



Research article

Effect of Oromo Dinich (*Plectranthus edulis*) flour supplemented on quality characteristics of teff-maize composite injeraAyana Fekadu^a, Yetenayet B. Tola^b, Addisalem Hailu Taye^b, Ebisa Olika Keyata^{a,*}^a Department of Food and Nutritional Science, Wollega University, PO Box 38, Shambu, Ethiopia^b Department of Post-Harvest Management, Jimma University, College of Agriculture and Veterinary Medicine, PO Box: 307, Jimma, Ethiopia

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ABSTRACT

Blending Oromo dinich flours with cereals-based flours significantly enhances the nutritional potential of cereals-based products. Therefore, this study aimed to develop and evaluate the quality of teff-based injera supplemented by underutilized indigenous tuber Oromo dinich (*Plectranthus edulis*) and maize flours. Fourteen formulations were generated using D-optimal constrained mixture design with a range of maize (5–15%), *Plectranthus edulis* (5–15%), and teff (70–90%). Statistical evaluation and optimization were done using D-optimal mixture design expert software. The results showed that the supplementation of more *Plectranthus edulis* flour in the formulations indicated better improvements in terms of protein (10–10.8%), fat (2.4–2.8%), gross energy contents (380.7–391.9 kcal/100g), total phenolic content (8.6–15.8 mg GAE/g) and total antioxidant capacity (66.20–82.7%) at the concentration of 3.32 mg/mL. The sensory acceptability of the injera was significantly ($p < 0.05$) liked in terms of aroma with increasing the ratio of *Plectranthus edulis* and maize flours. The optimum value of the blending ratio was 77.6% teff, 13.1% maize, and 9.3% *Plectranthus edulis* flours with desirable nutritional composition of injera, which varied for protein (10.7–10.8%), fat (2.62–2.8%) and energy (388.3–391.9 kcal/100g) and overall acceptance (5.5–6.3) with the desirability of 0.66. The optimization results indicated that supplementing *Plectranthus edulis* flour up to 10% with teff-maize composite flours were acceptable in terms of nutritional composition and sensory quality. Thus, supplementing underutilized indigenous *Plectranthus edulis* tuber flour with teff-maize flours significantly enhanced the nutritional potential of injera products.

1. Introduction

Oromo dinich (*Plectranthus edulis*) is one of the underutilized indigenous tubers in Ethiopia and has a long history of local usage and is important to the cultural, social, and economic life of households (Aschale and Tesfu, 2021). The tuber can grow at mid-to-high latitudes in the southern, north, and south-west of Ethiopia and produces edible tubers on below-ground stolons and highly advanced for nutritional undertake and starve satisfying expression (Taye et al., 2013). The same authors also indicated that in different growth areas of Ethiopia, the dissimilar vernacular name is used for *Plectranthus edulis*. These are Dinicha Oromo in Oromia, Wolaita Sodo around Wolaita, Gamo dinich around Gamo Gofa Zone, Agew Dinch in the northwest, and Gurage Dinich around Gurage zone.

Traditionally *Plectranthus edulis* tuber is consumed by boiling unpeel tuber with stew prepared from different spices and hot pepper in some regions of Ethiopia (Taye et al., 2007). It is recommended as a special food in the community for people recovering illness and has no impact on

the stomach when consumed (Mekbib and Weibull, 2012). Hellemans et al. (2017) and Gifty et al. (2018) reported that *P. edulis* tubers have a good nutritional potential such as protein (11.4–15.8%), fibre (4.2%), fat (10.9%), vit. C (60 mg/100g), reducing sugar (3.67–7.26%) and minerals (3.67–7.26%). It is also an important source of different health-enhancing bioactive compounds and antioxidant capacity (Melaku and Duguma, 2016). Because of this potential, the flour extracted from *P. edulis* tuber can be applied in food formulations to supplement macro and micronutrients and increase health benefits.

Accordingly, utilizing indigenous crops, like *P. edulis* tuber in teff-maize composite injera production would reduce the dependence on teff flours, an indigenous cereal crop used in Ethiopia, mainly to make injera (Bultosa, 2007). However, the Central Statistical Agency of Ethiopia (2019) reported that the nominal price of teff elevated by 72% from 2015 to mid-2018. To overcome the pressure of high price inflation on teff, it is a common practice to add less costly ingredients from different sources to teff flours to formulate acceptable quality injera (Abraha and Abay, 2017).

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So far, supplementing underutilized indigenous Oromo dinich (*P. edulis*) with staple teff and maize for injera formulation is not yet explored. Given this, the study was designed to formulate and optimize Oromo Dinich (*P. edulis*) flour supplementation on quality characteristics of Teff-Maize composite Injera for better nutritional and sensory acceptability, which could be an alternative ingredient to replace a portion of costly flours teff to sustain access to food for the low-income Ethiopian community.

2. Materials and methods

2.1. Experimental materials

About 25kg of local variety of Oromo dinich (*P. edulis*) tuber, red teff (local variety), and maize (BH-660) were sourced from a farmer in Horro

district, Oromia region, Western Ethiopia. The selection of ingredients was based on the food consumption culture of the local community, mainly using maize and teff grains as a staple food.

2.2. Raw materials preparation

2.2.1. Preparation of teff flour

Teff flour preparation was conducted according to Yassin and Getu (2019). Teff grain sample was cleaned manually by sifting and winnowing before milling to remove damaged grains and other extraneous materials and milled using miller (RRH-200, Zhejiang, and China) to whole flour fineness level of sieve size 0.5 mm and used for injera making. The prepared sample was sealed in a polyethene plastic bag and kept at room temperature for further laboratory analysis.



A. *P. edulis* tuber washing



B = *P. edulis* peel,



C = *P. edulis* slices



D = dried *P. edulis* slices,



E = *P. edulis* flour)

Figure 1. Oromo dinnich (*P. edulis*) flour preparation.

2.2.2. Preparation of maize flour

The maize sample was prepared according to the method reported by Cherie et al. (2018). The sample was cleaned, sorted manually, milled and sieved using a 0.5 mm sieve size. Finally, the flour was packed into a polyethylene plastic bag for further use and stored at room temperature.

