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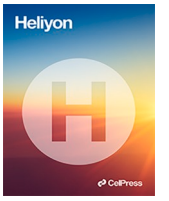

Research article

A comparative study of proximate compositions, phytochemical constituents, and anti-nutritional contents of pulps and seeds of *Garcinia buchananii* fruit

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ABSTRACT

Garcinia buchananii is a tropical wild edible plant that is locally consumed in the Southern Nations, Nationalities, and Peoples Regional state of Ethiopia. However, there is limited information comparing nutritional, phytochemical, and anti-nutritional factors present in fruit pulps and seeds of the fruit. Therefore, this study aimed to investigate and compare the proximate compositions, phytochemical constituents, and anti-nutritional contents of the fruit pulp and seeds. Data analysis was conducted using SPSS software version 20. The proximate analysis revealed that the pulp had higher moisture content (80.52 %) compared to the seed (42.4 %), whereas the seed contained more crude protein, crude fat, crude fiber and carbohydrate. However, the phytochemical constituents were relatively more abundant in the pulp compared to the seed. The pulp exhibited higher levels of total phenolic content (31.62 %), total flavonoid content (22.27 %), ascorbic acid (0.67 %), and inhibition percentage (15.31 %), but was lower in beta-carotene (4.60 %). The fruit seed has higher anti-nutritional values than the pulp. Overall, the pulp and seeds of the *Garcinia buchananii* fruit are nutrient-rich and can be used in food product development and formulation. Being high in moisture content and low in anti-nutritients the pup of the plant can be utilized in the form of juice.

1. Introduction

Wild edible plants are species collected from wild for consumption or drinking, and they are considered as primary source of nutrients and vital for human health. The work of [1] described that wild edible fruits are species that are neither farmed or domesticated, but are found in their natural habitat and are underutilized. They are highly valued for food and nutraceutical purposes [2]. Their easy availability, cheapness, and growth without fertilizer, drought tolerance, and pest resistance make them contribute toward reducing the problem of food scarcity.

Garcinia buchananii Baker is an even green tree fruit belonging to the Rhizophoraceae family, and it exists in Asia and Africa [3]. It is an indigenous tree widely available in East, Central, and South Africa [4]. The tree produces a fleshy edible fruit that has a characteristic spherical yellowish color with a pleasant sweet and sour taste when fully ripe. The fruit is hard, tough outer skin with a sticky

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pulp and a seed, which are traditionally used by local peoples for various purposes, including food, medicine, agroforestry, and ornamental purposes. In addition, sap is used as a dye, and tree branches are used to make tool handles, spoons, milk pots, and stools [5,6].

Ethiopia is home to approximately 413 kinds of WEPs that are being consumed [7], including *Garcinia buchananii*, which is found abundantly and used by localities as a food and medicinal fruit. It has been stated that these underutilized wild edible fruits are a good sources of macronutrients and micronutrients (minerals and vitamins), dietary fiber, and phytochemicals and they are known for their nutraceutical benefits for consumers [8,9]. Even though, they are used as additional food due to their seasonality, they play a great role in generating addition income for rural households as they market those fruits to the town population. In developing countries, it very important conducting an experiment and scientifically confirm the nutritional and the edibility forms of underutilized wild fruits so that the stakeholders can get baseline information for the food and pharmaceutical industry to develop food and nutraceutical products.

Even though, *Garcinia buchananii* is locally consumed in some parts of in Ethiopia such as southern nation, nationalities, and peoples, there is no documented scientific information regarding the nutritional, phytochemical, and anti-nutritional contents of the fruits to support their use in food and medicine and their potential for product development. Besides, comparing the nutritional and anti-nutritional contents of the seed and pulp of the fruit will help the users to decide in which forms they should use and convenient products from it. Therefore, this study aims to investigate and compare the proximate, phytochemical, antioxidant, and anti-nutritional contents of seed and pulp of the fruits.

Fig. 1. Fresh fruits during sorting (A), dried pulps (B), dried seeds (C), powder of pulps (D), powder of seeds (E).

