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Nutritional composition of *bulla* from cultivated enset [*Ensete ventricosum* (Welw.) Cheesman] landraces in central Ethiopia

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Abstract
Enset is a versatile root crop predominantly utilized as a staple food for more than 25 million people living in Ethiopia. However, despite the presence of various landraces, their nutritional and ant-nutritional composition is not well understood. The purpose of this study was to ascertain the proximate composition, minerals, anti-nutritional factors, mineral bioavailability, pH, and titratability of the *bulla* contents from the eight commonly cultivated enset landraces. Each *bulla* sample was ground into a fine powder before being subjected to standard food analysis procedures. The nutritional profile of analyzed enset landraces varies significantly. The proximate content varies in moisture content (48.45–50.55%), crude protein (0.63–1.94%), crude fat (0.11–0.63%), crude fiber (0.46–1.03%), and total ash (1.10–2.21%), while the total carbohydrates came to 94.79–97.62%, and gross energy was 387.90–395.59 kcal/100 g. The mean contents of minerals (mg/100 g) on a dry weight basis ranged from (59.25–76.46) for calcium, potassium (83.54–129.61), magnesium (7.78–17.15), phosphorus (17.98–30.28), sodium (3.68–5.26), iron (3.62–5.52), and zinc (0.31–0.67). The mean anti-nutritional values (mg/100 g) for oxalate, tannin, and phytate ranged from 5.41 to 8.10, 1.65 to 2.12, and 11.75 to 23.68, respectively. Accordingly, the analyzed *bulla* samples showed a considerable nutritional value with minimal anti-nutritional components and molar ratios below critical values. This comprehensive approach enables the selection of nutritious *bulla* with desirable properties for local and regional use and promotes enset cultivation for food security.

Keywords Anti-nutrients, Enset, Minerals, Molar ratios, Physiochemical, Proximate

1 Introduction

The *Ensete* is a monophyletic genus belonging to the Musaceae family within the order Zingiberales, currently containing seven distinct species in Africa (four species) and Asia (three species) [1]. Among these species, enset (*Ensete ventricosum*) has been widely distributed in a wild state in Africa, from central to eastern Africa and South Africa [2, 3]. However, its domestication, cultivation and utilization as food and non-food substances are restricted in Ethiopia [4]. *Ensete ventricosum* is also called false banana, Ethiopian banana, or Abyssinian banana due to its morphological similarity to a banana crop [5].

It is also recognized by different local names, such as *enset* (Amharic as well as English), *asat* (Guragegn), *wessa* (Hadiyyisa), and *wassa* (Sidamign). Enset has become of special importance for Ethiopian farming systems in the central, southern, and southwestern regions.

The enset-cultivating system is an indigenous production system, which sustains a more densely populated area of Ethiopia [4, 6]. Enset has historically and traditionally been placed as a primary food crop, and it is an essential staple food for about 25 million Ethiopian, mainly in the central, south, and southwest parts of the country [7]. Moreover, enset is considered to be comparatively drought-tolerant, and able to withstand flooding, severe rain, and frost damage [8, 9]. Enset is suitable for harvesting at any time of year, at any stage of growth throughout the year, including the early flowering stage and the fermented products can be kept for extended periods [10, 11], having significant cultural value and the capacity to provide sustainable food with little off-farm inputs [12]. Due to these features, enset plays a substantial role in food security in the regions where it is commonly grown.

Traditional food crops provide significant opportunities to vary the food base in addition to serving as a representation of heritage, brand, and culture [13]. Most of them are either native species found in a particular area or that were introduced long ago and, as a result of extensive use, have adapted and become deeply rooted in a community's culture [14]. Traditional staple crops such as roots and tubers are identified to be more resilient to local environmental conditions [15]. Since they play key roles in food security, mainly during years when cereal crops failed, and can combat hunger, and famine, and alleviate drought effects [16]. Enset is a multipurpose perennial herbaceous root crop, with high cultural meaning and capable of providing sustained, long-term food security for humans and domestic animals in different regions of Ethiopia. Generally, the two most commonly consumed and produced enset-based food products are *kocho (qocho)* and *bulla*, which are derived from the pseudostem and corm through sequential processing and traditional pit fermentation methods. Tsegaye and Striuke [11] and Daba and Shigeta [17] also state that *bulla* is a high-grade enset product.

Bulla is one of the starchy primary products of enset, which is made by squeezing a mixture of the unfermented scraped pseudostem and grated corm, decanting the liquid, and then letting it air dry [4, 17]. It is thought to be the best kind of enset diet [18, 19], and it is usually eaten as crumbles, gruel, and porridge [12]. ESTC [20] states that the paper, textile, and glue industries can all benefit from the starch made from enset. Also, *bulla* starch can be employed to dissolve and bind compacted tablets [21, 22]. Furthermore, by replacing pricey conventional agar and lowering the production costs of the culture media, *bulla* has been applied as a gelling agent in the micro-propagation media of pineapple [23], vanilla [24], cassava [25], and enset [26].

Given the fact that among the various enset-based food products, *bulla* offers sociocultural and nutritional benefits, acts as a gelling agent for plant tissue culture media, and serves as a binding agent in various materials. However, there are still, few scientific researches have been conducted to identify and document the rich indigenous knowledge of farmers on the different dishes of *bulla* for human utilization as food and for other purposes, as well as the nutritional compositions of the *bulla* produced from the commonly cultivated and frequently consumed enset landraces. Moreover, the available information is limited to the samples gathered from markets or unspecified few enset

landraces with limited nutritional parameters. For instance, Bekele et al. [27], Daba and Shigeta [17], and Tuffa [28] reported nutritional compositions from *bulla* of the four, one, and two distinct enset landraces, respectively. Thus, understanding the nutritional, anti-nutritional, and bioavailability profile of traditionally produced *bulla* is crucial for local and regional consumption. Likewise, that will help ensure food security and the enset plant's sustainable use. In light of these aspects, the present study was set up to identify and document proximate, minerals, anti-nutritional components, bioavailability, and physiochemical property, of *bulla* produced from eight widely cultivated and frequently consumed enset landraces. Information from this study will eventually help commercialize and expand the crop's use locally and globally.

2 Materials and methods

2.1 Plant materials

A total of eight mature enset landraces (*Agade*, *Anchire*, *Gimbo*, *Hayiwona*, *Hiniba*, *Qiniwara*, *Separa*, and *Sisqella*) were chosen for *bulla* preparation, based on enset growers and consumers, particularly by the aid of local knowledgeable and experienced female farmers. Women are solely accountable for activities including harvesting, processing, storing, preparing, and marketing enset products [11, 18, 29]. The chosen landraces were collected from a single farmer's homegarden in the Lemmo district of the Hadiya Zone, Central Ethiopia, to minimize variability due to management practices and environmental factors. The district, located at 2105–2510 m above sea level, experiences mean temperatures between 10.38 and 22.57 °C and 950–1540 mm of rainfall, with vertisol soil types and pH values between 5 and 6. The selected landraces were widely dispersed, frequently consumed, and dominant per enset farm across central Ethiopia [29, 30].