2.2.3. Oromo dinnich (*P. edulis*) tuber

The sample of *P. edulis* tuber was dried in a solar tunnel dryer according to the method described by Kaur et al, (2013) and indicated in Figure 1. Before the drying process, the uniform size of the *P. edulis* was sorted and then washed thoroughly to remove any dirt such as soil and minimize the load of micro-organisms or other impurities. Then tuber was boiled by using cooker at 96 °C for 5 min in boiling water to inactivate the peroxidase enzyme according to the method described by Sengül et al. (2014), then peeled and sliced into 0.5 cm thickness made it ready for drying. The sliced tubers were placed on a stainless steel tray and dried in a solar tunnel dryer for two days. The average drying temperature and relative humidity during daytime recorded outside the solar tunnel dryer were 40.8 ± 7.90C and 29.14 ± 10.31% RH. The average drying temperature and relative humidity during daytime for the inside solar tunnel dryer were 63.7 ± 14.60C and 12.7 ± 8.8% RH. The slice was dried until brittle enough, and then milled using a laboratory-scale grinder (RRH-200, Zhejiang, and China). The milled sample was sieved using a 0.5 mm sieve size, packed in polyethylene bags, and stored in a dry place until used for laboratory analysis.

2.3. Experimental design

Before choosing constraints to formulate injera, preliminary studies were conducted based on color, taste, aroma, and eyes of injera. D-Optimal mixture design within the constrained of teff (70–90%), *Plectranthus edulis* (5–15%) and maize flour (5–15%) was used after preliminary tests. Then, 14 runs were generated using design expert software.

2.4. Injera preparation

The injera was prepared according to the method described by Yetneberk et al. (2004) and presented in Figure 3. The method involves backslope fermentation, in which composite flour (200 g) was mixed with water (180 mL) and fermented dough from the previous batch (i.e. named “Ersho” in local language), allowed to ferment for 72 h at room temperature (i.e. first phase of fermentation) in the plastic jar. After fermentation was completed, 10% fermented dough was mixed with water (1:2) and cooked at 230 °C for 3 min to prepare dough binder (i.e. local name “absit”). Then, the whole content was cooled at room temperature and added back to the fermenting dough and kept for 4 h (i.e. second phase of fermentation). The bubble formation of the dough was indicated as the endpoint of fermentation.

2.4.1. Preparation of injera flours

Fresh baked injera was dried according to the method used by Yegrem et al. (2021). The samples were dried at 60 °C for 24 h in a drying oven (DHG-9203 (A)) and milled using a laboratory miller (RRH-200, Zhejiang, and China) a 0.5 mm sieve. Then the samples were kept in a sealed plastic bag at room temperature for further analysis.

2.5. Determination of proximate composition

The proximate composition such as moisture, crude protein, crude fat, crude fibre, and total ash contents was determined according to the Association of Official Analytical Chemists AOAC (2000) Methods No: 925.10, 920.87, 920.39, 962.09, and 923.03, respectively. A different method reported by FAO (1998) was used to determine TCC (total carbohydrate content), and Atwater’s conversion ratios were used to compute gross energy content: 4 kcal/g for protein, 9 kcal/g for fat, and 4 kcal/g for carbohydrate (FAO, 2002).

Table 1. Analysis of variance (ANOVA), Lack of fit, p-values and adjusted R² for proximate composition, energy, polyphenol content, anti-nutritional factors and sensory properties of injera prepared from teff-maize-*P. edulis* composite flours.

Source	MC		CP		CFA		CF		Ash		CHO		EN		TPC		antioxidant		Tan		Phy		Col		Aro		Tas		Tex		Ov	
	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*	Special-Cubic*	Cubic*		
Linear mixture	0.0001	0.0001	0.0001	0.0206	0.0077	0.0001	0.0058	0.0008	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0006
A*B	0.0002	0.0155	0.0155	0.0193	0.0031	0.5293	0.0066	0.0012	0.1055	—	—	0.0001	0.1337	0.0279	0.0193	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.0042
A*C	0.0003	0.0152	0.0152	0.0161	0.0066	0.0793	0.0119	0.0010	0.2133	—	—	0.0001	0.9698	0.4203	0.7041	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.0051	
B*C	0.0002	0.5112	0.5112	0.6290	0.0659	0.6216	0.0755	0.0646	0.0395	—	—	0.0009	0.0026	0.8350	0.0181	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1527	
A*B*C	0.0002	0.0003	0.0003	0.0241	0.0097	—	0.0069	0.0053	—	—	—	—	0.0114	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.0492	
AB (A-B)	—	—	—	0.0166	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
AC (A-C)	—	—	—	0.0203	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
BC(B-C)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Lack-of fit	0.3447	0.8588	0.8588	0.0551	0.05801	0.0575	0.059	0.116	0.1458	0.2142	0.1759	0.5708	0.4337	0.7222	0.5706	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.6621	
R ² adj	0.9905	0.9239	0.9239	0.7436	0.7438	0.8342	0.7019	0.8554	0.9643	0.6153	0.9962	0.9783	0.8470	0.8331	0.8339	0.8339	0.8339	0.8339	0.8339	0.8339	0.8339	0.8339	0.8339	0.8339	0.8339	0.8339	0.8339	0.8339	0.8339	0.8339	0.7978	

MC = moisture content, CP = crude protein, CFA = crude fat, CF = crude fibre, CHO = carbohydrate, EN = gross energy, TPC = total polyphenol content, Tan = tannin content and Phy = phytate content Col = Color, Aro = Aroma, Tas = Taste, Tex = Texture and Ov = Overall acceptability R = coefficient of determination, (* = P < 0.05), A = maize, B = *P. edulis*, C = teff.

2.6. Determination of antinutrient contents

The condensed tannin and phytate content was determined using a UV-Vis spectrophotometer (Cecilce 2031 Instruments Cambridge England) described by Maxson and Rooney (1972) and Vantraub and Lapteva (1988), respectively.

