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Functional, physicochemical, and sensory attributes of enset (*Ensete ventricosum*) varieties as novel sources for starch-based foods

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Abstract

Enset (*Ensete ventricosum*) is a climate-resilient but underutilized crop with considerable potential for starch-based food applications. This exploratory study evaluated three enset varieties (Ado, Madicha, and Midasho) to characterize their physicochemical composition, functional properties, and suitability for simple food products (porridge and chips). Proximate composition, mineral content, starch yield, water absorption capacity, and bulk density were determined using standard analytical methods. Sensory acceptability was assessed using a 7-point hedonic scale with a 50-member untrained consumer panel. Madicha exhibited the highest starch yield (10.8%) and comparatively higher mineral contents, including calcium (92.2 mg/100 g) and zinc (1.75 mg/100 g), whereas Midasho showed the highest dry matter content. Significant varietal differences ($p < 0.05$) were observed in functional properties and consumer acceptability scores for both porridge and chips. The sensory results provide preliminary indications of consumer preference and are interpreted as exploratory rather than definitive. Overall, the studied enset varieties exhibited distinct compositional and functional attributes that influence their potential suitability for different starch-based food applications. These findings provide baseline evidence to support the diversification and valorization of enset as a climate-resilient resource for food and agro-industrial development.

Keywords Enset, Starch yield, Functional properties, Consumer acceptability, Climate-resilient crops

1 Introduction

Enset (*Ensete ventricosum*), a perennial monocarpic crop domesticated exclusively in Ethiopia, plays a central role in national food security and supports the livelihoods of more than 25 million people, particularly in the southern and southwestern highlands [8, 11, 14]. Its agronomic importance derives from high biomass productivity, exceptional drought tolerance, long in-field storability, and a flexible harvest window, attributes that collectively buffer households against climatic variability and seasonal food shortages [17, 19, 25]. Under increasing climate uncertainty, these characteristics position enset as a strategically important crop for resilient food systems in sub-Saharan Africa.

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The edible pseudostem and corm are processed into several traditional foods, including kocho (fermented dough), bulla (a refined starch fraction), and amicho (boiled corm). Among these, kocho is the primary staple, while bulla is valued for its high starch purity, light color, smooth texture, and ease of digestibility, making it suitable for children, elderly individuals, and convalescent consumers [9, 10]. Consumer acceptance of enset foods is closely linked to sensory attributes such as color, texture, mouthfeel, and flavor, which are influenced by varietal differences, maturity stage, and processing practices [10, 25].

Nutritionally, enset-based foods are predominantly carbohydrate-rich and constitute a major dietary energy source in enset-growing regions. Although not a primary source of micronutrients, enset products can contribute minerals such as iron and zinc, with reported concentrations varying considerably by genotype and processing method [8, 14]. Beyond traditional consumption, growing research interest highlights enset as a promising alternative starch source for diversified food products and potential industrial applications, including porridges, snack foods, and specialty starch ingredients, owing to its functional versatility, local availability, and sustainability advantages over imported starches [9, 10] .

Despite these advantages, scientific research on enset has largely emphasized fermented products, while the direct utilization of fresh corms for starch extraction and non-fermented food development remains limited. This gap is particularly notable given the existence of more than 100 cultivated enset landraces, which have been selected over generations for agronomic performance, yield stability, and processing quality across diverse agro-ecological zones [8, 25]. Comparative evidence linking varietal differences to physicochemical composition, techno-functional behavior, and sensory acceptability of starch-based foods is scarce, constraining efforts to standardize processing and guide varietal selection for value-added applications.

Advancing the utilization of enset beyond fermentation-dependent systems requires a systematic understanding of how varietal characteristics influence starch yield, functional properties, and consumer response in simple food matrices. Such knowledge is essential for identifying cultivars suited to specific applications, supporting small-scale processing enterprises, and informing agro-industrial development strategies aligned with consumer preferences and nutritional needs.

Therefore, the objective of this study was to evaluate three enset varieties (Ado, Madicha, and Midasho) with respect to their physicochemical composition, functional properties, and performance in starch extraction, porridge preparation, and chip production. Sensory acceptability was assessed using an exploratory consumer hedonic approach. By integrating compositional, technological, and consumer-oriented analyses, this study addresses critical knowledge gaps and provides baseline evidence to support the broader utilization of enset as an underutilized, climate-resilient starch crop.

2 Materials and methods

2.1 Sample collection and plant material

Three enset (*Ensete ventricosum*) varieties, Ado, Madicha, and Midasho, were harvested at approximately five years of physiological maturity from a farmer-managed production field in Boricha Woreda, Sidama Region, Ethiopia (6°52′ N, 38°23′ E; altitude ≈ 1,800 m above sea level) in November 2023. The area represents a typical mid-altitude

enset-growing agroecological zone characterized by bimodal rainfall and loamy soils. All plants were cultivated under comparable agronomic conditions, including rain-fed production supplemented with traditional household irrigation during dry periods, manual weed control, and organic soil amendment using farmyard manure. No mineral fertilizers or pesticides were applied. Harvest maturity was determined based on farmer knowledge and morphological indicators, including pseudostem thickness and corm development. For each variety, three healthy plants were randomly selected, harvested, and treated as independent biological replicates.