2.2 Sample preparation

Each selected enset landrace was harvested and processed separately by experienced senior female farmers under the traditional methods of *bulla* preparation in late December 2020, during the semi-dry season. Traditionally, *bulla* extraction involves different sequential steps (Figs. 1, 2 and 3). Following two days of harvesting (Fig. 1B and C), each landrace's combined masses (pulverized corm and decorticated pseudostem) (Fig. 2A) were chopped with a sharp knife, then gradually put in a flat perforated bamboo bucket and squeezed to collect *bulla* (Fig. 2B). The extract was drained into an about 1 m × 0.3 m × 0.4 m rectangular pit carefully lined with fresh enset leaves and plastic sheets. The filtrate was decanted for eight to ten hours, wrapped with fresh enset leaves, and stored in a pit with other harvested enset products for three months. The surfaces of

Fig. 1 Harvesting steps for *bulla* production: **A** detaching of pseudostem, **B** scraping of pseudostem, **C** pulverizing of corm

Fig. 2 Traditional *bulla* extraction and packing: **A** mixed mass of harvested enset parts (pseudostem and corms), **B** squeezing for *bulla* production, **C***bulla*, **D** packed *bulla*

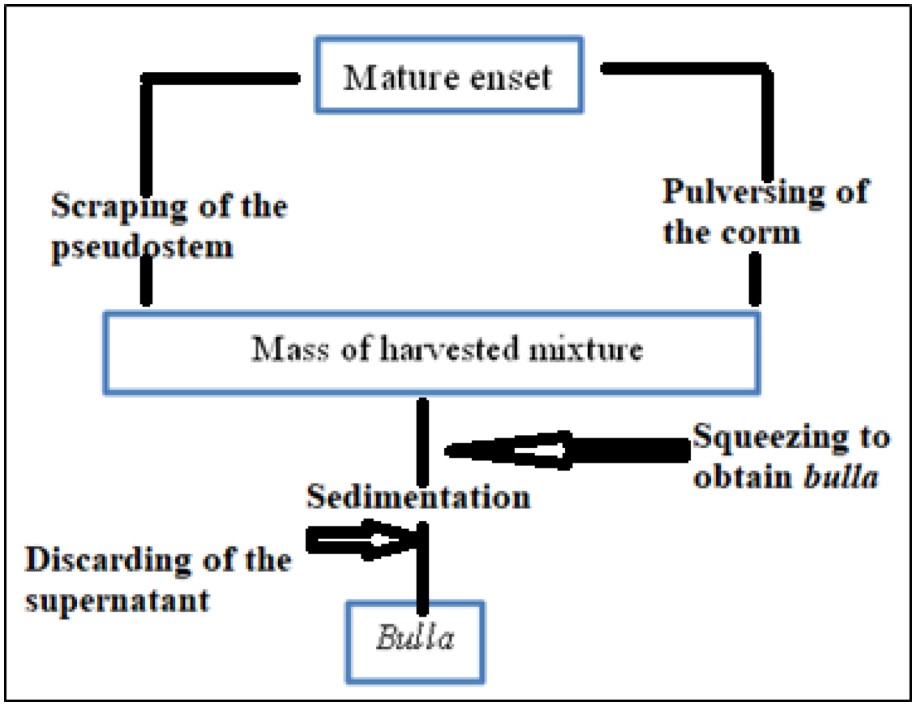

Fig. 3 A simplified flowchart illustrating the production process of *bulla*

each *bulla* sample were thoroughly cleansed with distilled water to get rid of any foreign substances before the laboratory analysis (Fig. 2C). Two kilograms of each *bulla* sample were placed in zippered polyethylene bags (Fig. 2D), kept in an ice box to prevent moisture loss, and then delivered to Addis Ababa University's Center for Food Science and Nutrition Laboratory. The moisture content of each *bulla* sample was determined before it was dried. For further laboratory analysis, each *bulla* sample was placed on an aluminum foil tray and dried overnight at 50 °C in a DHG 9055 A oven with minor adjustments [28]. Each dried *bulla* sample was filtered through a 0.425 mm sieve after being finely ground in an electric grinder. The ground *bulla* was then put into sealed polyethylene bags and kept at room temperature until it was required for proximate, mineral, and anti-nutritional analysis.

2.3 Analysis of proximate composition

All analyses were performed on a dry weight basis, except for moisture. Consequently, the dry matter contents of the samples were determined in triplicate after they had

been dried and milled into flour, and the results were expressed as (%), mg/100 g, and Kcal/100 g.

The moisture, crude protein, total ash, crude fat, and crude fiber contents of the *bulla* samples were evaluated according to methods described in AOAC [31]. To determine the moisture content in *bulla* samples, the standard 925.09 (DHG-9055 A) air-oven drying method was applied. The crude protein content in the *bulla* samples was analyzed using the Kjeldahl technique of the official method 979.09. The official method 923.03 was used to assess the total ash content in the *bulla* samples, using a (S30 2RR England) muffle furnace set at 550 °C for five hours. To extract and determine the crude fat contents in the *bulla* samples, the Soxhlet extraction (SZC-D fat determination meter, YLC 2000) device was applied following the standard procedures 920.39. To analyze the content of the crude fiber in *bulla* samples, the steps of digestion, filtration, washing, drying, and combustion were performed according to the official method 962.09. The total carbohydrate content in each *bulla* sample was computed using a formula: total carbohydrate content (%TCHO) = 100 − (% crude protein + % crude fiber + % total ash + % crude fat). The energy content (kcal/100 g) of *bulla* samples was determined from the values of total carbohydrates, crude fat, and crude protein by applying the following conversion ratios, based on Atwater: Gross energy (kcal/100 g) = (4 × g crude protein) + (9 × g crude fat) + (4 × g total carbohydrate) [32].

2.4 Determination of minerals

The mineral contents of the powdered *bulla* samples of the selected enset landraces was ignited to ash at 550 °C for five hours in a muffle furnace, dissolved in 20% HCl, boiled to bring the ash into solution form. The digested *bulla* sample was filtered into an acid-washed volumetric flask of 100 ml after cooling, and the volume was then adjusted with distilled, deionized water. The mineral contents were determined using calibration curves made using the standard solutions for the minerals. The same reagents and the same method as the samples and standards were used to prepare blank solutions in order to evaluate any potential contamination. The mineral elements of magnesium, calcium, zinc, and iron contents in the *bulla* samples were analyzed employing an atomic absorption spectrophotometer (Shimadzu, model AA-6800) at wavelengths of 285.2, 393.4, 213.9, and 372.0 nm, respectively [31], while potassium and sodium values were measured applying atomic emission spectrometry (AES) at wavelengths of 766.5 and 589.0 nm, respectively [31]. The phosphorus was determined using a UV-VIS spectrophotometer (Thermo Scientific model; Evolution 220, USA).