2. Materials and methods

2.1. Experimental site

The fruits of the plant were collected from Gurafarda woreda in the Bench-Maji Zone of Southern Nations, Nationalities, and Peoples' Regional State of Ethiopia. The laboratory study was conducted at Postharvest Management Laboratory of Jimma University. It is located 352 km southwest of Addis Ababa and is geographically at 7°33′N latitude and 36°57′E longitude with an elevation of 1710 m.a.s.l. The temperatures and relative humidity of the laboratory room during the experiment period were in the range of 14.8–26.8 °C and 61.8–88.4 %, respectively.

2.2. Sample collection and preparation

Fresh and ripe fruit of *Garcinia buchananii* Baker were gathered from the natural habitat of Gurafarda district. The ripe fruit samples were carefully collected from over 10 randomly selected trees and combined to minimize variations in composition arising from soil and maturity differences. Immediately after harvest, the freshly harvested fruit samples were packed in an icebox and promptly transported to the postharvest laboratory at Jimma University. Upon arrival, the fruit samples underwent sorting, washing, and subsequent separation into pulp and seed and processed to powder (Fig. 1). Both the seed and pulp were dried at 65 °C in a hot air oven (Leicester, LE675FT, England) for 24 h. Following the drying process, the samples were ground into a fine powder using a pestle and mortar, and then sieved using a 0.5 μm sieve. The resulting powder samples were securely packed in high-density polyethylene bags and stored at a temperature of 4 °C until analysis was completed.

2.3. Data collection

2.3.1. Determination of proximate compositions

The proximate compositions of the *Garcinia buchananii* fruit powder samples were assessed following the Association of Official Analytical Chemists (AOAC) guidelines. The analysis was carried out following [10] methods. The moisture content of the sample was determined using a hot air oven (Leicester, LE675FT,England). The measurement of crude protein was conducted by the Kjeldal method using the Velp Scientifica instrument, while the crude fiber content was analyzed using the Fibertec TM 8000 auto-fiber analysis system. The crude fat was determined gravimetrically using the Soxhlet extractor. The determination of crude ash content was conducted using the (SX-5-12 China) Muffle Furnace, which operated at a temperature of 550 °C overnight. To calculate the carbohydrate content (CC), the difference method described by Ref. [11] was employed. It was obtained by subtracting the sum of moisture content, crude protein, crude fat, crude fiber, and total ash from 100 % (Eqn. (1)).

$$\text{Carbohydrate content (CC \%)} = 100\% - (\%\ \text{moisture content} \%\ \text{crude protein} + \%\ \text{crude fat} + \%\ \text{crude fiber} + \%\ \text{total ash}) \quad (1)$$

2.3.2. Determination of phytochemical contents

The extraction of fruit powder samples was undertaken in methanol solution as described in the method of [12]. A quantity of 0.5 g of fruit powder was shaken for 24 h in a capped bottle along with 20 mL of methanol. The bottle was securely placed on an orbital shaker, set 180 rpm, and maintained at room temperature. After the maceration process, the extract was homogenized and centrifuged at 1000 rpm for 10 min. This centrifugation step facilitated the separation of the supernatant, which was then carefully collected for further analysis. The prepared extract was marked as 25 mg/mL stock solution, which further diluted to analyze to some phyto-chemicals such as total phenolic content, total flavonoid content, and DPPH radical scavenging activity or inhibition percentage.

2.3.2.1. Total phenolic contents. Determination of total phenolic content of the sample was carried out using the techniques described by Ref. [13]. 1.00 mL sample (from previously prepared methanolic extract) was introduced to the pre-cleaned test tube, and 2 mL of 2 N the Folin-Ciocalteu reagent was added. Next, 2.5 ml of 7.5 % $NaHCO_3$ solution was poured into each sample. Subsequently, 0.5 mL of distilled water was poured into each sample and kept at 32 °C for 30 min. Then, absorbance e of the sample was undertaken using UV–Vis spectrophotometer (T80, Ltd., UK) at 765 nm. The calibration curve was drawn from the stock solution of gallic acid in a methanol standard of 0, 50, 100,150, 250, and 500 mg/L ($R^2 = 0.9912$). Eventually, TPC content of the sample was computed and expressed in milligrams of gallic acid equivalent per gram of sample (mg GAE/100 g).