2.2 Hamicho preparation

The underground corm (hamicho) was manually separated from the pseudostem, washed thoroughly with potable water to remove adhering soil, peeled using stainless-steel knives, and trimmed to remove damaged tissues. Fresh hamicho was immediately processed for starch extraction, porridge preparation, and chips production to minimize enzymatic browning and moisture loss. All experimental work was conducted at the School of Food Science and Technology, Hawassa University, in collaboration with the Ethiopian Agricultural Research Institute.

2.3 Preparation of enset-based products

Porridge preparation: Starch (bulla) extracted from hamicho was air-dried at ambient temperature (25 ± 2 °C) and milled into flour using a laboratory grinder. Porridge was prepared by cooking starch flour with boiling distilled water at a starch-to-water ratio of 1:3 (w/v). This ratio and cooking time were selected based on preliminary trials and traditional preparation practices reported for bulla porridge [7] to obtain a homogeneous, spoonable consistency. The mixture was continuously stirred for 8 min, after which salt was added at 2.5% (w/w). Each formulation was prepared in triplicate.

Chips preparation: Hamicho was sliced to approximately 2 mm thickness using a manual stainless-steel slicer to ensure uniform heat transfer during frying. Two pretreatments were applied: (i) rinsing in cold potable water for 5 min to remove surface starch and (ii) blanching in boiling water (95 °C) for 3 min. Pretreatment conditions were established based on preliminary trials and commonly applied practices for root- and tuber-based chips. Treated slices were deep-fried in refined palm oil at 170 °C for 8 min using an oil-to-sample ratio of 5:1 mL: g). Refined palm oil was selected due to its high oxidative stability and widespread use in commercial frying applications. Fresh oil was used for each replicate to avoid cumulative oil degradation effects. Potato chips prepared under the same conditions served as controls. All treatments were conducted in triplicate.

2.4 Experimental design

Chemical, functional, and physicochemical analyses were conducted using a completely randomized design (CRD). Sensory evaluation was performed using a randomized complete block design (RCBD), with individual panelists treated as blocks to account for inter-panelist variability. Chip processing experiments followed a 2×4 factorial arrangement, examining the effects of pretreatment method (rinsing and blanching) and sample type (potato control, Ado, Madicha, and Midasho enset varieties). All experiments were

carried out using three independent biological replicates, and each analytical measurement was performed in triplicate (Table 1).

2.5 Starch extraction and yield determination

Fresh hamicho samples were peeled, chopped, and homogenized with distilled water at a 1:1 (w/v) ratio using a laboratory blender (R23, H. BIAUGEAUD, France). The resulting slurry was allowed to sediment at ambient temperature for 12 h to facilitate starch separation. The supernatant was decanted, and the starch suspension was filtered through a 710 µm stainless-steel mesh sieve to remove fibrous residues. The filtrate was then centrifuged to recover the starch fraction. The obtained starch sediment was sun-dried to constant weight, packed in polyethylene bags, and stored at room temperature until further analysis. Starch yield was expressed as a percentage of fresh hamicho weight and calculated using the following equation:

$$\text{Starch yield } (\%) = \left(\frac{\text{Weight of isolated starch (g)}}{\text{Weight of fresh hamicho (g)}}\right) \times 100$$

2.6 Functional properties of starch

- **Water absorption capacity (WAC)**: Water absorption capacity was determined according to Samsher [23]. One gram of starch sample was mixed with 10 mL of distilled water in a centrifuge tube and stirred for 3 min. The mixture was centrifuged at 3,000 rpm for 25 min, after which the supernatant was carefully decanted. WAC was expressed as milliliters of water absorbed per gram of starch and calculated as:

$$\text{SWAC (mL/g)} = \left(\frac{\text{Volume of water absorbed (mL)}}{\text{Sample weigh t (g)}}\right)$$

- **Bulk density**: Bulk density was measured following the method of Adebowale et al. [3]. Fifty grams of starch were gently filled into a graduated cylinder and tapped repeatedly until a constant volume was obtained. Bulk density was expressed as grams per milliliter (g/mL) and calculated as:

$$\text{Bulk Density (g/mL)} = \left(\frac{\text{Final weight} - \text{Initial weight}}{\text{Volume (mL)}}\right)$$

Table 1 Factorial arrangement of chips processing treatments

Processing method	Control (potato)	Ado	Madicha	Midasho
Rinsed (5 min)	COR	ARR	MRR	MIR
Blanched (3 min)	COB	ABR	MBR	MIB

COR: Control rinsed; COB: Control blanched; ARR: Ado rinsed; ABR: Ado blanched; MRR: Midasho rinsed; MBR: Midasho blanched; MIR: Midasho rinsed; MIB: Midasho blanched

Chemical composition analysis: Moisture, ash, and crude fiber contents were determined using standard AOAC methods (AOAC 930.15, 923.03, and 962.09, respectively). All analyses were performed in triplicate.