2.5 Determination of anti-nutritional factors

The phytate value in the *bulla* samples was determined using Latta and Eskin [33] as modified by Vaintraub and Lapteva [34]. A 1.0 g sample of *bulla* was extracted for one hour using 10 ml of 0.2 N HCl, and then it was centrifuged for 30 min at 3000 rpm. Wade reagent (2 ml) was added to 3 ml of the supernatant solution, and the combination was centrifuged. An ultra violet spectrophotometer was employed to determine the absorbance at 500 nm (Lambda 950) (Thermo Scientific model Evolution 220, USA). The tannin value was measured applying the procedures of Burns [35], as modified by Maxson and Rooney [36]. After centrifuging at 1000 rpm for five minutes, the produced supernatant solutions from 1 g of *bulla* were combined with 5 ml of vanillin-HCl reagent. Once

the reaction was completed, a spectrophotometer set to 500 nm was used to quantity the absorbance. The oxalate concentration of the *bulla* was ascertained through the methods indicated by Ukpabi and Ejidoh [37], which consist of three steps— digestion, oxalate precipitation, and permanganate titration.

2.6 Determination of mineral bioavailability

The molar ratios between anti-nutrients and minerals, phytates: calcium, phytates: iron, phytates: zinc, phytates × calcium: zinc, and oxalates: calcium, were used to predict the bioavailability of calcium, iron, and zinc [38].

2.7 pH value and titratable acidity analysis

The pH in the *bulla* samples were measured by homogenizing a 1:10 dilution of the sample (10 g of *bulla* samples in 90 ml of distilled H_2O) and by connecting a glass electrode to a digital pH meter at room temperature after calibrating the pH meter at 7.00, 4.00, and 9.2 with a known buffer solution. The experiment was performed in triplicate.

The sample was titrated with the addition of a standard base (0.1 N NaOH) to 3–5 drops of 1% phenolphthalein indicator until the endpoint, which was identified by the sample changing color to pink. This permitted for the estimation of the total titratable acidity of the *bulla* samples. The equation given below determines the % titratable acidity based on lactic acid, the predominant organic acid in *bulla* samples, using the volume of NaOH [39].

$$\text{Titratable acidity } (\%) = \frac{Vol.NaOHused(ml) * 0.1NNaOH * 0.009 * 100}{\text{W}}.$$

Where W is the weight of the *bulla* sample, 0.009 is the milli-equivalent factor for lactic acid, N is the normality of the NaOH used, and Vol is the volume of the 0.1 N NaOH used.

2.8 Statistical analysis

All the data collected were analyzed using SAS software (version 9.4 USA). One-way analysis of variance (ANOVA) and Duncan's multiple range test were used to examine the sample differences at the significance level of $P < 0.05$.

3 Results and discussion

3.1 Proximate composition

3.1.1 Moisture content (MC)

The mean moisture contents of the *bulla* of the eight enset landraces differed significantly, with a mean MC content ranging from 48.55 to 50.55% on wet weight bases (Table 1). Relatively, the *bulla* sample produced from the *Qiniwara* enset landraces exhibited the highest value, while the lowest value was produced in the *Hiniba* enset landraces. However, the mean moisture value of the *bulla* derived from the *Agade*, *Anchire*, and *Sisqella* from *Gimbo*, *Hayiwona*, and *Separa* landraces did not reveal significant differences ($p > 0.05$). The present result is slightly comparable with the findings of Atlabachew and Chandravanshi [40] (44–55%) and Bekele et al. [27] (47.76–50.27%). In contrast, Abebe et al. [41] reported the highest moisture contents (54–58%) for the *bulla* sample prepared from the enset landrace. The variation might be attributed

Table 1 Proximate composition (%) and gross energy (Kcal/100 g) of *bulla* produced from eight selected Enset landraces

Landrace	Moisture content[1]	Total ash	Crude protein	Crude fat	Crude fiber	Total carbohydrate	Gross energy
Agade	50.15 ± 0.13^{ab}	1.23 ± 0.12^{bc}	0.72 ± 0.21^{de}	0.21 ± 0.04^{c}	0.78 ± 0.11^{e}	97.12 ± 1.15^{b}	393.08 ± 2.11^{abc}
Anchire	50.10 ± 0.21^{ab}	1.44 ± 0.11^{b}	1.81 ± 0.31^{a}	0.15 ± 0.06^{c}	0.95 ± 0.35^{b}	95.73 ± 2.05^{d}	391.43 ± 1.82^{c}
Gimbo	49.40 ± 0.17^{abc}	1.15 ± 0.21^{bc}	0.63 ± 0.06^{e}	0.52 ± 0.11^{b}	0.86 ± 0.11^{c}	97.04 ± 1.06^{bc}	394.95 ± 2.21^{ab}
Hayiwona	49.30 ± 0.32^{bc}	1.22 ± 0.13^{bc}	1.94 ± 0.20^{a}	0.63 ± 0.23^{a}	0.67 ± 0.06^{f}	95.63 ± 0.95^{d}	395.59 ± 1.96^{a}
Hiniba	48.45 ± 0.43^{c}	1.10 ± 0.11^{c}	1.33 ± 0.12^{b}	0.14 ± 0.31^{c}	0.46 ± 0.08^{h}	96.90 ± 2.11^{bc}	394.17 ± 1.55^{abc}
Qiniwara	50.55 ± 0.22^{a}	0.83 ± 0.08^{d}	0.92 ± 0.07^{c}	0.11 ± 0.02^{c}	0.58 ± 0.06^{g}	97.62 ± 1.30^{a}	395.02 ± 1.25^{ab}
Separa	49.30 ± 0.16^{bc}	1.42 ± 0.13^{b}	0.82 ± 0.09^{cd}	0.17 ± 0.11^{c}	0.82 ± 0.05^{d}	96.81 ± 0.84^{c}	392.01 ± 2.35^{bc}
Sisqella	50.10 ± 0.32^{ab}	2.21 ± 0.23^{a}	1.83 ± 0.25^{a}	0.18 ± 0.05^{c}	1.03 ± 0.25^{a}	94.79 ± 1.13^{e}	387.90 ± 1.65^{d}
CV(%)	1.27	13.04	6.45	21.16	2.06	0.14	0.44

Mean values are the results of the triple analysis, and the values in a column with different superscripts indicate significant differences at the $p < 0.05$ level. 1 = Wet basis, CV = Coefficient of variance

to differences in landraces used, processing methods, and environmental factors. In general, enset-based food products show notable variations in moisture content. For instance, fermented *kocho* (*qocho*) and corm contain 59.9–63.3% and 68–79%, Karssa and Papine [42] and Dilebo et al. [30], respectively. Food moisture content is a sign of food solids content and an indication of storage stability [43]. Consequently, *bulla* has better storability compared to *kocho* and corm (*amicho*) of the enset food products.