2.7. Determination of total phenolic contents

Total phenolic content (TPC) was determined using a UV-Visible spectrophotometer according to the method of Singh et al. (2014). A 0.1g sample was added to 20 mL of methanol for extraction. Then the sample was placed in a mechanical shaker (Hy-2(C), Shanghai, China) at room temperature for 24 h. Then, the sample was centrifuged (Sigma 2-16KC, USA) for 15 min at 1107 g and filtered with Whatman No.1 paper. Then one millilitre of extracts was mixed with two millilitres of 2N Folin-Ciocalteu reagent. Immediately, two millilitres of 7.5% sodium carbonated solution were added, and the volume was filled with deionized water to make the total 10 mL. During oxidation with FC reagent, a phenol compound was reduced to blue-colour molybdenum and tungsten oxides. After 90 min, the absorbance of the solution was measured by UV-Vis spectrophotometer at a wavelength of 765 nm against the blank sample. The total phenolic content was determined from standard curve of Gallic acid equivalent (GAE) (25–600 mg/L, $Y = 0.001X + 0.112$, $R^2 = 0.995$) and expressed as mg of GAE/g.

2.8. Determination of total antioxidant capacity

The total antioxidant capacity was determined according to the method of Rajauria et al. (2010). For assay of 2, 2-diphenyl-1-picrylhydrazyl (DPPH), 0.1 g of powdered food sample was weighed, and 20 mL methanol (99.8%) was added to the sample for extractions. Then the sample was put in a mechanical shaking (ZHWHY- 103B) at 3 g, room temperature for 24 h. After the extraction, the sample was centrifuged (Sigma 2-16KC, USA) for 15min (1107 g) and filtered with Whatman No.1 filter paper. DPPH solution was prepared by dissolving four milligrams of DPPH with 1000 mL of methanol (99.8%), covered the DPPH solution, and kept in refrigerators. The series solution was prepared using 2 mL of 0.004% DPPH solution and mixed with various concentrations (0.8, 1.6, 2.4, and 3.32 mg/mL) of the sample extracts in methanol.

Finally, the solution was incubated in the dark at 30 °C for 60 min; then, absorption was measured at 517 nm by UV-Vis spectrophotometer. The percent inhibition of free radical DPPH was calculated according to Eq. (1).

$$\text{Radical scavenging activities(\%)} = \frac{\text{Control abs} - \text{test abs}}{\text{Control abs}} * 100 \quad \text{Eq. 1}$$

The extract concentration that provides 50% of radical scavenging activity (IC50) was calculated from the graph percentage of DPPH inhibition versus extract concentration (Burits and Bucar, 2000).

2.9. Sensory evaluation

The sensory evaluation was carried out by 50 semi trained panellists using staff and students of Food Science and Nutrition at Wollega University's Shambu Campus who had the knowledge of sensory attributes such as colour, appearance, aroma, taste, texture, rollability, number of eyes, and overall acceptability. The injera samples prepared for sensory evaluations within 2 h after baking. The age ranges of the panellists ranged from 20–35 years old. Twenty-two (22) participants were female, while twenty-eight (28) were male. A product sample was arranged, and each panellist was instructed on the sensory evaluation procedure. Panellists were instructed to make their assessments according to their best feeling after testing the product. The parameters tested for injera were flavour, aroma, colour, rollability, appearance, and overall acceptance using a 7-point hedonic scale (1 = dislike very much, 2 = dislike moderately, 3 = dislike slightly, 4 = neither like nor a dislike, 5 = like 6 = like moderately, 7 = like very much).

2.10. Ethical approval

Ethical clearance was obtained from the ethics committee of the Board of College of Agriculture and Veterinary Medicine, Jimma University. Written consent was taken from the panellists for their participation before the start of the test.

2.11. Optimization of injera formulations

Optimizations of injera formulations were performed using design expert software based on the maximization of crude protein, crude fat,

Table 2. Proximate composition and gross energy contents of teff based injera supplemented with Oromo dinich (*P.edulis*) and maize flours.

Maize (%)	<i>P.edulis</i> (%)	Teff (%)	MC	Crude Protein	Crude Fat	Crude Fiber	Ash	UCHO	Energy
5	15	80	65.8 ± 0.6	10.7 ± 0.0	2.4 ± 0.0	4.8 ± 0.0	3.0 ± 0.1	79.0 ± 0.7	380.7 ± 2.8
5	5	90	58.7 ± 0.5	10.7 ± 0.0	2.4 ± 0.1	3.5 ± 0.0	3.6 ± 0.1	79.9 ± 0.5	383.8 ± 2.5
15	5	80	59.8 ± 0.4	10.4 ± 0.0	2.6 ± 0.0	2.9 ± 0.0	2.8 ± 0.2	81.4 ± 0.5	390.5 ± 2.1
15	5	80	59.9 ± 0.4	10.5 ± 0.0	2.6 ± 0.1	2.9 ± 0.1	2.8 ± 0.1	81.0 ± 0.4	389.1 ± 1.9
15	15	70	64.8 ± 0.5	10.1 ± 0.0	2.6 ± 0.0	2.4 ± 0.0	2.9 ± 0.0	82.0 ± 0.5	391.9 ± 1.6
5	10	85	63.6 ± 0.7	10.6 ± 0.0	2.4 ± 0.0	3.7 ± 0.0	3.4 ± 0.2	79.9 ± 0.9	383.8 ± 3.6
10	5	85	60.4 ± 1.0	10.4 ± 0.0	2.8 ± 0.0	2.6 ± 0.1	3.1 ± 0.1	81.1 ± 1.1	391.3 ± 4.1
5	5	90	58.5 ± 0.4	10.7 ± 0.0	2.9 ± 0.0	3.5 ± 0.1	3.5 ± 0.1	79.7 ± 0.6	384.2 ± 2.2
5	15	80	65.5 ± 0.4	10.5 ± 0.0	2.4 ± 0.0	4.7 ± 0.0	3.2 ± 0.1	79.2 ± 0.6	380.7 ± 2.0
10	15	75	64.9 ± 1.3	10.6 ± 0.0	2.8 ± 0.1	4.1 ± 0.1	3.1 ± 0.1	79.5 ± 1.4	385.2 ± 5.3
10	8	82	63.8 ± 1.0	10.7 ± 0.0	2.4 ± 0.0	2.7 ± 0.1	3.0 ± 0.3	81.3 ± 1.1	389.2 ± 4.7
15	15	70	65.8 ± 0.8	10.0 ± 0.0	2.6 ± 0.1	2.5 ± 0.1	3.0 ± 0.04	82.0 ± 0.6	391.1 ± 3.9
10	10	80	62.9 ± 0.8	10.8 ± 0.0	2.7 ± 0.1	2.6 ± 0.4	3.0 ± 0.2	81.0 ± 1.4	390.9 ± 5.9
15	10	75	61.7 ± 0.7	10.7 ± 0.0	2.7 ± 0.0	4.3 ± 0.0	3.1 ± 0.1	79.3 ± 0.5	384.2 ± 2.5
		Mean	62.6 ± 0.3	10.52 ± 0.1	2.56 ± 0.11	3.36 ± 0.4	3.09 ± 0.1	80.45 ± 0.6	386.9 ± 1.6
CV			8.04	1.63	4.28	12.69	3.31	0.71	0.4
P < 0.05			0.0002	0.0003	0.0355	0.0097	0.0104	0.0069	0.0053
R ² adj			0.9905	0.9239	0.7436	0.7438	0.8342	0.7019	0.8553