2.7 Mineral analysis (Ca, Fe, Zn)

Mineral contents were determined following the method described by Arinathan et al. [6]. Dried samples were dry-ashed in a muffle furnace at 550 °C for 6 h. The ash was dissolved in dilute hydrochloric acid and filtered, and the final volume was adjusted with distilled water. Calcium, iron, and zinc concentrations were quantified using an atomic absorption spectrophotometer (Shimadzu AA-6800, Japan). Mineral content was expressed as mg/100 g dry weight and calculated as:

$$\text{Mineral}\,(\text{mg}/100\text{g}) = \left(\frac{C_s - C_b}{10 \times W}\right) \times V$$

where: C_s = concentration in sample, C_b= blank reading, W = sample weight (g), V = final volume (mL).

2.8 Characterization of Hamicho chips

- **Oil uptake**: Oil content was determined by Soxhlet extraction using diethyl ether as solvent for 8 h, following AOAC [4]. Oil uptake was expressed as a percentage of fried chips weight and calculated as:

$$\text{Oil Uptake}\ (\%) = \left(\frac{(\text{Weight of extracted oil}}{\text{Weight of fried chips}}\right) \times 100$$

Texture analysis:Chips hardness was measured using a TA.XTplus100 Texture Analyzer (Stable Micro Systems, UK) equipped with a P/1S stainless steel probe. The force required to fracture each chips was recorded at a test speed of 1 mm/s over a distance of 3 mm. Measurements were performed in triplicate for each sample.

- **Viscosity**: Porridge viscosity was measured at 52 °C using a Brookfield RVDV-IT viscometer fitted with spindle No. 6 at 50 rpm, following the method of Tizazu et al. [24]. Measurements were conducted in triplicate.

2.9 Sensory evaluation

Sensory evaluation was conducted using a consumer hedonic panel comprising 50 untrained participants (18 men and 32 women, aged 20–40 years) from Hawassa University. Panelists were selected based on regular consumption of enset- and potato-based foods and absence of known food allergies. An orientation session was provided to explain the evaluation procedure and hedonic scale, without descriptive or intensity training. Porridge and chips samples were evaluated using a 7-point hedonic scale (1 = dislike very much; 7 = like very much) for appearance, color, flavor, taste, crispness (chips only), and overall acceptability [20]. Samples were coded with three-digit random numbers and presented in randomized order. Commercial bulla porridge and commercially

available potato chips served as reference controls. Drinking water was provided for palate cleansing between samples. The Institutional Research Ethics Committee of Hawassa University approved the sensory evaluation protocol, and written informed consent was obtained from all participants prior to the study.

2.10 Statistical analysis

Data were analyzed using JMP Pro 13.2.1 (SAS Institute, Cary, NC, USA). Data normality was assessed using the Shapiro–Wilk test, and homogeneity of variances was evaluated using Levene's test. One-way analysis of variance (ANOVA) was applied to starch and porridge data, while two-way ANOVA was used to assess the effects of variety and pretreatment on chips quality attributes. Mean comparisons were performed using Tukey's HSD test at a significance level of $p < 0.05$. Pearson correlation analysis was conducted to examine associations among chemical composition, functional properties, and sensory acceptability, with correlations interpreted strictly as associative rather than causal relationships.

3 Results and discussion

3.1 Effect of enset variety on bulla yield and functional properties

Enset genotype significantly influenced starch yield and functional attributes of bulla (Table 2). Madicha exhibited the highest starch recovery (10.8%, wb), associated with its lower fresh corm moisture content (75.2%), indicating superior dry-matter concentration and starch extractability. This positions Midasho as the most promising variety for industrial starch production. In contrast, Ado and Madicha produced lower yields (6.7% and 5.5%, respectively) and higher moisture contents, consistent with their traditional uses in fresh-corm cooking, chip preparation, and fermented products such as kocho and bulla.

Bulk density differed significantly among the enset starch varieties evaluated. Ado exhibited the highest bulk density (0.95 g/cm^3), followed by Madicha (0.88 g/cm^3), while Midasho showed the lowest value (0.84 g/cm^3). Elevated bulk density is technologically advantageous for energy-dense food formulations, improved packaging efficiency, and reduced transportation volume [9, 33].

The strong negative correlation observed between bulk density and calcium content ($r = -0.90$; Table 3) suggests an associative relationship between mineral composition and starch particle packing behavior. Divalent cations such as Ca^{2+} are known to

Table 2 Functional properties of bulla flour (starch) from three enset (Ensete ventricosum) varieties

Variety	Fresh moisture (%, wb)	Bulk density (g/mL)	Water absorption capacity (WAC, %)	Starch yield (%, wb)
Ado	79.62^b	0.95^a	112.97^a	6.72^b
Midasho	86.54^a	0.84^b	107.16^a	5.53^c
Madicha	75.18^b	0.88^b	114.44^a	10.80^a
SE	1.24	0.0095	3.32	0.040

Mean values are separated using Tukey's honestly significant differences test at α ($p < 0.05$); Mean values not connected by same letter are significantly different

SE: Standard. error; Mean values within each column followed by different superscript letters (a, b, c) are significantly different at $p < 0.05$ according to Tukey's Honestly Significant Difference (HSD) test. Values sharing the same letter are not significantly different.