3.1.2 Total ash content

The analyzed mean contents of total ash of *bulla* samples differed statistically and varied from 0.83 to 2.21% (Table 1). *Bulla* prepared from the *Sisqella* landrace had the maximum total ash content (2.21%), whereas the *Qiniwara* landrace had the minimum ash content (0.83%). However, the *bulla* samples derived from the *Anchire* and *Separa* as well as *Hayiwona*, *Agade*, and *Gimbo* revealed a nearly comparable proportion of mean ash value and no discernible variations ($p > 0.05$) (Table 1). The mean ash value analyzed in this study was greater than that of Atlabachew and Chandravanshi [40] and Tuffa [28], who reported 0.2% and 0.58%, respectively. However, similar mean ash levels were reported by Daba and Shigeta [17] (1.08%) and Bekele et al. [27] (0.88–1.27%) for the *bulla* of the different enset landraces. Yet, the *bulla* sample of the *Sisqella* landrace exhibited the maximum mean ash value among others in this and previous studies. This confirms that the ash values within and among enset landraces and their food products vary. Compared to other enset food products (*qocho* and *amicho*), the total ash value of *bulla* exhibited a lower content than that of *qocho*; it ranged from 1.25 to 2.35%, as reported by Forsido et al. [44], Yirmaga [45], and Tuffa [28], and that of raw corm was 2.01–4.60%, as reported by Dilebo et al. [30]. The amount of ash in plant materials has been directly correlated with the amount of inorganic elements present [46].

3.1.3 Protein content

Table 1 displays the range of the measured mean crude protein value of *bulla* samples taken from eight distinct enset landraces. These results indicated that the protein level of the analyzed *bulla* samples varied significantly within landraces. The mean value for crude protein in the *bulla* samples under analysis ranged from 0.63 to 1.94%. The maximum crude protein value was obtained in the *bulla* sample of the enset landrace

Hayiwona (1.94%), followed by *Sisqella* (1.83%) and *Anchire* (1.81%). In comparison, the minimum value was measured in the *bulla* samples derived from the *Gimbo* (0.63%) landrace. The mean protein content of *bulla* samples from *Hiniba* (1.33%), *Anchire* (1.81%), *Sisqella* (1.83%), and *Hayiwona* (1.94%) landraces in the present study is higher than the reports of the previous studies. However, the mean crude protein content of *bulla* obtained from *Gimbo* (0.63%), *Agade* (0.72%), *Separa* (0.82%), and *Qiniwara* (0.92%) landraces is in close agreement with the works of Atlabachew and Chandravanshi [40] (0.4–0.8%), Bekele et al. [27] (0.56–0.91%), Daba and Shigeta [17] (0.65%), and Tuffa [28] (0.45) for *bulla* samples of different landraces. The existing discrepancy in protein levels between our results and the earlier findings may be explained by variations in soil composition, environmental conditions, and genetic diversities. Dietary proteins are necessary for the biochemical synthesis and maintenance of hormones, enzymes, bodily tissues, and other substances required for regular functioning [47].

3.1.4 Crude fat content

The mean crude fat value in *bulla* samples varied significantly ($p < 0.05$) from 0.11 to 0.63% (Table 1). The mean crude fat value of *Hayiwona* (0.63%) was higher, followed by *Gimbo* (0.52%), whereas that of *Qiniwara* (0.11%) was significantly lower. In contrast, the remaining five landraces showed no significant variations ($p > 0.05$) in their mean crude fat level, which ranged from 0.14 to 0.21%. These values are in line with the findings of Atlabachew and Chandravanshi [40], Bekele et al. [27], Daba and Shigeta [17], and Tuffa [28], who reported between 0.1 and 0.4%. In contrast, Forsido et al. [44] described higher mean crude fat contents, 1.11%. These variations may be mainly caused by the environment, maturation stage, and type of landraces utilized. Fat levels in *bulla* are lower compared to other proximate constituents in this study. In general, the fat content in enset-based food products is below 1% [10, 28, 30, 48]. Fat is essential for food energy and physiological processes like digestion, absorption, and transport of fat-soluble vitamins in the body [49].

3.1.5 Crude fiber content

The mean crude fiber content in the *bulla* samples derived from the eight enset landraces is presented in Table 1. The mean results differed significantly ($p < 0.05$), which ranged from 0.46 to 1.03%. The lowest content was measured in *Hiniba*, while the highest was in the *Sisqella* landrace. Comparable findings were described by Atlabachew and Chandravanshi [40], Bekele et al. [27], Daba and Shigeta [17], and Tuffa [28], who reported between 0.6 and 1.08% of mean crude fiber contents for *bulla* samples derived from different enset landraces. Crude fiber is essential for healthy digestion and can avoid many gastrointestinal ailments [50, 51]. It also serves as a component of food and is becoming considered a useful tool in regulating oxidative processes in food products [52]. *Bulla* has lower contents of crude fiber when compared with enset corms, 2.40–4.50% [30, 53] and *qocho*, 3.22–5% [10, 42]. However, some *bulla*-derived dishes are regularly prepared with vegetables and cereals that promote and balance the fiber content in the diet.

3.1.6 Total carbohydrate content

The total carbohydrate content of the *bulla* produced from eight enset landraces is presented in Table 1 and is significantly varied ($p < 0.05$). The mean total carbohydrate values

ranged from 94.79% for the *Sisqella* landrace to 97.62% for the *Qiniwara* landraces. Nevertheless, there were no statistical variations ($p > 0.05$) in the mean total carbohydrate contents of the *Gimbo* and *Hiniba* and the *Anchire* and *Hayiwona* landraces, which were 96.90% and 95.63% on a dry basis, respectively. Comparable findings' were also notified by Atlabachew and Chandravanshi [40], 93–98%; Bekele et al. [27], 97.7%; Daba and Shigeta [17], 97.17%, for the mean total carbohydrate values of the *bulla* obtained from different enset landraces. These values are also higher than those of enset corms (*amicho*) and *qocho* from different studies. This study's laboratory findings also showed that the *bulla* samples taken from each enset landrace had high carbohydrate content values, supporting the notion that enset plants are often abundant in those nutrients.