2.3.2.2. Total flavonoid contents. Quantification of total flavonoid content (TFC) was conducted following procedures described by Ref. [14]. First, 1 mL of sample extract was mixed with 0.3 mL of 5 % $NaNO_2$. Also, the extract was kept for 5 min and also 0.3 mL of 10

% $AlCl_3$ was added, followed by addition of 2 mL of 1M of NaOH. Then, 2.4 mL of distilled water was added immediately, and resulting in a final volume of 8 mL. Then, reading of absorbance was conducted by UV–Vis spectrophotometer (T80, Ltd., UK) at 510 nm. At last, TFC of the sample was determined from standard curve made from catechin at concentrations of 0, 6.25, 12.5, 25, 50, 100 μg/mL (R^2 = 0.9881). Finally, the results were expressed in milligram of catechin equivalent per gram of sample (mg CE/100 g).

2.3.2.3. Beta (β) carotene. β-carotene content of the sample was determined using the techniques outlined by Ref. [15]. Briefly, 2.5 g of sample was mixed with an equal amount of $CaCl_2.H_2O$ in an analytical conical flask and 50 mL of extraction solvent of hexane, acetone, and ethanol (2:1:1:1 v/v/v) containing 0.1 % Butylated Hydroxytoluene (BHT). Then, the mixture was stirred at room temperature for 30 min, and 15 mL of distilled water was added and stirred again for 15 min. Then, organic phase containing the β-carotene was separated from the water phase using a separation funnel and filtered using Whatman filter paper No.1. The extracted β-carotene was estimated from absorbance read at 450 nm using a UV–Vis spectrophotometer (T80, Ltd., UK) and compared with the β-carotene standard. The pure β-carotene standard (Stigma Aldrich) used for the calibration curve was prepared in a concentration of 0, 0.1, 0.2, 0.4, and 0.8 μg/ml (y = 0.1537x+0.0391; R^2 = 0.9904) of the extraction solvent.

2.3.2.4. L-ascorbic acid (vitamin C). L-ascorbic acid content of *Garcinia buchananii* was determined using 2,6- dichloroindophenol visual titration method as described by Ref. [16]. Firstly, solvent for extraction was made by mixing 15 g of metaphosphoric acid (HPO3), and 40 mL of acetic acid (CH_3COOH) in 500 mL distilled water. Then, 5 g of the sample powder was extracted with 50 mL of the extraction solvent. Next, extracted sample was filtered using Whatman No.1 filter paper. Then, the filtrate was titrated using indophenol standard which was prepared from 50 mg of 2,6 indophenol sodium salt and 42 mg of $NaHCO_3$ in 200 mL of distilled water. The titration was performed until a light pink endpoint was reached. The L-ascorbic acid was calculated using the following formula (Eq. (2)).

$$L-ascorbic\ acid\left(\frac{mg}{g}\right)=\frac{(A-B)*C*50}{10S} \tag{2}$$

Where: A = volume of indophenol solution used for sample extraction, B = volume of indophenol solution used for blank, C = mass of L-ascorbic acid equivalent to 1 mL of standard indophenol solution, S = mass of sample, 50 = volume of extraction solution, and 10 = volume of filtrate titrated.