Table 3 Pearson correlations among physicochemical properties of enset varieties ($n = 9$)

Variable 1	Variable 2	Correlation (r)	p-value	Significance
Calcium (mg/100 g)	Fresh moisture (%, wb)	0.7263	0.0267	*
Calcium (mg/100 g)	Total moisture content (%)	0.9862	< 0.0001	***
Zinc (mg/100 g)	Fresh moisture (%, wb)	0.6931	0.0384	*
Zinc (mg/100 g)	Crude fiber (%)	–0.8171	0.0072	**
Iron (mg/100 g)	Crude fiber (%)	0.8315	0.0055	**
Bulk density (g/cm^3)	Moisture content (%)	–0.9237	0.0004	***
Bulk density (g/cm^3)	Calcium (mg/100 g)	–0.8997	0.0010	**
Starch yield (%)	Fresh moisture (%, wb)	–0.8505	0.0037	**
Starch yield (%)	Crude fiber (%)	0.8684	0.0024	**
Starch yield (%)	Zinc (mg/100 g)	–0.8248	0.0062	**
Starch yield (%)	Iron (mg/100 g)	0.7248	0.0272	*

interact with hydroxyl groups on starch polymers, potentially modifying granule surface characteristics, inter-particle cohesion, and aggregation behavior. Such interactions can reduce packing efficiency, leading to lower bulk density despite similar granule size distributions. This interpretation is consistent with post-2010 evidence on starch structure–function relationships and mineral–starch interactions in food systems [17, 26]. However, the correlation remains associative and does not imply causality, warranting further targeted studies to elucidate the underlying mechanisms.

Water absorption capacity (WAC) ranged from 107% in Midasho to 114% in Madicha and did not differ significantly among the genotypes evaluated. The comparable WAC values indicate a uniformly high hydration potential, which is technologically desirable for applications such as porridges, soups, and complementary foods where water uptake and viscosity development are critical.

WAC is primarily governed by starch granule architecture, the availability of hydrophilic functional groups, and particle size distribution, which collectively determine the extent of water binding and swelling. The absence of significant genotypic differences suggests broadly similar starch structural characteristics among the varieties. This interpretation is consistent with previous findings on root and tuber starches, where hydration behavior was linked to granule morphology and polymer organization rather than varietal origin alone [1, 2, 24].

3.2 Correlations among physicochemical properties

Pearson correlation analysis (Table 3) revealed significant associations among starch yield, moisture, fiber, and mineral contents. Starch yield was inversely correlated with fresh moisture content ($r = -0.85$, $p = 0.0037$) and positively associated with iron content ($r = 0.72$, $p = 0.027$), suggesting that high-yielding varieties such as Midasho may be associated with improved micronutrient retention rather than implying a direct causal relationship.

Crude fiber exhibited a positive association with iron ($r = 0.83$, $p = 0.0055$) and negative associations with zinc ($r = -0.82$, $p = 0.0072$) and starch yield ($r = -0.82$, $p = 0.0062$). These patterns suggest that fiber-rich fractions may preferentially bind or co-localize with iron while limiting zinc extractability and starch release during processing. Such associations are consistent with evidence that mineral distribution within plant tissues and fiber–mineral interactions influence mineral partitioning and bioaccessibility without necessarily reflecting causality [21, 35].

Table 4 Flour Physicochemical and Mineral Properties of Bulla Flour

Variety	Fresh moisture (%)	Moisture content (%)	Ash (%)	Fiber (%)	Ca (mg/100 g)	Zn (mg/100 g)	Fe (mg/100 g)
Madicha	86.54 ± 0.69^{a}	13.77 ± 0.52^{a}	0.52 ± 0.18^{a}	0.26 ± 0.02^{b}	92.18 ± 5.30^{a}	1.75 ± 0.09^{a}	1.57 ± 0.12^{b}
Midasho	75.18 ± 2.61^{b}	8.45 ± 0.41^{b}	0.50 ± 0.17^{a}	0.40 ± 0.05^{a}	60.81 ± 1.87^{b}	1.45 ± 0.10^{b}	2.30 ± 0.20^{a}
Ado	79.62 ± 2.01^{b}	4.91 ± 0.02^{c}	0.55 ± 0.12^{a}	0.23 ± 0.01^{b}	47.19 ± 1.53^{c}	1.63 ± 0.06^{ab}	0.84 ± 0.10^{c}

Values are mean ± SD ($n = 3$). Different superscript letters within a column indicate significant differences among Bulla flour varieties using Tukey's Honestly Significant Difference (HSD) test ($p < 0.05$)Within each column, means followed by different superscript letters (a, b, c, ab) are significantly different at $p < 0.05$ according to Tukey's Honestly Significant Difference (HSD) test. Shared letters (e.g., "ab") indicate no significant difference between those groups.

Table 5 Oil uptake and hardness of hamicho and control (potato) chips across genotypes and pretreatment methods

Variety	Pretreatment	Oil Uptake (%)	Hardness (g)
Control	Blanching	20.50 ± 0.12^{g}	166.51 ± 3.40^{ab}
Control	Cold water rinsing	20.50 ± 0.12^{g}	166.51 ± 3.40^{ab}
Ado	Blanching	30.25 ± 0.60^{c}	220.06 ± 38.92^{a}
Ado	Cold water rinsing	28.00 ± 0.26^{d}	210.05 ± 40.63^{a}
Madicha	Blanching	33.13 ± 0.40^{a}	124.43 ± 9.20^{b}
Madicha	Cold water rinsing	32.19 ± 0.23^{b}	173.02 ± 32.62^{ab}
Midasho	Blanching	24.83 ± 0.20^{e}	122.52 ± 13.54^{b}
Midasho	Cold water rinsing	22.27 ± 0.24^{f}	129.55 8.59^{b}

Mean values (n = 3) are separated using Tukey's honestly significant difference test at α = 0.05. Values not sharing the same superscript letter in a column differ significantly Values are mean ± SD (n = 3). Within each column, means followed by different superscript letters (a, b, c, …, g) are significantly different at $p < 0.05$ according to Tukey's Honestly Significant Difference (HSD) test. Shared letters indicate no significant difference between those values.