3.2 Gross energy value

The gross energy value (kcal/100 g) of the *bulla* samples derived from the eight enset landraces ranged from 387.90 for the *Sisqella* landrace to 395.59 for the *Haywona* landrace, with a significant difference ($p < 0.05$), as indicated in Table 1. However, there were no statistically significant variations ($p > 0.05$) in the mean gross energy value of the *Agade* and *Hiniba* landraces, which were 393.08 and 394.17 on a dry basis, respectively. Likewise, in the *bulla* samples of the landraces *Gimbo* (394.95) and *Qiniwara* (395.02) enset, there was no statistically significant variation ($p > 0.05$) recorded for the mean gross energy value (kcal/100 g). The values of the present analysis are in line with what was described by Bekele et al. [27] and Daba and Shigeta [17], 393.19–394.24 and 393.71 kcal/100 g, respectively, for the mean gross energy value of the *bulla* sample obtained from the various enset landraces. This implies that *bulla* is an appreciated and least costly source of energy for humans. In general, enset-based foods are excellent sources of dietary energy from a nutritional perspective [10, 17].

3.3 Mineral content

Table 2 displays the mean mineral composition (calcium, potassium, magnesium, phosphorus, sodium, iron, and zinc) of *bulla* samples from eight selected enset landraces. The findings indicated significant ($p < 0.05$) variation between the *bulla* samples. The differences in genetic contents between landraces could cause variations in mineral concentrations of *bulla* samples.

Table 2 Mineral contents (mg/100 g) of *bulla* produced from eight Enset landraces

Landrace	Calcium	Potassium	Magnesium	Phosphorus	Sodium	Iron	Zinc
Agade	69.70 ± 2.08^{bc}	101.24 ± 2.15^{d}	12.78 ± 0.25^{b}	29.69 ± 0.34^{a}	3.86 ± 0.07^{cd}	4.15 ± 0.12^{d}	0.58 ± 0.06^{b}
Anchire	72.32 ± 1.85^{b}	119.33 ± 3.04^{b}	11.76 ± 0.32^{bc}	28.48 ± 0.28^{a}	5.15 ± 0.11^{a}	3.62 ± 0.08^{e}	0.42 ± 0.07^{cd}
Gimbo	65.42 ± 1.12^{d}	114.72 ± 2.17^{b}	12.42 ± 0.34^{b}	25.37 ± 0.85^{b}	5.26 ± 0.14^{a}	5.47 ± 0.21^{a}	$0.38 \pm 0.03d^{e}$
Hayiwona	68.73 ± 1.28^{c}	87.67 ± 1.56^{e}	10.78 ± 0.22^{cd}	19.85 ± 0.19^{d}	3.68 ± 0.09^{d}	4.85 ± 0.13^{c}	0.67 ± 0.09^{a}
Hiniba	$62.36 \pm 2.08d^{e}$	107.84 ± 2.34^{c}	9.91 ± 0.16^{d}	17.98 ± 0.21^{e}	5.21 ± 0.21^{a}	4.35 ± 0.17^{d}	0.54 ± 0.11^{b}
Qiniwara	64.16 ± 2.21^{d}	129.12 ± 2.57^{a}	17.15 ± 0.18^{a}	20.89 ± 0.19^{d}	4.31 ± 0.12^{bcd}	5.52 ± 0.22^{a}	0.31 ± 0.03^{e}
Separa	59.25 ± 1.86^{e}	83.54 ± 1.86^{e}	7.78 ± 0.13^{e}	22.98 ± 0.32^{c}	4.65 ± 0.06^{abc}	5.15 ± 0.07^{b}	0.38 ± 0.05^{de}
Sisqella	76.46 ± 1.75^{a}	129.61 ± 3.02^{a}	10.66 ± 0.18^{cd}	30.28 ± 0.56^{a}	4.78 ± 0.016^{ab}	3.84 ± 0.05^{e}	0.49 ± 0.08^{bc}
CV(%)	2.75	2.60	6.51	4.12	9.44	3.59	10.92

Mean values are the results of the triple analysis, and the values in a column with different superscripts indicate significant differences at the $p < 0.05$ level. CV = Coefficient of variance

The mean calcium concentration in the *bulla* samples varied from 59.25 to 76.46 mg/100 g, with the highest content observed in the *bulla* sample of the *Sisqella* landrace and the lowest in the *bulla* sample of the *Separa* landrace. Daba and Shigeta [17] reported the calcium values of *bulla* from the *Gena* enset landrace as 63.67 mg/100 g, which falls within the range of our findings in the present study. However, Abebe et al. [41] and Atlabachew and Chandravanshi [40] reported lower calcium content (44 mg/100 g) and (38.5–44.6 mg/100 g), respectively. Conversely, Bekele et al. [27] reported greater calcium concentrations of *bulla* from four enset varieties, ranging from 168 to 318 mg/100 g. The variation may result from management practices, genetics, or the environment of enset landraces. In general, enset-based food products provide a good amount of calcium content. It may be the reason that has traditionally been recommended by local consumers for some bone-related problems in humans as well as cattle [18]. Calcium concentrations are vital for human blood coagulation, tooth development, and bone composition [54, 55]. Calcium also sustains and carries out the biological processes of glandular production, muscle contraction, and nerve transmission [56].

The mean potassium concentration of *bulla* samples from eight enset landraces ranged from 83.54 to 129.61 mg/100 g on a dry weight basis, indicating significant variation (Table 2). The mean potassium concentration in *bulla* samples from the *Sisqella* and *Qiniwara* landraces was the highest, while those from the *Separa* landrace had the lowest content. These findings were slightly comparable to the works of Atlabachew and Chandravanshi [40], who reported 70.8–87.5 mg/100 g of potassium value in *bulla* samples. In contrast, Daba and Shigeta [17] and Tuffa [28] reported greater calcium concentrations (387 mg/100 g) and (211–331 mg/100 g) for *bulla* samples from various enset landraces, respectively. These larger disparities appeared to be caused by the climate, soil types, enset crop varieties utilized in the experiment, and the length of the fermentation process. Potassium is essential for the body's ability to control hypertension, heart rate, neurotransmission, and water balance [54, 57]. According to Gebeyehu et al. [58], potassium can also benefit those using diuretics for hypertension, regulate osmotic pressure and pH homeostasis, and enhance iron consumption.

The mean magnesium concentrations in the *bulla* samples varied from 7.78 mg/100 g for *Separa* to 17.15 mg/100 g for *Qiniwara*, as displayed in Table 2. The analyzed results indicated no significant differences within the *bulla* samples of *Agade* and *Gimbo and Hayiwona* and *Sisqella* enset landraces. The mean magnesium content of *bulla* samples in this finding was higher than that reported by Tuffa [28] (4–6.4 mg/100 g) and lower than the findings of Bekele (2015) (31.51–56.05 mg/100 g). However, the value reported by Atlabachew and Chandravanshi [40] and Daba and Shigeta [17] is comparable to the present findings. Genetic diversities, environmental factors, and soil composition differences may cause the variations in magnesium content between our results and those of previous studies. Magnesium is necessary for protein metabolism as well as the healthy operation of the nervous and muscular systems [59]. Also, it promotes bone density, a strong immune system, and blood sugar management, all of which support normal blood pressure [60]. Furthermore, magnesium is required for muscle contraction, maintenance of neuronal and membrane electrical potential, proper metabolism of calcium and phosphorus, and the operation of several enzyme systems [61].