2.3.2.5. DPPH radical scavenging activity. The DPPH (2, 2-diphenyl-1-picrylhydrazyl) scavenging activity (inhibition percentage) of the methanolic extract of the sample was determined following the steps outlined by Ref. [17]. First, a 0.004 % solution of DPPH radical scavenging was made in in methanol. Then, 4 mL of the DPPH solution was well mixed with 5 mg/mL of extracted sample in methanol. Finally, the samples were kept at room temperature for 30 min. Next, reading of the sample and control absorbance was read at 517 nm using UV–Vis spectrophotometer (T80, Ltd., UK). Lastly, the DPPH free radical scavenging activity or inhibition percentage or of the sample was calculated using the equation below (Eq. (3))

$$Inhibition\ (\%)=\frac{AB(C)-AB(S)}{AB(C)}\quad *100 \tag{3}$$

Where: $AB_{(C)}$=Absorbance of control; $AB_{(S)}$ = Absorbance of sample.

2.4. Anti-nutrient determination

2.4.1. Phytate

The phytate content was determined by the method of [18]. An extraction of the sample was carried out by mixing 0.5 g of the samples with 10 mL of 2.4 % of HCl. It was done on mechanical shaker (HY-2(A)) at room temperature for an hour, and then centrifuged at 3000 rpm for 30 min. Next, the clear supernatant of an extracted sample was used for a phytate determination. A 2 mL aliquot of Wade reagent (containing 0.03 % solution of $FeCl_3.6H_2O$ and 0.3 of sulphosaliclic acid in water) was mixed on a Vortex (Maxi II) for 5 s. The absorbance of the sample was measure at 500 nm using a UV–Vis spectrophotometer (T80, Ltd., UK). Standard solution prepared from analytical grade sodium phytate at a concentrations of 0, 10, 60, 90, 120, and 150 μg/mL in 0.2 N HCl. A 3 mL of sample of standard was added to 15 mL centrifuge tubes with 3 mL distilled water, which was used as a blank. Then, 1 mL of Wade reagent was added and mixed on a Vortex for 5 min. The mixtures were centrifuged for 10 min, and the absorbance of the solutions both the sample and standard) were measured at 500 nm using deionized water as a blank. A standard curve was created by plotting absorbance versus concentration. Finally phytate content was determined using the following equation (Eq. (4)).

Table 1
Proximate composition of pulp and seeds of *Garcinia buchananii*.

Proximate composition (g/100 g db)	Pulp	Seed	p-value
Moisture content	80.52 ± 0.34[a]	42.40 ± 0.09[b]	0.000
Crude protein	3.20 ± 0.10[b]	5.23 ± 0.11[a]	0.003
Crude fat	1.2 ± 0.05[b]	6.70 ± 0.10[a]	0.003
Crude fiber	3.63 ± 0.05[b]	7.00 ± 0.10[a]	0.004
Carbohydrate	9.28 ± 0.54[b]	34.06 ± 0.13[a]	0.001
Total ash	2.13 ± 0.05[b]	4.60 ± 0.10[a]	0.002

Note: Data are expressed as mean ± SD (n = 3); means that do not share the same letter across the row are not significantly different; db = dry base.

$$Phytate\ (\mu g\ /\ g) = \frac{absorbance - intercept}{density^{*}slope^{*}sample\ weight} \tag{4}$$

2.4.2. Condensed tannin

The determination of condensed tannin undertaken using the procedures described by Ref. [19]. Two gram of the sample were weighed and transferred to a scew-cap test tube and extracted with 10 mL of 1 % HCl in methanol for 24 h at room temperature using a mechanical shaker (HY-2(A)). After shaken for 24 h, the solution was placed in a centrifuge (SIGMA model,-z-16KC, Germany) and centrifuged at 1000 rpm for 5 min. One milliliter of supernatant was taken and mixed with 5 mL of vanillin-HCl reagent (made by combining an equal volume of 8 % of concentrated HCl in methanol and 4 % vanillin in methanol). A stock solution was prepared by dissolving 40 mg of catechin hydrate with 1 % HCl in 1000 mL of methanol. A 0, 5, 10, 30, 40, and 60 g/mL stock solution was taken the test tube, and the volume of each test tube was adjusted to 1 mL with 1 % in methanol. Then, 5 mL reagent made from vanillin- HCl was added to each sample. After 20 min, the absorbance of the sample solution and standard solutions was measured at 500 nm using a UV–Vis spectrophotometer (T80, Ltd., UK). The following formula equation (5) was used to compute the tannin content of the sample.