3.3 Chemical composition and mineral content of bulla flour

The chemical composition of bulla flour varied significantly among enset genotypes (Table 4). Moisture content ranged from 4.91% (Ado) to 13.77% (Madicha), with Midasho intermediate (8.45%), consistent with previous reports [15] and within safe storage limits [10, 12] . Lower moisture was associated with higher flour compactness ($r = -0.924$).

Ash content (0.50–0.55%) did not differ significantly among genotypes but exceeded values in national food composition tables, indicating superior mineral retention in directly extracted bulla. Crude fiber was highest in Midasho (0.40%) and positively correlated with starch yield and iron, suggesting that fibrous fractions contribute to micronutrient retention during processing. Despite low absolute fiber levels, combining bulla with high-fiber foods could improve dietary value.

Mineral composition differed significantly by genotype. Calcium was highest in Madicha (92.18 mg/100 g) and positively associated with moisture content, reflecting its role in water binding and tissue integrity [32]. Iron peaked in Midasho (2.30 mg/100 g), correlating with starch yield and fiber content, consistent with its localization in structural tissue. Zinc was highest in Madicha (1.75 mg/100 g) and lowest in Midasho (1.45 mg/100 g), showing positive correlation with moisture but negative correlations with fiber and starch yield. These mineral levels, while nutritionally relevant, remain below adult RDAs, emphasizing the importance of dietary diversification.

3.4 Oil uptake, texture, and sensory properties of hamicho chips

Oil uptake and hardness: Oil uptake and hardness were significantly influenced by genotype, pretreatment, and their interaction (Table 5). All enset chips absorbed more

oil than potato controls (20.5%), ranging from 22.3% (Midasho, rinsed) to 33.1% (Madicha, blanched). Higher oil absorption in Madicha corresponds to lower dry matter and higher initial moisture, which enhance porosity and facilitate oil migration during frying [13, 22].

Blanching increased oil uptake (29.4%) relative to cold water rinsing (27.5%), consistent with structural softening, cell wall disruption, and increased surface porosity that promote oil migration [25]. The largest effect was observed in Madicha-blanched chips (~60% higher oil absorption than potato controls), highlighting the combined influence of genotype and pretreatment on oil retention.

Hardness varied among genotypes ($p < 0.05$). Ado chips were the hardest (≈215 g), comparable to potato controls (≈167 g), while Midasho produced the softest chips (≈126 g), particularly under blanching. Pretreatment alone did not significantly alter hardness, but a genotype × pretreatment interaction was evident, reflecting varietal differences in starch gelatinization, cell wall composition, and structural collapse during frying [26, 32].

From a product development perspective, Ado chips combine high crispness with moderate oil uptake for premium snacks, Midasho is suited to low-oil or industrial starch applications, and Madicha offers versatility depending on processing conditions.

3.5 Sensory evaluation of hamicho chips

Consumer panel results confirmed significant effects of genotype and pretreatment on appearance, flavor, crispiness, taste, and overall acceptability (Table 6). Potato controls scored highest (>6.3), serving as the benchmark. Among enset varieties, Ado and Madicha rinsed samples achieved moderate acceptability (~5.6), while Midasho-blanched chips received the lowest ratings (<4.8), consistent with softer texture and lower oil retention.

Cold water rinsing improved acceptability relative to blanching, particularly in Midasho, where appearance and flavor scores increased by 10–14%. Genotype × pretreatment interactions were critical, indicating that rinsing can enhance sensory quality in varieties with moderate oil uptake and hardness. These patterns align with instrumental measurements, supporting the use of Ado for consumer-preferred fried snacks and Midasho for low-fat or starch-focused applications.

Table 6 Sensory evaluation scores (mean ± SD) of Hamicho chips prepared from three enset varieties subjected to different pretreatments