P. edulis = *Plectranthus edulis*.

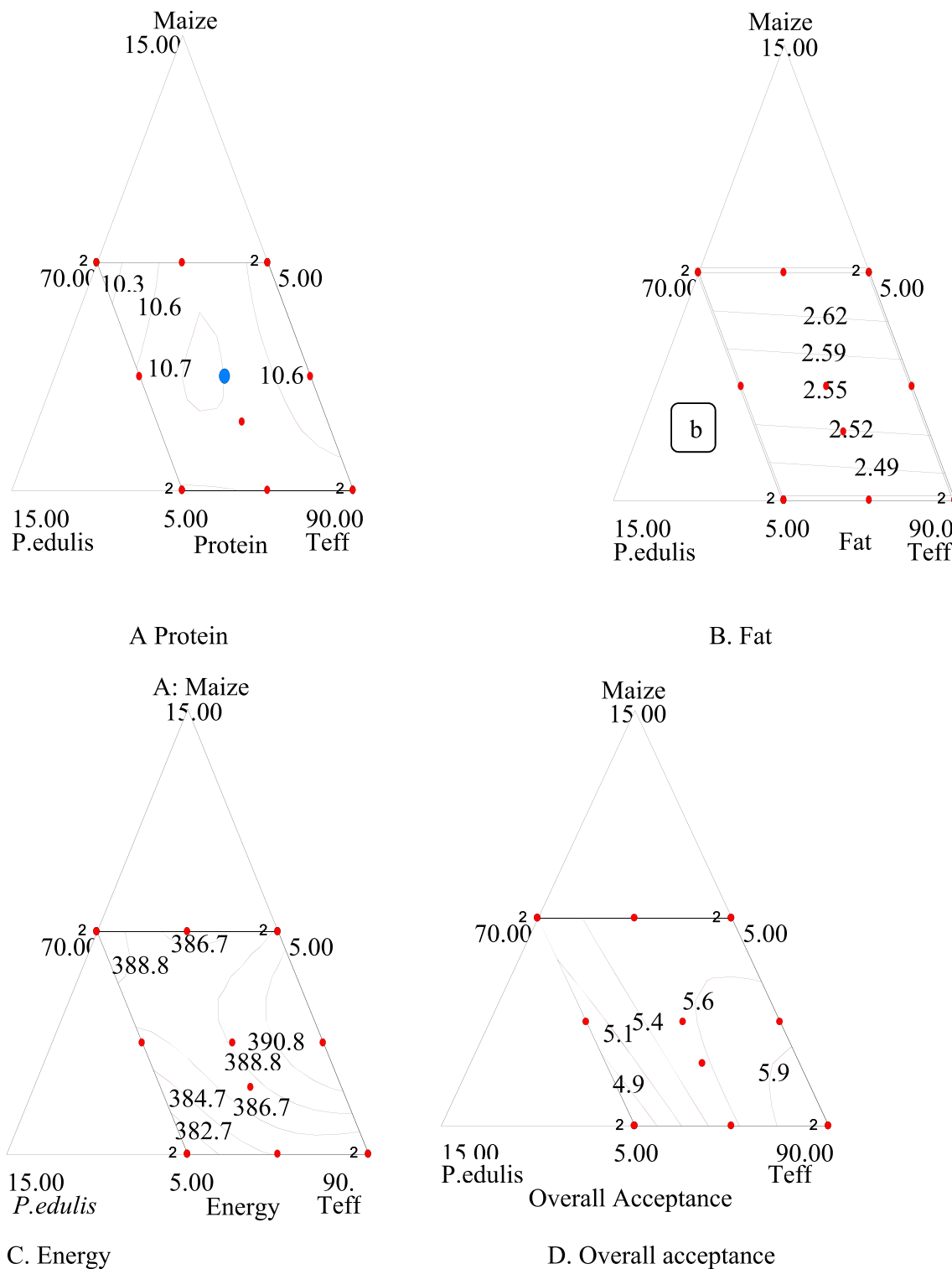


Figure 2. Contour plots displaying selected proximate composition and sensory acceptability of composite injera flour: A. Crude protein B. Crude fat C. Gross energy D. Overall acceptability.

gross energy, and sensory acceptability while minimization of other parameters.

2.12. Statistical analysis

The data obtained from the experiment were analysed using design expert software (design expert[®] version 6.02, Minneapolis, USA). The

statistical significance was examined by analysis of variance (ANOVA) for each response, and the significance test level was set at 5% ($p < 0.05$). All of the parameters' fitted models such as linear, quadratic, cubic and special cubic were generated. Graphical optimization was done to determine the optimum blend of teff, P. edulis, and maize composite injera with desirable chemical composition and overall sensory acceptability.

Table 3. Anti-nutritional factor of teff based injera supplemented with Oromo dinich (*P.edulis*) and maize flours.