Mineral analysis of the observed *bulla* samples of the different enset landraces showed a significant variation ($p < 0.05$) in phosphorus concentration, with the highest content of 30.28 mg/100 g for *Sisqella* and the lowest content of 17.98 mg/100 g for *Hiniba bulla* samples recorded on a dry weight basis. However, the mean phosphorus content of the *bulla* samples of the *Sisqella*, *Agade*, and *Anchire* landraces did not differ statistically ($p > 0.05$) (Table 2). The mean value of phosphorus in the *Anchire*, *Agade*, and *Sisqella* landraces in this study is consistent with the content reported by Daba and Shigeta [17] (mg/100 g) and Tuffa [28]. However, the mean values in other landraces were lower than the previous findings. Such differences within and among studies might be due to genetic and environmental factors. Phosphorus plays a crucial part in the production of nucleic acids, the formation and repair of healthy cells, and the ossification of bones by being deposited as calcium phosphate [62, 63]. Similarly, phosphorus is an essential component of all living cells and contributes to the enzyme-regulated energy-yielding metabolism, which also helps to manage the blood's acid-alkaline balance [58, 64].

There was variation in the mean sodium values among the analyzed *bulla* samples of landraces, from 3.68 mg/100 g in *Hayiwona* to 5.26 mg/100 g in *Gimbo* (Table 2). However, the measured mean values didn't indicate statistically significant variations within the landraces of *Anchire*, *Gimbo*, and *Hiniba* and *Qiniware*, *Separa*, and *Sisqelle* regarding sodium concentrations. The findings of the present mineral tests for the *bulla* samples of eight different enset landraces showed comparable sodium concentrations to those found by Daba and Shigeta [17] (4.01 mg/100 g). However, these values were much lower than the contents described by Atlabachew and Chandravanshi [40] (40.2–44.2 mg/100 g) for the different enset landraces. The deviation could be attributed to differences in the *bulla* production methods, the growth environment, or the genetic makeup of the enset landraces. According to Seifter and Chang [65], sodium is the primary extracellular ion in the body, controlling physiological fluids and preserving tissue's electric potential. On the other hand, consuming excess sodium may raise blood pressure [58, 66].

The iron contents in the *bulla* samples of enset differed significantly ($P < 0.05$) between the landraces in this study, ranging from 3.62 mg/100 g in the *Anchire* landrace to 5.52 mg/100 g in *Qiniwara* (Table 2). However, the analyzed mean values did not show statistically significant deviations within the landraces of *Gimbo* and *Qiniware*, *Agade* and *Hiniba*, and, *Anchire* and *Sisqelle* regarding iron concentrations. The mean value of iron in the present study is closely similar to the findings of Abebe et al. [41] and Atlabachew and Chandravanshi [40]. However, Bekele et al. [27] and Daba and Shigeta [17] reported relatively lower iron contents (1.5–2.55 mg/100 g) and higher contents (7.58 mg/100 g), respectively, for the *bulla* samples of different enset landraces. These deviations in iron content may be described by variations in genetic differences, climate factors, soil compositions, and production methods of the *bulla* samples. Iron is the primary component needed for the formation of hemoglobin, which is essential for the transportation of oxygen throughout the body as well as the oxidation of carbohydrates, lipids, and proteins [67, 68]. Anemia can result from hemoglobin levels falling below normal due to a chronic iron deficit [69].

As indicated in Table 2 the mean content of zinc differs significantly ($p < 0.05$) within *bulla* samples of the analyzed enset landraces, and the mean contents varied from 0.31 to 0.67 mg/100 g. *Qiniwara* had the lowest mean zinc concentration among the examined

landraces, while *Hayiwona* had the highest. Bekele et al. [27], Daba and Shigeta [17], and Tuffa [28] also described the zinc values (0.22–0.76 mg/100 g), which is in line with the contents of this study. In contrast, a greater mean zinc value that varied from 2.20 to 4.43 mg/100 g and a lower zinc value was noted by Atlabachew and Chandravanshi [40] and Abebe et al. [41], respectively; this could be attributed to several variables, including genetics, agronomic practices, environmental changes, and the production methods of samples. According to Ratsavong et al. [70], there are considerable differences in plant mineral concentrations depending on several factors, including disease, multiple transfers, sanitation, genotypes, and soil pollution. Zinc is a vital trace mineral critical for many biological functions, including healthy growth, brain development, behavioral response, bone production, and wound healing [71]. Similarly, Ratsavong et al. [70] described that the mineral concentration of plants differs significantly based on several aspects such as disease, multiple transferring, sanitation, genotypes, and soil pollution. It is also essential for good immunity, infection resistance, and healthy skin [72]. Furthermore, zinc is vital for synthesizing DNA and proteins, insulin function, liver activity, the metabolism of the ovaries, testes, and cell division [72, 73]. Overall, minerals are vital parts of the human diet because of their many physiological and metabolic roles [74].

3.4 Anti-nutritional factors

The normal metabolism of plants produces chemical substances known as anti-nutritional factors, or anti-nutrients, found in natural feedstuffs [75]. Some of these plant chemicals may be beneficial or harmful to human and animal health, depending on the amount consumed [76]. Previous research on the anti-nutrient values (such as oxalate, tannin, and phytate) of the enset *bulla* has not yet been conducted, except for Abebe et al. [41] and Bekele et al. [27], who reported on the *bulla* of the enset landrace's phytate and tannin value. Table 3 displays the *bulla* samples' phytate, tannin, and oxalate levels for the eight enset landraces (*Agade*, *Anchire*, *Gimbo*, *Hayiwona*, *Hiniba*, *Qiniwara*, *Separa*, and *Sisqelle*).