Control blanched	Appearance	Flavor	crispiness	Taste	Overall acceptability
	6.16 ± 0.68^{a}	**6.32 ± 0.82^{a}**	**6.18 ± 0.63^{a}**	**6.22 ± 0.82^{a}**	**6.32 ± 0.62^{a}**
Control rinsed	6.26 ± 0.69^{a}	6.36 ± 0.75^{a}	6.28 ± 0.57^{a}	6.24 ± 0.80^{a}	6.4 ± 0.61^{a}
Ado blanched	5.22 ± 1.07^{c}	4.74 ± 1.08^{c}	5.42 ± 1.31^{b}	5.04 ± 1.05^{b}	4.98 ± 1.23^{c}
Ado rinsed	5.48 ± 0.86^{bc}	5.22 ± 1.15^{bc}	5.48 ± 0.89^{b}	4.96 ± 1.14^{b}	5.6 ± 0.99^{b}
Madicha blanched	5.02 ± 1.04^{cd}	5.12 ± 1.24^{bc}	5.22 ± 0.93^{bc}	5.2 ± 1.20^{b}	4.88 ± 1.00^{c}
Madicha rinsed	5.94 ± 0.79^{ab}	5.64 ± 0.88^{b}	5.46 ± 0.91^{b}	5.32 ± 0.98^{b}	5.56 ± 0.76^{b}
Midasho blanched	4.24 ± 1.02^{e}	4.66 ± 1.10^{c}	4.8 ± 1.14^{cd}	4.78 ± 1.31^{b}	4.72 ± 1.01^{c}
Midasho rinsed	4.48 ± 1.15d^{e}	4.96 ± 0.95^{c}	4.62 ± 1.11^{d}	4.78 ± 0.89^{b}	4.86 ± 0.99^{c}

Values are expressed as mean ± standard deviation (n = 50). Means within a column followed by different superscript letters (a–e) are significantly different at p < 0.05 according to Tukey's HSD test

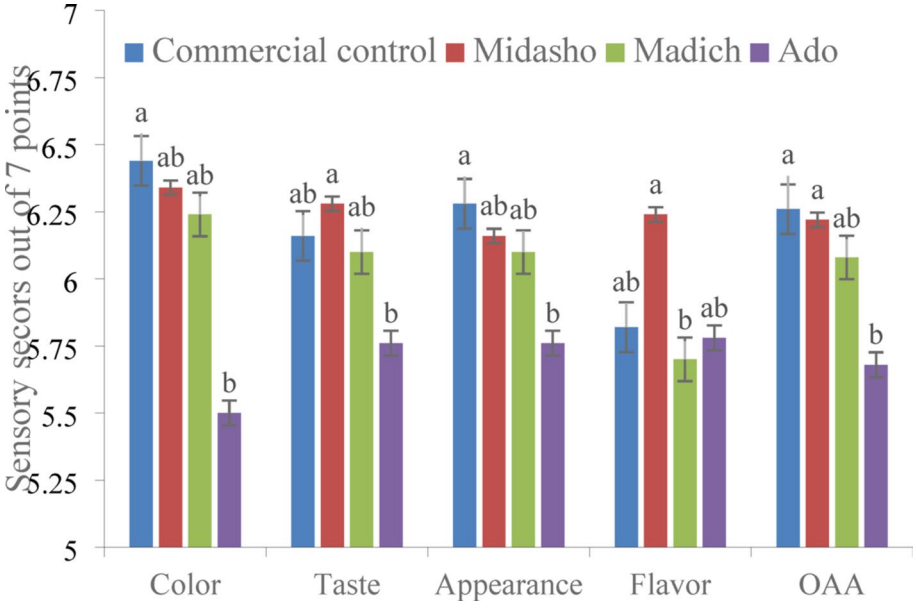

Fig. 1 porridge sensory properties influenced enset genotypes

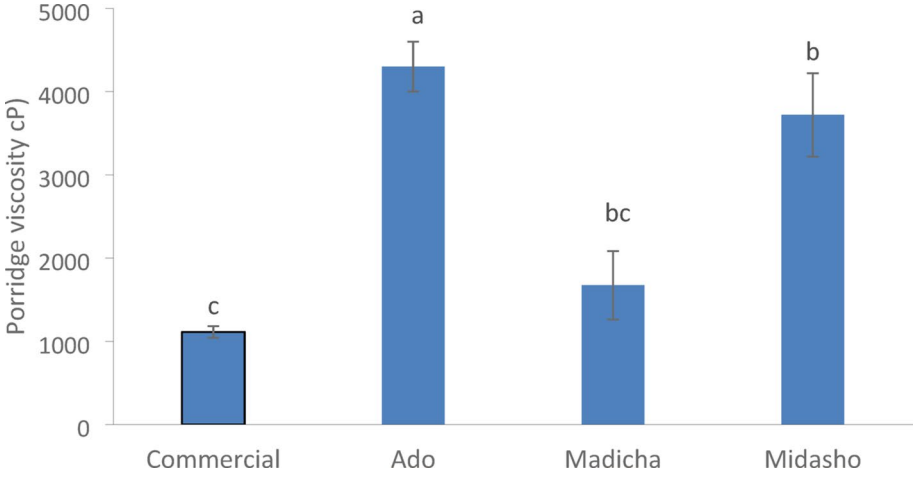

Fig. 2 Viscosity of porridges prepared from three enset varieties and commercial bulla control. Control*- Commercial bulla from market

3.6 Porridge characterization and functional properties

Sensory evaluation of porridges prepared from three enset varieties and a commercial bulla control revealed significant differences across all attributes (Fig. 1). Midasho porridge scored highest for color (6.34), taste (6.28), appearance (6.16), flavor (6.24), and overall acceptability (6.22), statistically comparable to the commercial control. Ado porridge was least preferred due to higher starch content and excessive viscosity, resulting in a stiff, pasty mouthfeel. Madicha porridge scored intermediate, better than Ado but below Midasho and the control.