Maize %	<i>P.edulis</i> %	Teff %	Tannin mg/100g	Phytate mg/100g
5	15	80	4.2 ± 0.5	135 ± 0.1
5	5	90	3.3 ± 0.4	138.3 ± 1.0
15	5	80	30.6 ± 0.7	151.9 ± 0.1
15	5	80	30 ± 1.3	151.8 ± 0.9
15	15	70	22.9 ± 0.5	143.4 ± 0.2
5	10	85	4.7 ± 0.5	140.3 ± 0.3
10	5	85	9.9 ± 1.1	144.3 ± 0.2
5	5	90	3.03 ± 1.4	138.9 ± 0.8
5	15	80	3.5 ± 0.72	136 ± 0.2
10	15	75	6.8 ± 0.7	137.4 ± 0.6
10	8	82	8.34 ± 2.2	141.2 ± 0.2
15	15	70	21.9 ± 0.5	145.5 ± 1.0
10	10	80	10.4 ± 0.4	142.8 ± 0.2
15	10	75	28.5 ± 2.3	147.2 ± 0.8
	Mean		13.4 ± 0.7	142.4 ± 0.8
	CV		4.65	0.55
	P < 0.05		<0.0001	0.0114
	R ² adj		0.9962	0.9783

3. Results and discussion

3.1. Proximate composition, antinutrient contents antioxidants capacity, and sensory properties of formulated injera

3.1.1. Model selection

The ANOVA p-values for proximate, energy, TPC, antioxidant capacity, antinutrient contents, and sensory quality of injera are presented in Table 1. The result shows that the special cubic model can describe changes in moisture content, protein, crude fibre, utilizable carbohydrate, gross energy, and phytate content, as well as the texture of developed composite injera ($p < 0.05$), as shown in Table 1. The quadratic model can well describe the variations in the total ash, tannin content, and phenolic content as well as colour, aroma, and overall acceptability of composite injera at a significant level of ($p < 0.05$) (Table 1). The cubic model can describe the difference in the crude fat content of baked injera at a ($p < 0.05$) significant level. The linear models for total antioxidant capacity and taste had a high predictive power to express the changes in the formulated injera ($p < 0.05$). The non-significant ($p > 0.05$) lack of fit in models confirmed that the selected models fit well with the proximate composition, antinutrients, total phenolic content (TPC), total antioxidant capacity, and sensory attributes of formulated injera.

3.1.2. Proximate composition and energy contents

The proximate composition and gross energy contents of the injera flour formulated from teff, maize, and *Plectranthus edulis* are presented in Table 2.

The blending ratio had a significant ($p < 0.05$) effect on the moisture content of the composite injera samples. The mean moisture content of the formulated injera increased from 59.34 to 62.83% with the blending ratios of *P. edulis* flour to teff-maize flours. This might be due to the higher water-binding capacity of the starch in *P. edulis* flour and the low moisture content of *P. edulis* flour (Gifty et al., 2018). The moisture content of the composite injera sample in this study was within the acceptable range of moisture content of fresh injera reported by Ashagrie & Abate (2012) (62–65%) and Cherie et al. (2018) (58.47–65.81%).

The mean crude protein content of the 14 formulated injera flours varied from 10.0 to 10.8 % (Table 2), depending on the type and percentage of ingredients proportion incorporated in each formulation. The

Table 4. Total phenolic content and antioxidant capacity of teff based injera supplemented with Oromo dinich (*P.edulis*) and maize flours.

Maize %	<i>P.edulis</i> %	Teff %	TPC mg/g	DPPH %	IC ₅₀ mg/ml
5	15	80	15.6 ± 0.3	82.7 ± 0.8	1.6 ± 0.0
5	5	90	9.2 ± 1.4	75.2 ± 0.1	1.8 ± 0.1
15	5	80	8.9 ± 0.7	66.8 ± 1.2	2.2 ± 0.01
15	5	80	9.3 ± 0.4	66.0 ± 0.3	2.0 ± 0.0
15	15	70	13.4 ± 0.3	77.1 ± 0.9	1.5 ± 0.1
5	10	85	11.5 ± 0.1	79.9 ± 1.2	1.2 ± 0.1
10	5	85	8.7 ± 0.4	74 ± 1.0	1.7 ± 0.3
5	5	90	9.4 ± 0.3	71.8 ± 0.6	2.0 ± 0.01
5	15	80	14.8 ± 0.3	80.1 ± 2.2	1.7 ± 0.1
10	15	75	15.4 ± 0.3	77.7 ± 0.3	1.8 ± 0.1
10	8	82	12 ± 0.6	79.6 ± 3.2	1.6 ± 0.1
15	15	70	13.3 ± 0.1	80.5 ± 1.4	1.1 ± 0.04
10	10	80	11.2 ± 0.6	80.2 ± 0.3	1.1 ± 0.1
15	10	75	10.3 ± 0.4	79.9 ± 0.8	1.5 ± 0.1
	Mean		11.6 ± 0.5	76.7 ± 3.3	1.6 ± 0.2
	CV		4.04	4.30	12.58
	P < 0.05		0.0454	0.0021	0.0471
	R ² adj		0.9643	0.6153	0.5779

results showed that the protein content of composite injera flour increased with a reduction in the proportion of maize and *P. edulis* flour and an increase in teff flour in the formulation (Figure 2a). Similar protein content (9.4–13.3%) was reported from injera formulated with teff, sorghum, and maize (Legesse, 2015). The findings showed that supplementing *P. edulis* flour with maize and teff flour did not significantly improve the protein contents in the formulated injera. This could be due to tuber flour adding more carbohydrates than protein contents. The multiple regression model of crude protein contents with all three variables indicated in Table 6.

Dietary fat enhances the palatability of food by absorbing and retaining flavours (Mezgebo et al., 2018). The fat content increased from 2.4 to 2.8% with an increase in maize ratios in the formulation of teff-based injera (Figure 2b). The increment of fat content in this study could be due to the fat content of maize (4.45%) being more than double teff (2%) (Bultosa et al., 2002). The obtained result was higher than the fat content (0.13–1.84%) of injera developed from teff-maize-cassava composite injera (Woldemeskel et al., 2014). This might be due to the incorporation of different proportion ratios of maize flour and the variation of fat content in *P. edulis* and cassava flour. The results depicted that incorporation of *P. edulis* flour with maize and teff flour did not enhance fat contents in the formulated product because of the low-fat content of tuber flours.