As shown in Table 3, the mean phytate levels of the considered enset landraces varied statistically ($P < 0.05$), ranging from 11.75 to 23.68 mg/100 g for *bulla* derived from the *Qiniwara* and *Agade* landraces, respectively. The *bulla* sample of *Agade* landrace provided twice higher phytate contents than that of *Qiniwara*, *Separa*, and *Hiniba*, which implies that there may be differences in phytate levels within enset landraces. These findings were slightly higher than those of Bekele et al. [27], who found 9.72–14.70 mg/100 g phytate levels in *bulla* samples of four enset cultivars. Environmental factors, genetic

Table 3 Anti-nutritional factors (mg/100 g) of *bulla* of eight Enset landraces

Landrace	Phytate	Tannin	Oxalate
Agade	23.68 ± 0.31^{a}	1.95 ± 0.03^{abc}	6.82 ± 0.12^{c}
Anchire	13.87 ± 0.22^{cd}	1.73 ± 0.02^{d}	5.41 ± 0.8^{f}
Gimbo	13.12 ± 0.18^{cd}	2.12 ± 0.05^{a}	6.15 ± 0.11^{d}
Hayiwona	17.13 ± 0.14^{b}	2.05 ± 0.02^{ab}	7.11 ± 0.06^{b}
Hiniba	12.48 ± 0.13^{cd}	2.00 ± 0.06^{ab}	6.14 ± 0.02^{d}
Qiniwara	11.75 ± 0.11^{d}	1.65 ± 0.03^{d}	5.97 ± 0.04^{d}
Separa	12.37 ± 0.16^{cd}	1.78 ± 0.02^{cd}	5.69 ± 0.03^{e}
Sisqella	15.20 ± 0.21^{cb}	1.93 ± 0.04^{bc}	8.10 ± 0.13^{a}
CV(%)	10.25	5.21	1.62

Mean values are the results of the triple analysis, and the values in a column with different superscripts indicate significant differences at the $p < 0.05$ level. CV = Coefficient of variance

diversity, and production procedures of the *bulla* seem to have contributed to this disparity among studies. Chandrasekara and Kumar [77] also described that a crop's phytic acid content may differ based on its genetic composition, environmental conditions, and farming methods. Phytate is the primary barrier to mineral absorption in plant-derived foods. Furthermore, the formation of insoluble mineral chelates in the body and food reduces the bioavailability of dietary minerals [78]. Therefore, to diminish the negative effects of phytates on mineral uptake, phytate levels should be lowered to less than 200 mg/100 g DM [79].

The mean tannin content values in *bulla* samples statistically varied ($p < 0.05$) across eight enset landraces, ranging from 1.65 to 2.12 mg/100 g. Relatively, *the Gimbo* landrace had the greatest tannin content (2.12 mg/100 g), followed by the *Hayiwona* (2.05 mg/100 g) and *Hiniba* (2.00 mg/100 g) landraces, but the *bulla* sample of the *Qiniwara* landrace, which has the lowest tannin content (Table 3). In contrast to the present study, the tannin level of *bulla* samples for the four enset landraces notified by Bekele et al. [27] was below detectable levels on a dry basis. These discrepancies may be caused by the enset plant's age variation, genetics, and production techniques. Tannin is a high molecular weight, water-soluble compound that drastically impacts nutritional values. Jacob et al. [54] state that tannin-rich foods are regarded as having low nutritional value because they can precipitate proteins and prevent digestive-related enzymes from working and reabsorption processes. Humans can safely take up to 560 milligrams of tannin daily [80, 81]. As a result, all enset *bulla* samples had low tannin levels and are safe for human consumption.

The mean amount of oxalate in *bulla* samples from eight distinct enset landraces in this study ranged from 5.41 to 8.10 mg/100 g, and there were significant differences ($p < 0.05$) among them. The *Anchire* landrace sample exhibited lower amounts of oxalate (5.41 mg/100 g), whereas the *bulla* sample of the *Sisqella* landrace had higher levels (8.10 mg/100 g), based on dry weight. However, these values fall far lower than the oxalate levels cited by Urga et al. [48] for the enset landraces' *qocho* sample (220 mg/100 g). Likewise, the values analyzed in this study are lower than those for other recognized Ethiopian tuber and root crops. Oxalate-rich diets can be detrimental to human nutrition and health, particularly because they impair calcium absorption and increase the risk of kidney stones [54, 82, 83]. The study's findings suggest that bulla doesn't contain enough oxalate to be hazardous to human health.

3.5 Molar ratios and bioavailability of minerals

The molar ratios of anti-nutrients to minerals are used to analyze the anti-nutrient inhibitory effect on the bioavailability of minerals in food and diet [84]. According to Gibson et al. [85], bioavailability is the proportion of a nutrient, particularly a mineral, absorbed and utilized through normal metabolic processes. It is influenced by the presence of oxalates, tannins, phytates, and dietary fiber [86]. As a result, only a small portion of the minerals in the food will be absorbed by the digestive system [87]. When the molar ratios of phytate to calcium, iron, and zinc surpass 0.24, 1, and 15, respectively, these minerals will undergo degradation and exhibit limited bioavailability [87, 88].

Table 4 shows the computed molar ratios of phytates-to-calcium, iron, and zinc, and phytates × calcium to zinc, in the *bulla* samples from eight enset landraces, which revealed significant variations ($p < 0.05$). The mean phytate-to-calcium molar ratio for all

Table 4 Calculated molar ratios of phytate to calcium, iron, and zinc and oxalate to calcium of *bulla* from eight Enset landraces

Landrace	Phytate: Ca	Phytate: Fe	Phytate: Zn	[Ph][Ca]/[Zn]	Oxalate: Ca
Agade	0.02 ± 0.00^{a}	0.49 ± 0.02^{a}	4.00 ± 0.5^{a}	6.92 ± 0.7^{a}	0.05 ± 0.02^{a}
Anchire	0.01 ± 0.00^{b}	0.32 ± 0.01^{c}	3.50 ± 0.3^{c}	6.30 ± 0.4^{b}	0.03 ± 0.00^{c}
Gimbo	0.01 ± 0.00^{b}	0.20 ± 0.01^{g}	3.33 ± 0.2^{d}	5.47 ± 0.2^{d}	0.04 ± 0.01^{b}
Hayiwona	0.02 ± 0.00^{a}	0.30 ± 0.02^{d}	2.60 ± 0.1^{g}	4.45 ± 0.1^{g}	0.05 ± 0.01^{b}
Hiniba	0.01 ± 0.00^{b}	0.26 ± 0.00^{e}	2.50 ± 0.1^{h}	3.90 ± 0.3^{h}	0.05 ± 0.00^{a}
Qiniwara	0.01 ± 0.00^{b}	0.18 ± 0.01^{h}	3.60 ± 0.4^{b}	5.76 ± 0.2^{c}	0.04 ± 0.01^{b}
Separa	0.01 ± 0.00^{b}	0.21 ± 0.00^{f}	3.17 ± 0.3^{e}	4.69 ± 0.3^{f}	0.04 ± 0.02^{b}
Sisqella	0.01 ± 0.00^{b}	0.33 ± 0.02^{b}	2.88 ± 0.1^{f}	5.46 ± 0.5^{e}	0.05 ± 0.01^{a}
CV(%)	33.84	3.81	2.67	1.84	31.13

Mean values are the results of the triple analysis, and the values in a column with different superscripts indicate significant differences at the $p < 0.05$ level. CV = Coefficient of variance

measured landraces falls between 0.01 and 0.02. Moreover, except for *Agade* and *Hayiwona* landraces, all the remaining landraces didn't show statistically significant differences. Accordingly, the observed mean molar ratios are lower than the critical values (< 0.24). This suggests that the dietary components of the *bulla* samples of the enset landraces under study could not be affected by phytates and exhibited good calcium bioavailability.