Instrumental viscosity measurements (Fig. 2) corroborated the sensory findings. Midasho exhibited the highest viscosity (3720 cP), followed by Ado (3600 cP), whereas Madicha (1673 cP) and commercial bulla (1113 cP) showed lower values. High viscosity is culturally valued in traditional Ethiopian diets for satiety and perceived quality.

Despite Ado's elevated viscosity, its lower sensory scores highlight the importance of mouthfeel and texture alongside viscosity in determining consumer acceptance [2, 8].

Overall, Midasho appears most suitable for porridge production due to its favorable combination of sensory and functional properties. Ado and Madicha may require formulation adjustments or blending to enhance palatability and consumer acceptability.

4 Conclusion

This study demonstrated clear varietal differences among three enset genotypes, Ado, Madicha, and Midasho, significantly affected physicochemical composition, functional properties, and performance in starch-based applications. Madicha exhibited the highest starch yield, indicating suitability for direct starch extraction and formulation. Midasho, with higher dry matter and favorable viscosity, is promising for thicker porridges. Ado, especially following blanching, produced chips with desirable texture and sensory attributes, suitable for fried snack development. Porridges and chips from all varieties achieved acceptable hedonic ratings, demonstrating consumer receptivity to non-fermented enset products. These findings highlight enset's potential as a versatile, climate-resilient crop for diverse food applications and provide guidance for selecting genotypes for industrial starch production, thick-porridge formulations, and fried snack development. Limitations include the small number of varieties, exploratory consumer panel, and correlational analyses. Future work should expand varietal evaluation, employ advanced sensory profiling, and assess processing scalability and nutritional bioavailability to support industrial utilization.

Author contributions

M.B. designed the study, conducted laboratory experiments, performed data collection, and contributed to data analysis. D.A. conceptualized the research, supervised the laboratory work, performed statistical analysis, and wrote the main manuscript draft. T.F.T. assisted in methodology development, interpreted sensory data, and contributed to manuscript revision. All authors reviewed and approved the final manuscript.

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Data availability

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the ethical standards of relevant institutional and national research committees. Ethical approval for the sensory evaluation involving human participants was obtained from the School of Nutrition, Food Science and Technology Ethics Committee, Hawassa University, Ethiopia. All procedures complied with the Declaration of Helsinki and institutional guidelines. Written informed consent was obtained from all participants prior to inclusion. Sensory evaluation panelists comprised undergraduate students and staff (aged 20–40 years) from the Department of Food Science and Technology, Hawassa University. Participation was voluntary, and participants were fully informed of the study purpose, procedures, and their right to withdraw at any time without penalty.

Consent for publication

Written informed consent for participation and publication of anonymized data was obtained from all participants.

Competing interests

The authors declare no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Plant material collection and guidelines

Ensete ventricosum plant materials were collected in compliance with local and national regulations governing research on cultivated plants. Samples were obtained from sources commonly used for food production in Ethiopia. No endangered or protected species were involved.

Permissions and licences

Permission to collect and use Ensete ventricosum for research purposes was obtained from relevant local authorities and landowners where applicable. No additional permits or licences were required.