The crude fibre contents of developed injera decreased from 4.8 to 2.4%, with a decrease in the proportion of *P. edulis* flours and increase teff and maize flours in the formulation. This could be due to the crude fibre content of *P. edulis* (2.84–3.49%) (Gifty et al., 2018) higher than in maize flour (1.7%) (Tsegay et al., 2019). The result was greater than the fibre content (2.32%) of teff-cassava composite injera reported by Tadesse (2016). The findings highlight that naturally, tuber flour contains a high amount of fiber compared to cereal grain. Because of this, reduction of *P. edulis* proportion ration decreases fiber contents in formulated injera than teff and maize flours.

The ash content indicates the complete mineral makeup of a specific amount of food (Mishra and Chandra, 2012). The study showed that the total ash content of composite injera increased from 2.78 to 3.58%, increasing the proportion of teff and decreasing ratios of *P. edulis* and maize flours in the formulation. This might be because of total ash content of teff (3.16%) was higher than maize flour (1.20%) (Mesfin and Shimelis, 2013).

Table 5. Sensory property of injera supplemented with Oromo dinich (*P.edulis*), maize and teff flours.

Maize	<i>P.edulis</i>	Teff	Color	Aroma	Taste	Texture	Rollability	No eyes	Appearance	OVA
5	15	80	4.17 ± 0.58	6.58 ± 0.67	4.42 ± 0.67	4.25 ± 0.75	4.27 ± 0.89	5.58 ± 1.00	4.00 ± 0.60	4.75 ± 0.45
5	5	90	5.83 ± 0.71	5.33 ± 0.65	5.50 ± 0.80	5.58 ± 0.67	6.27 ± 0.78	5.50 ± 0.67	5.92 ± 1.00	5.92 ± 0.67
15	5	80	5.33 ± 0.49	5.33 ± 0.65	5.58 ± 0.79	5.08 ± 0.30	4.18 ± 0.75	6.08 ± 0.67	5.33 ± 0.49	5.58 ± 0.67
15	5	80	5.25 ± 0.45	5.25 ± 0.75	5.75 ± 1.14	4.58 ± 0.51	3.64 ± 1.22	6.00 ± 0.60	4.92 ± 0.30	5.00 ± 0.43
15	15	70	4.92 ± 0.67	5.92 ± 0.67	4.75 ± 0.45	4.33 ± 0.65	4.45 ± 0.52	5.33 ± 0.78	5.08 ± 0.67	5.25 ± 0.75
5	10	85	5.33 ± 0.65	5.58 ± 0.67	5.17 ± 0.58	5.33 ± 0.65	5.55 ± 0.79	5.42 ± 0.67	5.08 ± 0.67	5.42 ± 0.67
10	5	85	5.83 ± 0.58	5.50 ± 0.8	6.00 ± 0.74	6.42 ± 0.67	6.00 ± 0.60	6.08 ± 0.79	6.17 ± 0.93	5.92 ± 0.79
5	5	90	6.42 ± 0.67	5.33 ± 0.65	6.17 ± 0.58	6.00 ± 0.60	6.00 ± 0.43	5.33 ± 0.65	5.92 ± 0.79	6.25 ± 0.62
5	15	80	4.42 ± 0.52	6.17 ± 1.03	4.33 ± 0.65	4.33 ± 0.78	4.36 ± 0.67	5.33 ± 0.78	3.92 ± 0.67	4.67 ± 0.65
10	15	75	4.58 ± 0.67	6.17 ± 0.58	4.25 ± 0.75	4.50 ± 0.67	4.00 ± 0.67	5.67 ± 1.23	4.33 ± 0.65	4.75 ± 0.45
10	8	82	5.67 ± 0.49	5.33 ± 0.78	5.25 ± 0.62	5.67 ± 0.65	5.64 ± 0.78	5.08 ± 0.52	5.83 ± 0.72	5.75 ± 0.62
15	15	70	5.00 ± 0.74	5.58 ± 0.67	4.92 ± 0.67	4.33 ± 0.89	4.45 ± 1.00	5.25 ± 0.75	5.08 ± 0.79	5.25 ± 0.62
10	10	80	5.17 ± 0.58	5.42 ± 0.67	5.33 ± 0.65	5.00 ± 0.60	5.09 ± 0.52	5.00 ± 0.43	5.25 ± 0.75	5.50 ± 0.80
15	10	75	4.83 ± 0.39	5.42 ± 0.67	5.08 ± 0.52	4.50 ± 0.67	4.27 ± 0.78	5.17 ± 0.72	5.00 ± 0.85	5.50 ± 0.80
		Mean	5.2 ± 0.24	5.64 ± 0.17	5.18 ± 0.24	4.99 ± 0.26	4.87 ± 0.26	5.49 ± 0.21	5.13 ± 0.23	5.39 ± 0.22
		CV	4.6	2.96	4.73	5.2	5.37	3.76	4.41	4.02
		P < 0.05	0.0132	0.0304	<0.0001	0.0492	0.0251	0.012	0.0436	0.0117
		R ² adj	0.847	0.8331	0.8339	0.8649	0.9083	0.6653	0.8948	0.7978

Table 6. Regression models for proximate compositions, total phenolic, anti-nutrients and sensory acceptability of injera prepared from teff, maize and *P. edulis*.

