0.9[a]	2.3±0.9[a]
	Minimum	1.0	1.0
	Maximum	4.0	4.0
Seed weight (g)	Mean	0.5±0.2[a]	0.7±0.2[b]
	Minimum	0.3	0.4
	Maximum	0.9	1.1
Seeds length (cm)	Mean	1.2±0.1[a]	1.3±0.1[b]
	Minimum	1.0	1.1
	Maximum	1.6	1.5
Seeds width (cm)	Mean	0.7±0.1[a]	0.8±0.1[b]
	Minimum	0.6	0.6
	Maximum	0.8	0.9
Seed breadth	Mean	0.8±0.1[a]	0.8±0.1[a]
	Minimum	0.6	0.6
	Maximum	0.9	1.0

Data are means of 360 replicates for fruits and 1080 for seeds ±standard deviation

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Table 2: Chemical characteristics and nutritional composition of *G. buchananii* fruit pulp from Uganda and Rwanda

Variable	*G. buchananii* fruit samples	
	Uganda	**Rwanda**
Chemical characteristics		
Titratable acid (g/100g)	6.1±0.8[a]	7.1±0.1[a]
pH	2.7±0.0[a]	3.0±0.2[b]
Proximate composition		
Moisture content (g/100g)	85.6±0.9[b]	77.00±1.8[a]
Total ash(g/100g)	2.4±0.0b[b]	1.6±0.1[a]
Crude protein(g/100g)	4.3±0.0[a]	6.8±0.1[b]
Dietary fibre(g/100g)	20.0±0.4[a]	22.6±1.8[b]
Crude fat(g/100g)	1.7±0.0[b]	1.1±0.0[a]
Total carbohydrates (g/100g)	14.8±1.1[a]	15.6±2.5[b]
Energy (Kcal)	60.6±4.2[a]	98.1±9.7[b]
Vitamin composition		
Vitamin C (mg/100g)	42.0±3.3[b]	32.8±3.2[a]
Beta carotene (mg/100g)	0.9±0.1[b]	0.6±0.0[a]
Mineral composition		
Sodium(mg/100g)	10.9±0.1[a]	11.6±0.1[b]
Potassium(mg/100g)	702.8±50.9[b]	613.0±0.7[a]
Calcium(mg/100g)	10.3±0.2[a]	14.2±0.4[b]
Iron (mg/100g)	4.8±0.2[a]	6.5±0.8[b]
Copper(mg/100g)	0.2±0.1[a]	0.2±0.0[a]
Zinc(mg/100g)	1.1±0.0[a]	2.5±0.1[b]
Magnesium(mg/100g)	52.9±0.1[b]	40.9±0.0[a]

Note: Data was analyzed in triplicate ($p \leq 0.05$)

Table 3: Phytochemical ingredients of *G. buchananii* fruit pulp from Uganda and Rwanda

Phytochemicals compounds	*G. buchananii* pulp	
	Uganda	Rwanda
Volatile oils	+	+
Reducing compounds	++	++
Saponins	-	+
Tannins	++	+
Alkaloids	+	+
Anthracenocides	-	-
Coumarins	++	+
Sterols & triterpenes	++	+
Steroid glycosides	++	+
Flavonosides	-	+
Anthocyanosides	+	+

+ = Slightly present ++ = Abundant - = Absent

Table 4: Bioactive compounds and antioxidant activity of *G. buchananii* fruits from Uganda and Rwanda

Bioactive compound	*G. buchananii* pulp	
	Uganda	Rwanda
Total flavonoids (mg/100g as Rutin Equivalent)	66.5±2.1[a]	87.4±5.6[b]
Total phenolic compounds (mg/100g) Garlic Acid Equivalent (GAE)	1147.5±47.4[b]	996.7±50.5[a]
Total anthocyanins (mg/100g pigment)	4.9±0.0[a]	4.0±0.1[a]
Antioxidant activity as IC_{50} mg/g Ascorbic Acid Equivalent (AAE)	8.0±0.2[a]	8.4±0.1[a]

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Table 5: Physico-chemical characteristics of *G. buchananii* seed oil from Uganda and Rwanda

Physico-chemical characteristics	*G. buchananii* seed oil	
	Uganda	**Rwanda**
Oil yield	24.3±0.6[b]	16.0±0.0[a]
Colour	Yellow-Green	Yellow-Green
State at room temperature	Semi solid	Semi solid
Refractive index	1.482±0.001[a]	1.485±0.000[a]
Acid value(mgKOH/kg)	12.5±1.2[a]	10.9±2.3[b]
Iodine value(I_2g/100g)	45.7±3.5[a]	46.1±1.7[a]
Fatty acids (%)		
Palmitic (16:0)	6.9±0.4[a]	7.5±0.1[a]
Stearic (18:0)	29.0±1.7[a]	34.2±2.7[b]
Oleic (18:1n9)	58.1±6.1[a]	56.7±2.5[b]
Linoleic (18:2n6)	1.4±0.1[a]	1.7±0.4[a]
Ratio of Oleic to Linoleic	**42.1**	**34.6**
Total Saturated Fatty Acid (SFA)	36.2	41.6
Total Monounsaturated Fatty Acids (MUFA)	58.1	56.7
Total Poly Unsaturated Fatty Acids (PUFA)	1.4	1.7
Total Un Saturated Fatty Acids (UFA)	59.5	58.4
Ratio of PUFA/SFA	**0.04**	**0.04**

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