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References

1. Adebowale KO, Olu-Owolabi BI, Lawal OS. Functional properties and retrogradation behaviour of native and chemically modified starches from Mucuna pruriens. Int J Food Sci Technol. 2011;46(11):2278–86.
2. Adebowale KO, Henle T, Schwarzenbolz U, Doert T. Modification and functional properties of African yam bean (Sphenostylis stenocarpa) starch. Food Chem. 2012;130(2):250–6
3. Adebowale YA, Adeyemi IA, Oshodi AA. Functional and physicochemical properties of flours of six Mucuna species. Afr J Biotechnol. 2005;4(12):1461–8.
4. AOAC. Official methods of analysis. 15th ed. Washington, DC: Association of Official Analytical Chemists; 1990.
5. AOAC. Official methods of analysis. 21st ed. Gaithersburg, MD: AOAC International; 2019.
6. Arinathan V, Mohan VR, Maruthupandian A. Nutritional and anti-nutritional attributes of some underutilized tubers. Trop Subtropical Agroecosystems. 2009;10(2):273–8.
7. Asrat W. Development of suitable processes for Ethiopian traditional foods using quality protein maize. In: Proceedings of the 3rd National Maize Workshop of Ethiopia. CIMMYT: Addis Ababa. 2012. pp. 261–267
8. Ayele, D. A., Teferra, T. F., Frank, J., & Gebremedhin, S. Optimization of nutritional and functional qualities of local complementary foods of southern Ethiopia using a customized mixture design. Food Science & Nutrition, 2022;10(1), 239–252.
9. Ayenew, E., Tesfaye, K., & Chanyalew, D. Characterization of enset starch for food and industrial applications. International Journal of Food Science, 2021;2021, 1–10.
10. Bello, K. O., Akanji, A. O., Irekhore, O. T., & Lala, A. O. Anti-endoparasitic effects of garlic (Allium sativum) as a supplement in diets of rabbits reared under deep litter system. Applied Tropical Agriculture, 2016; 21(2), 1–7.
11. Birmeta G, Nybom H, Bekele E. Genetic variation and population structure of enset (Ensete ventricosum) landraces used in traditional Ethiopian agriculture. Agron Sustain Dev. 2019;39:1–12.
12. Bolade MK, Adeyemi IA, Ogunsua AO. Influence of particle size on physicochemical properties of maize flour and textural characteristics of non-fermented gels. Int J Food Sci Technol. 2009;44(3):646–55
13. Bosha T, Dalbato AL, Tana T, Mohammed A. Nutritional and anti-nutritional composition of enset (Ensete ventricosum) corm and pseudostem products consumed in Ethiopia. Food Sci Nutr. 2016;4(6):929–35.
14. Brandt SA, Spring A, Hiebsch C, McCabe JT, Tabogie E, Diro M, Welde-Michael G, Yntiso G, Shigeta M, Tesfaye S. The tree against hunger: enset-based agricultural systems in Ethiopia. AAAS; 2014.
15. Chandra S, Singh S, Kumari D. Evaluation of functional properties of composite flours and sensory attributes of biscuits. J Food Sci Technol. 2015;52(6):3681–8.
16. Chantaro P, Chalermchaiwat P, Harnsilawat T. Effect of pre-treatment on quality of cassava chips. RMUTP Res J. 2020;14(1):154–64.
17. Charrondière, U. R., & Burlingame, B. Nutritional composition of Ensete ventricosum (Welw.) Cheesman. Food Chemistry, 2011; 127, 1232–1237.
18. Feleke S, Mekbib F, Tesfaye K. Diversity, production systems, and utilization of enset (Ensete ventricosum) in Ethiopia: A review. J Ethnobiol Ethnomed. 2022;18:1–15.
19. Gebremariam MM, Solomon T, Teshome A. Influence of oil uptake and crispness on consumer acceptability of deep-fried snacks. Food Res Int. 2021;139:109966.
20. Getachew A, Desta W, Bekele A. Comparison of enset starch with commercial starches and its pharmaceutical applications. Br Biotechnol J. 2016;14:1–8.
21. Gibson, R. S., Bailey, K. B., Gibbs, M., & Ferguson, E. L. A review of phytate, iron, zinc, and calcium concentrations in plant-based complementary foods used in low-income countries and implications for bioavailability. Food and Nutrition Bulletin, 2018;39(2), 163–179.
22. Jane J-L, Ao Z, Duvick SA, Wiklund M, Yoo S-H, Wong K-S, Gardner C. Structures of amylopectin and their relationships to physicochemical properties of starch. Carbohydr Polym. 2012;87(1):224–31.
23. Joy EJM, Ander EL, Young SD, Black CR, Watts MJ, et al. Dietary mineral supplies in Africa. Physiol Plant. 2014;151(3):208–29.
24. Hiwot, B. Effect of enset (Ensete ventricosum (Welw.) Cheesman) variety and fermentation on nutritional composition, anti-nutritional factors, physicochemical characteristics and functional properties of bulla (MSc thesis). Hawassa University, Ethiopia, 2015.
25. Kita, A., & Lisińska, G. The influence of blanching on the quality of fried potato products. LWT – Food Science and Technology, 2015; 63(1), 72–78.
26. Kita, A., Lisinska, G., & Golubowska, G.The effects of oils and frying temperatures on the texture and fat content of potato chips. Food Chemistry, 2014; 146, 53–59.
27. Mohammed B, Gabel M, Karlsson LM. Nutritive values of the drought-tolerant food crop enset. Afr J Agric Res. 2013;8(20):2326–33.
28. Olaoye OA, Onilude AA, Oladoye CO. Breadfruit flour in biscuit making: Effects on product quality. Afr J Food Sci. 2007;1(2):20–3.
29. Olango TM, Tesfaye B, Catellani M, Pè ME. Indigenous knowledge and on-farm management of enset diversity in southern Ethiopia. J Ethnobiol Ethnomed. 2015;11:1–14.
30. Pedreschi F, Moyano P. Effect of pre-drying on texture and oil uptake of potato chips. LWT – Food Sci Technol. 2005;38(6):599–604.
31. Samsher, Chandra S. Assessment of functional properties of different flours. Afr J Agric Res. 2013;8(38):4849–52.
32. Sobukola, O. P., Kajihausa, O. E., Onwuka, G. I., & Esan, T. A. Physical properties and frying characteristics of potato slices as affected by pretreatment methods. Journal of Food Processing and Preservation, 2019; 43(3), e13880.
33. Suresh, C., Samsher, S., & Prakash, J. Effect of processing on physicochemical and functional properties of cereal-based food powders. Journal of Food Science and Technology, 2013, 50, 1020–1026.
34. Tizazu S, Urga K, Abuye C, Retta N. Improvement of energy and nutrient density of sorghum-based complementary foods using germination. Afr J Food Agric Nutr Dev. 2010 https://doi.org/10.4314/ajfand.v10i8.60875

35. Welch, R. M., & Graham, R. D. Agriculture: The real nexus for enhancing bioavailable micronutrients in food crops. Journal of Trace Elements in Medicine and Biology, 2015; 31, 76–82.
36. Yemataw Z, Tesfaye K, Zeberga A, Blomme G. Exploiting indigenous knowledge of enset landraces to improve resilience. Genet Resour Crop Evol. 2018;65:227–40.
37. Zhu F. Interactions between starch and minerals: A review. Food Res Int. 2015;74:173–83.

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