$$Tannin\left(\frac{\mu g}{g}\right) = \frac{absorbance - intercept}{density^{*}slope^{*}sample\ weight} \tag{5}$$

2.4.3. Oxalate

The oxalate content of the extracts was determined following the method outlined by Ref. [20]. In the procedure, 2 g of sample were mixed with 190 mL of distilled water in 250 mL volumetric flasks. To this, 10 mL of 6 M HCl was added, and the solutions were incubated at 100 °C for an hour to facilitate the digestion. After cooling, distilled water was added to bring the total volume to 250 mL. The solutions were filtered, and 125 mL of the filtrates was transferred into beakers in triplicate. Methyl red indicator was added to each beaker, followed by addition of concentrated NH_4OH solution until a color change from salmon pink to faint yellow was observed. The solutions were then heated to 90 °C, and 10 mL of a 5 % $CaCl_2$ solution was added while stirring. After overnight cooling at 5 °C, the solutions were centrifuged, and the supernatant was removed. The precipitates were dissolved in 10 mL of a of 20 % H_2SO_4 solution, which was heated and titrated against a 0.05 M standardized $KMnO_4$ solution until a faint pink color persisted for 30 s. The amount of oxalate acid present was calculated using the formula indicated in Equation (6).

$$\text{Oxalate}\left(\frac{mg}{g}\right) = \frac{T \times (Vme)(Df) \times 10^5}{M_e \times Mf} \tag{6}$$

Where: T = titer of $KMnO_4$ (mL); Vme = volume-mass equivalent; Df = dilution factor; Me = molar equivalent of $KMnO_4$ in oxalate; Mf = mass of flour used.

2.4.4. Total alkaloid

The sample's total alkaloid content was determined using the standard method described in Ref. [21]. Briefly, 2.5 g of the sample was added to the 200 mL of solvent which was made from 10 % CH_3COOH and 90 % ethanol in a 250 cm^3 beaker. Then, it was kept for 4 h at ambient temperature. The extract was concentrated to a quarter of its original volume in a water bath at 90 °C. Then, 15 cm3 of concentrated NH4OH was added dropwise until cloudy fume formed. After 3 h, the supernatant was discarded, and the precipitate was washed with 20 cm^3 of NH_4OH and filtered using pre-weighed (W_1) Whatman No. 1. Then, the filter paper containing the precipitate was dried in an oven at 60 °C for 30 min and weighed (W_2) after allowing them to cool for a few min. Finally, the total alkaloid content was calculated gravimetrically as follows

Table 2
Phytochemical contents of the pulp and seeds of *Garcinia buchananii*.

Phytochemical contents (db)	Pulp	Seed	p-value
Total phenolics (mgGAE/100g)	31.62 ± 0.02^{a}	22.26 ± 0.04^{b}	0.001
Total flavonoid (mgCE/100g)	22.27 ± 2.02^{a}	14.20 ± 2.08^{b}	0.000
Ascorbic acid (mg/100g)	0.67 ± 0.04^{a}	0.28 ± 0.04^{b}	0.004
β-carotene (mg/100g)	4.60 ± 0.10^{b}	5.43 ± 0.06^{a}	0.002
Inhibition%	15.31 ± 0.96^{a}	10.32 ± 0.11^{b}	0.002

Note: Data are expressed as mean ± SD (n = 3); means that do not share the same letter across the row are not significantly different; inhibition % is the percentage of DPPH radical scavenging activity; db = dry base.

$$Total\ alkaloid\left(\frac{mg}{g}\right) = \frac{W2 - W1}{Weight\ of\ sample} \tag{7}$$

Where: W_1 = weight of filter paper; W_2 = weight of alkaloid and filter paper.