Parameters	Regression model
Moisture	49.73X ₁ +61.24X ₂ +58.57X ₃ +38.45X ₁ X ₂ +22.44X ₁ X ₃ +23.28X ₂ X ₃ -64.79X ₁ X ₂ X ₃
Total ash	3.11X ₁ +2.42X ₂ +3.54X ₃ +0.90X ₁ X ₂ -2.10X ₁ X ₃ +0.52X ₂ X ₃
Crude protein	11.66X ₁ +10.75X ₂ +10.74X ₃ -4.85X ₁ X ₂ -3.01X ₁ X ₃ -0.63X ₂ X ₃ +16.9X ₁ X ₂ X ₃
Crude fiber	11.86X ₁ +13.34X ₂ +3.59X ₃ -40.34X ₁ X ₂ -21.5X ₁ X ₃ -11.97X ₂ X ₃ +53.18X ₁ X ₂ X ₃
Crude fat	-22.4X ₁ +2.39X ₂ +2.44X ₃ +50.45X ₁ X ₂ +50.3X ₁ X ₃ 61.92X ₂ X ₃ +31.78X ₁ X ₂ X ₃
Total Carbohydrate	69.5X ₁ +71.07X ₂ +79.7X ₃ +46.3X ₁ X ₂ +25.38X ₁ X ₃ +15.24X ₂ X ₃
Gross energy	339X ₁ +355.9X ₂ +383.6X ₃ +174X ₁ X ₂ +110.7X ₁ X ₃ +43.57X ₂ X ₃ -218.5X ₁ X ₂ X ₃
Total Phenolic Content	5.37X ₁ +27.28X ₂ +9.15X ₃ -11.48X ₁ X ₂ +6.49X ₁ X ₃ -11.36X ₂ X ₃
1.1.1. Condensed tannin	107X ₁ -12.30X ₂ +2.98X ₃ -99.77X ₁ X ₂ -99.18X ₁ X ₃ +33.80X ₂ X ₃
Phytate	164.78X ₁ +109.72X ₂ +138.55X ₃ +28.59X ₁ X ₂ -0.41X ₁ X ₃ +46.24X ₂ X ₃ -95X ₁ X ₂ X ₃
Color	3.26X ₁ +2.19X ₂ +6.18X ₃ +8.58X ₁ X ₂ +2.07X ₁ X ₃ +0.51X ₂ X ₃
Aroma	5.01X ₁ +9.82X ₂ +5.34X ₃ -6.53X ₁ X ₂ +0.67X ₁ X ₃ -4.87X ₂ X ₃
Taste	5.95X ₁ +3.23X ₂ +5.77X ₃
Texture	-2.9X ₁ +0.049X ₂ +5.82X ₃ +23.13X ₁ X ₂ +13.78X ₁ X ₃ +5.35X ₂ X ₃ -21.82X ₁ X ₂ X ₃

The total carbohydrate content of composite injera was increased from 79.1 to 82.0% with increasing the blending ratios of maize and *P. edulis* flour and decreasing teff flour in the formulations. Similar result was observed on composite injera of teff-taro by [Abera et al. \(2016\)](#). The result was also comparable with the carbohydrate content (75.91–79.47%) of teff, maize, and rice composite injera ([Cherie et al., 2018](#)). The findings highlighted that continued production and consumption of root crops could be encouraged to ensure the adequacy and diversity of the supply of carbohydrates ([Nantel, 1999](#)). The findings showed that incorporating more *P. edulis* flour proportion in the formulations gave a high amount of total carbohydrate in the formulated injera.

Food energy is released from carbohydrates, fat, proteins, and other organic components ([Van Alfen, 2014](#)). The result showed that the energy content of the formulations increased with an increase in the proportion of maize and *P. edulis* flours and decreased with an increase in teff flour ([Figure 2c](#)). The gross energy values (380.7–391.9 kcal/100g) of composite injera flour obtained in this study were higher than the composite injera formulated from teff-cassava (349–362 kcal/100g) ([Banti et al., 2020](#)). This might be due to the variation of carbohydrates, fat, and protein found in the ingredients used in the formulation. Thus, adding more *P. edulis* flour in teff-based composite flours significantly enhanced gross energy contents in the baked injera products.

3.1.3. Antinutrient contents

The high condensed tannin content of food decreases the protein quality of foods and interferes with dietary iron absorption ([Gemede and Ratta, 2014](#)). The condensed tannin content of the formulated injera decreased from 4.50 to 3.21 mg/100g with an increase in the blending ratio of *P. edulis* and a decrease in the proportion of maize in the formulation ([Table 3](#)). This might be due to the high tannin content of maize flour (65 mg/100g) ([Umata et al., 2005](#)), which was greater than teff flour (11.1mg/100g) ([Mezgebo et al., 2018](#)). The result obtained in the formulated products are below the maximum tolerable level (560 mg/100g) ([Anonymous, 1973](#)). Food with tannin below recommended value is safe to eat, has no side effects, and may even benefit human health by activating metabolic enzymes ([Rao and Prabhavathi, 1982](#)).

The presence of phytate content in the food harms the bioavailability of divalent and trivalent mineral ions when consuming high levels of phytate-containing foods ([Natesh et al., 2017](#)). The phytate content of composite injera was decreased from 151.83 to 135.00 mg/100g by reducing the proportion of maize flours in the blend ([Table 3](#)). The reduction of phytic acid in the composite injera could be due to the phytate content in the maize flour (14.43 mg/g) [Abebe et al. \(2007\)](#) being greater than in teff flour (12.88 mg/g) [Kiewlicz and Rybicka \(2020\)](#). The findings showed that phytate contents in the formulated samples are below the maximum tolerable level (200 mg/100g) ([Hurrell, 2004](#)), which may not impair the bioavailability of zinc, calcium, iron, and proteins digestibility ([Oghbaei and Prakash, 2016](#)).