The mean content of the phytate-to-iron molar ratio differed from 0.18 to 0.49. The *bulla* sample prepared from the *Agade* landrace was observed to have the greatest, while the *Qiniwara* landraces had the lowest. This finding demonstrated that the phytate-to-iron molar ratios in the *bulla* samples were below the threshold value (1). This implies that the absorption of iron in the *bulla* samples was unaffected by phytate. Gibson et al. [85] described that iron bioavailability is regarded to be small when the phytate-to-iron molar ratio is greater than 1.

The mean phytate-to-zinc molar ratios of the *bulla* samples of *Hiniba* and *Agade* landraces exhibited the lowest (2.50) and highest (4.00) values. Based on this result, the *bulla* sample from the analyzed enset landraces indicated good zinc bioavailability. Given that the landraces' molar ratios fell below the threshold of levels (< 15). According to Gibson et al. [85], a phytate-to-zinc molar ratio higher than the threshold (> 15) signifies low zinc bioavailability.

The mean [phytate] [calcium]-to-zinc molar ratio of the computed *bulla* samples of enset landraces exhibited a significant difference ($P < 0.05$); the *Agade* (6.92) and *Hiniba* (3.90) landraces had the highest and lowest ratios, respectively. The mean values found in this study were lower than critical values, which indicated good zinc bioavailability. Hence, the [phytate] [calcium]-to-zinc molar ratio in the *bulla* samples of the analyzed enset landraces was by far lower than 200, which shows good zinc bioavailability [87]. In comparison to the phytate-to-zinc molar ratio alone, [phytate] [calcium]-to-zinc provides a more accurate measure of zinc bioavailability [85].

The mean value of the oxalate-to-calcium molar ratios of the *bulla* samples produced from eight different enset landraces oscillated between 0.03 and 0.05. Hence, the mean values of all analyzed samples were below the crucial values. This suggests that oxalates may not impact the bioavailability of calcium in the considered *bulla* samples due to the low amount of oxalate. The oxalate-to-calcium molar ratio below the critical value (1) is an indication of good calcium bioavailability [89].

Table 5 The pH value and titratable acidity (%) of *bulla* obtained from eight different Enset landraces

Landrace	pH value	TTA%
Agade	3.87 ± 0.6^{e}	1.14 ± 0.01^{c}
Anchire	4.07 ± 0.4^{a}	1.01 ± 0.00^{g}
Gimbo	3.87 ± 0.5^{e}	1.14 ± 0.02^{c}
Hayiwona	3.89 ± 0.4^{d}	1.12 ± 0.02^{d}
Hiniba	4.02 ± 0.5^{b}	1.03 ± 0.01^{f}
Qiniwara	3.68 ± 0.3^{f}	1.16 ± 0.03^{b}
Separa	3.67 ± 0.4^{g}	1.18 ± 0.04^{a}
Sisqella	3.92 ± 0.2^{c}	1.09 ± 0.00^{e}
CV(%)	1.92	1.28

Mean values are the results of the triple analysis, and the values in a column with different superscripts indicate significant differences at the $p < 0.05$ level. CV = Coefficient of variance

3.6 pH and total titratable acidity

The mean pH and total titratable acidity value of the *bulla* samples derived from the eight enset landraces are displayed in Table 5. Among the enset landraces analyzed, the *bulla* samples from *Anchire* landraces had the highest mean pH value (4.07), while the samples from *Separa* landraces had the lowest (3.67). However, Bekele et al. [27] reported lower pH values (2.80–3.42) for 30-day fermented *bulla* samples from four enset varieties. The observed variations could be explained by factors such as the age of the enset crop, fermentation length, agronomic methods, genetic makeup, and environment. On the other hand, Urga et al. [48] (3.80) and Yirmaga [45] (3.79) observed similar mean pH values for the fermented *qocho* samples, another enset product from different enset landraces. This demonstrates that the *bulla* samples utilized in this study had acidic pH values, meeting quality standards and being deemed suitable. Food samples that have a pH of 4 or below would exhibit a typically sour taste and odor due to fermentation [90]; the pH value is an appropriate quality determiner for naturally fermented foods [91]. Hence, the pH is a significant intrinsic component in fermented food since it establishes the microbiological stability against pathogenic microbes and food deterioration, in addition to being linked to the flavor of the product [92].

Table 5 displays that there was a significant variation in the mean percentage of total titratable acidity among the analyzed *bulla* samples of the enset landraces in the present study. The *bulla* sample derived from *Separa* had the highest mean titratable acidity value (1.18%), while the *Anchire* landraces had the lowest mean titratable acidity percent (1.01%). Urga et al. [48] reported the titratable acidity value of the *qocho* sample (1.54%), which was higher than the *bulla* of enset titratable acidity in the present study. Conversely, the results of these findings are higher than the titratable acidity notified by Yirmaga [45] (0.87%) for the 30-day fermented enset *qocho* samples. The differences could be attributed to the genotypic, environmental, and length of the fermentation and the types of enset food samples used.

4 Conclusion

This study has displayed notable differences in the nutritional and anti-nutritional components of *bulla* samples obtained from the eight commonly cultivated enset landraces. The study found that *Sisqella*, *Hayiwona*, and *Qiniwara bulla* samples exhibited the highest contents of proximate and minerals compared to other landraces analyzed. The present findings indicate that all *bulla* samples from the enset landraces analyzed exhibit

a lowered content of anti-nutritional factors, making them nutritionally beneficial. In a similar vein, the *bulla's* molar ratios for oxalate-to-calcium, phytate-to-calcium, phytate-to-iron, phytate-to-zinc, and [phytate] [calcium]-to-zinc were all below the critical values, indicating suitable mineral bioavailability. Thus, the present findings provide useful information on the nutritional and anti-nutritional contents of *bulla*, which vary significantly due to landrace differences. *Bulla* could be an excellent source for food diversification. Future research will expand the analysis to include microbial activity and sensory evaluations, beyond the current focus on nutritional and anti-nutritional aspects. Furthermore, to ensure food and nutrition security in the country, sustainable conservation methods and expansion to new areas are crucial.

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Author contributions
TD. wrote the main manuscript text and prepared figures. The author reviewed the manuscript.

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Data availability
The data that support the findings of this study are available from the author upon reasonable request.

Declarations

Consent for publication
Not applicable.

Ethics approval
The plant materials (*bulla)* used in this study were extracted and collected traditionally from widely cultivated enset landraces, employing *bulla*-producing procedures that adhere to local practices.

Consent to participate
Not applicable.

Competing interests
The authors declare no competing interests.

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