2.4.5. Saponin

The saponin content in the samples was determined using the method described by Ref. [22]. In this method, 1g of the sample was mixed with 10 mL of petroleum ether. The resulting suspensions were carefully transferred to beakers containing another 10 mL of petroleum ether. Then, supernatant of the solution was separated and combined with the initial supernatants. Next, mixture was evaporated to remove any remaining moisture, and then 6 mL of ethanol was added. Then, 2 mL of the resulting mixtures were transferred to test tubes, where they were kept for 30 min. Then, reading of the absorbance of the solution was conducted at 550 nm. To quantify the saponin content, a standard saponin (aescin) was used and analyzed under the same conditions. The saponin content in each sample was expressed as milligrams of aescin equivalent (mg AE) per gram of sample.

2.5. Data analysis

Statistical analysis was conducted using variance tests and analysis of variance using SPSS software version 20. All experiments were done in triplicates, and results obtained from analysis were expressed as mean ± standard deviation (mean ± SD). Duncan's multiple range test was used to determine the differences between samples, and $p < 0.05$ was deemed statistically significant.

3. Results and discussion

3.1. Proximate compositions of pulp and seeds of Garcinia buchananii fruit

The study conducted on *Garcinia buchananii* revealed a significant difference ($p < 0.05$) in the proximate composition between the pulp and seeds, as presented in Table 1. Notably, the seed of *Garcinia buchananii* exhibited a higher preference in terms of proximate composition compared to its pulp. Specifically, the seed contained lower moisture content than the pulp. Proximate composition analysis serves as an indicator of nutritional value and quality of food [23].

In this study, the moisture content of *Garcinia buchananii* pulp was determined to be 80.52 g/100 g. This value falls within a range of moisture content observed in similar studies conducted in Rwanda (77.0 g/100 g) and Uganda (85.6 g/100 g). The variation in moisture content might be attributed to geographical differences and agronomical practices associated with the cultivation of the plant [24]. Moisture content plays a crucial role in the shelf stability of food products. Foods which are low in moisture content tend to have longer shelf lives compared to those with higher moisture content. Based on the finding of this study, it is suggested that the edible pulp of *Garcinia buchananii* can be utilized for juice production, as it does not require extended storage durations to maintain its quality.

According to Table 1, the seeds of *Garcinia buchananii* showed higher levels of crude protein, crude fat, carbohydrate, and total ash compared to its pulp. The availability of higher crude protein content in food plays a crucial role in the natural synthesis of compounds necessary for maintaining enzymes, body tissues, and hormones, as reported by Ref. [25]. The higher fat content in the seeds provides caloric density, nutritional value, and serve as a source of energy and essential fatty acids [26]. Fat in the diet is crucial as it acts as carriers for fat-soluble vitamins, provides energy, regulates body temperature, and plays a significant role in various physiological functions.

In contrast, the pulp of *Garcinia buchananii* contained relatively lower levels of crude fiber compared to its seeds. Crude fiber is essential for optimal health and well-being, aiding in digestion, preventing constipation, managing weight, and minimizing the risk of chronic diseases [27,28]. It also sanitize digestive tract by removing cancer causing substances, and excess cholesterol absorption [29,

30]. This finding aligns with previous studies comparing crude fiber content in the pulp and seeds of similar wild edible fruits, such as those conducted by Refs. [31,32].

The pulp of *Garcinia buchananii* contains easily absorbed and digested carbohydrates, serving as a quick source of energy. In contrast, the seeds contain complex carbohydrates, such as starch, which are more difficult to digest [33]. The carbohydrate content in the pulp was 9.28 g/100 g, while in the seeds; it was significantly higher at 34.06 g/100 g. The presence of resistant starch and fiber in the seeds may contribute to slower digestion and a more sustained release of energy, and promoting satiety. In this study, the contents of indigestible fiber which are highly important for the gut health and preventing constipation are not conducted, so further study should investigate and compare the indigestible content of the pulp and seed of the fruits.

Ash content represents the total mineral content remaining after the combustion of organic matter. In Table 1, the total ash content of the pulp and seeds of *Garcinia buchananii* exhibited significant variation. The pulp had an ash content of 2.13 g/100 g, which was lower than the ash content of the seeds (4.60 g/100 g). This finding is consistent with the study of [34], which reported higher ash content in the seeds of *Garcinia xanthochyma* compared to its pulp. The difference in ash content could be attributed to the higher moisture content in the pulp compared to the seeds. Foods with higher moisture content tend to have lower ash content, as discussed by Ref. [35].

3.2. Phytochemical contents of the pulp and seeds of Garcinia buchananii

The phytochemical analysis of *Garcinia buchananii* pulp and seeds in Table 2 revealed a significant difference ($p < 0.05$). The pulp of the fruits showed high in phenolics, flavonoids, ascorbic acid, and inhibition percentage, except for beta-carotene content, compared to the seeds. These findings suggest that the pulp of *Garcinia buchananii* may possess greater antioxidant and bioactive properties, making it potentially beneficial for health.

Phenolic compounds found in *Garcinia buchananii* play a vital role in combating diseases due to their anti-inflammatory, anti-aging, and antioxidant properties. These substances act as antioxidants scavenging free radicals and chelating metals [36]. The pulp of *Garcinia buchananii* fruits contains higher amounts of phenolics, flavonoids, ascorbic acids, and antioxidants compared to its seeds. This disparity could be attributed to the biological function of phenolics in the fruit part of the plant, which helps protect it against environmental stresses [37]. Similar findings have been reported by Ref. [34], indicating higher total flavonoid contents in the pulp compared to the seeds of the fruit.

Although the values of total phenolic content, total flavonoid content, ascorbic acid, and antioxidant activity in this study are slightly lower than those reported by Ref. [5] for both pulp and seeds, variations in phytochemical constituents can be attributed to agro-ecological factors. The specific conditions in which the plant is grown can influence the levels of phytochemicals in its fruits.

In conclusion, the pulp of *Garcinia buchananii* exhibits significantly higher phytochemical contents compared to its seeds. Incorporating these phytochemical-rich pulps into the diet can provide nutraceutical benefits and contribute to overall wellness.

3.3. Anti-nutrients in the pulp and seeds of Garcinia buchananii

Table 3 demonstrates that there are significant differences ($p < 0.05$) in the anti-nutrient content between the pulp and seeds of *Garcinia buchananii* fruit. The seeds consistently showed higher concentrations of anti-nutrients compared to the pulp.

The comparison of anti-nutrient content between the seed and pulp of *Garcinia buchananii* fruit reveals interesting findings. Phytate, a well-known anti-nutrient, was found to have higher levels in the seed (0.4917 mg/g) compared to the pulp (0.409 mg/g). Phytate has the potential to reduce the bioavailability of amino acids and form complexes with cations, hindering their absorption in the body. As a result, minerals may become less accessible and their absorption may be compromised [38].

Similarly, the tannin content in *Garcinia buchananii* fruit showed a similar pattern, with the seed containing significantly higher concentrations (3.73 mg/g) compared to the pulp (2.37 mg/g). Tannins are polyphenolic compounds known for their astringent properties. However, they can also have negative effects on nutrition. The availability of anti-nutrients in foods can inhibit the bioavailability of desirable nutrients and need to be minimized [39]. Tannins have been shown to reduce food appeal, hinder the function of specific enzymes, and bind with proteins, thereby decreasing their solubility and digestibility. The high tannin content in the seed of *Garcinia buchananii* fruit suggests that it may pose significant health risks [40]. It is worth noting that the tannin content reported in this study is greater than the levels reported for comparable forest fruits by Ref. [41].

Table 3
Anti-nutritional contents of the pulp and seeds of *Garcinia buchananii*.

Anti-nutrients (mg/g db)	Pulp	Seed	p-value
Phytate	0.4097 ± 0.022^{b}	0.4917 ± 0.020^{a}	0.004
Tannin	2.37 ± 0.058^{b}	3.73 ± 0.058^{a}	0.000
Oxalate	2.50 ± 0.100^{b}	3.76 ± 0.057^{a}	0.002
Total alkaloid	0.743 ± 0.012^{b}	0.860 ± 0.017^{a}	0.003
Saponin	0.233 ± 0.005^{b}	0.343 ± 0.005^{a}	0.004

All values are means of triplicate determinations ± SD (n = 3); Different superscripts within the same row are significantly different from each other at $p < 0.05$; db = dry base.

Furthermore, the seed of *Garcinia buchananii* fruit exhibited a higher oxalate content (3.76 mg/g) compared to the pulp (2.50 mg/g). Oxalates can inhibit renal calcium absorption, especially at concentrations around 4 up to 5 g/100g. However, the levels observed in this study are considerably below the levels deemed dangerous. This suggests that consuming fruits may not pose any issues regarding mineral absorption in the body [42]. It is highly valued to note that oxalates can still contribute to the emergence of kidney stones in individuals predisposed to such conditions.

Regarding saponins and total alkaloids, the seed of *Garcinia buchananii* fruit contained slightly higher levels (0.343 mg/100g, and 0.860 mg/100g, respectively) compared to the pulp (0.233 mg/100g and 0.743 mg/100g, respectively). Saponins, when present in significant quantities, can give food a characteristic bitter taste and cause foaming in water-based solutions. While saponins have been known to break down erythrocytes and potentially lead to feelings of nausea and vomiting, they can provide benefits to individuals with hypocholesterolemia [43].

In summary, the seeds of *Garcinia buchananii* fruit contained higher concentrations of phytate, tannins, oxalates, saponins, and total alkaloids compared to the pulp. These anti-nutrients may have implications for the use and processing techniques employed for the fruit. It is important to consider the potential health impacts and nutritional value associated with these differences in anti-nutrient content between the seed and pulp of *Garcinia buchananii* fruit.

4. Conclusion

In this study, the researchers focused on investigating and comparing the proximate compositions, phytochemical constituents, and anti-nutritional contents of the pulp and seeds of *Garcinia buchananii* fruit from the southern part of Ethiopia. The proximate compositions, which provide information about the basic nutritional components, were found to be higher in the seeds compared to the pulp. The pulp of the *Garcinia buchananii* fruit demonstrated elevated levels of phytochemicals in comparison to its seeds, with the exception of beta-carotene. In terms of anti-nutrients, the seed of *Garcinia buchananii* fruit contains higher amounts compared to the pulp. These anti-nutrients are undesirable for consumption as they can have negative effects on human health. Based on the findings, the seed of the fruit needs pretreatment or processing to reduce the levels of anti-nutrients before consumption and can be used in food product development and formulation. The presence of high moisture and low anti-nutritional factors makes convenient pulp of the fruit for juice production. Further studies are recommended to investigate and compare the functional properties and mineral contents of the pulps and seeds of *Garcinia buchananii* fruit. These additional analyses would provide thorough understanding of the fruit's potential benefits and aid in optimizing its utilization for human consumption.

CRediT authorship contribution statement

Zeneba Kadir Abdisa: Conceptualization, Methodology, Formal analysis, Validation, Writing – original draft, and Writing – review & editing. **Kumsa Negasa Andersa:** Conceptualization, Methodology, Formal analysis, Visualization, Validation, Writing – original draft, and Writing – review & editing. **Abebe Yimer Tadesse:** Conceptualization, Methodology, Formal analysis, Visualization, Validation, Writing – original draft, and Writing – review & editing. **Endris Hussen Ahmed:** Methodology, Validation, Writing – original draft, and Writing – review & editing. **Tolcha Techane Alemu:** Methodology, Validation, Writing – original draft, and Writing – review & editing. **Hayat Hassen Mohammed:** Conceptualization, Methodology, Validation, Writing – original draft, and Writing – review & editing.

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Data availability statement

Data are available upon request from corresponding author.

Declaration of competing interest

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

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