3.1.4. Total phenolic content and total antioxidant capacity

The blending ratio of composite flours of injera was a significant (p < 0.05) difference in the total phenolic content (TPC). The TPC of composite flour of injera in this study was increased from 8.6 to 15.8 mg

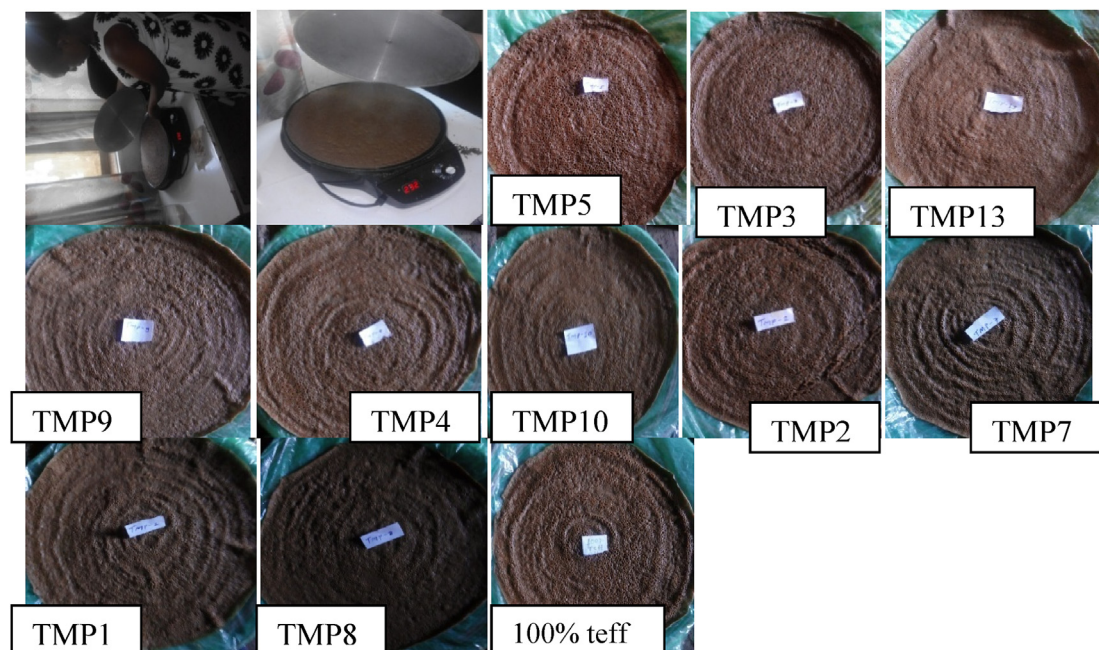


Figure 3. Picture taken during preparation of composite injera. (Where TMP1= 90% teff, 5% maize, 5% *P. edulis* TMP2=80% teff, 5% maize, 15% *P. edulis* TMP3 = 75%teff,10%maize, 15%*P. edulis* TMP4 = 85%teff,10%maize, 5%*P. edulis* TMP5 = 70%teff,15%maize, 15%*P. edulis* TMP7 = 80%teff,10%maize, 10%*P. edulis* TMP8 = 85%teff, 5%maize, 10%*P. edulis* TMP9 = 80%teff,15%maize, 5%*P. edulis* TMP10 = 75%teff,15%maize, 10%*P. edulis* TMP 13= 82%teff,10%maize, 8%*P. edulis*).

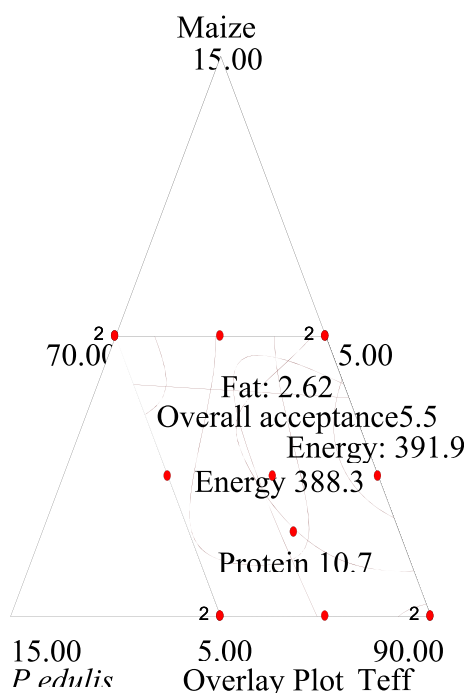


Figure 4. Overlay plot showing the optimum values of proximate and sensory of injera formulated by blending *P. edulis* flour with teff based composite flours.

GAE/g with an increase in the *P. edulis* flour ratios and a decrease in ratios of maize flour (Table 4). The significant reduction of TPC in the developed Injera due to maximum addition of maize flour in the formulation was similar with the findings of Forsido et al. (2013), who reported that maize flour containing low TPC (0.37 mg GAE/g). The findings highlighted that supplementing *P. edulis* flour with teff and maize during the formulation of injera significantly improved total phenolic content.

The percentage of DPPH radicals scavenging activity of formulated composite injera flour increased from 66.20 to 82.7% at the DPPH concentration of 3.32 mg/mL (Table 4). The scavenging percentage of composite injera flour increased as *P. edulis* flour was incorporated into maize-teff flours. This might be due to the high potential scavenging activity of *P. edulis* flour, as reported by Melaku and Duguma (2016). The result was in agreement with the total antioxidant capacity percentage of composite injera formulated from different teff varieties (Boka et al., 2013).

IC50 is the amount of sample required to scavenge 50% of a given concentration of free radical (Yoon et al., 2012). In this study, the IC50 values of injera formulated from red teff, maize, and *P. edulis* flour ranged from 1.09 to 2.24 mg/mL at a concentration of 3.32 mg/mL (Table 4). The highest IC50 value (2.24 mg/mL) was observed in the ratio of 80% red teff, 15% maize, and 5% *P. edulis*, and the lowest value (1.09 mg/ml) was recorded in the ratio of 80% teff, 10% maize and 10% *P. edulis* flour. The result also showed that increasing the ratio of *P. edulis* flour in teff-maize flours was significantly ($p < 0.05$) decreased the IC50 value of composite injera. The lower IC50 value expressed the higher total phenolic content and antioxidant capacity of the product. In general, supplemented *P. edulis* flour in teff-based injera would lower the product's IC50 value and higher phenolic content and antioxidant activity.

3.1.5. Sensory properties

Sensory evaluation is an important parameter for evaluating the quality of baked products to meet consumer requirements. The mean scores of sensory attributes such as colour, taste, aroma, texture, rollability, number of eyes and overall acceptability of baked injera are presented in Table 5.

Colour is the most important sensory attribute in determining the quality of food. The result of a colour evaluation by panellists showed that there was a significant ($p < 0.05$) variation among the treatments. The finding indicated that the highest score of colour (6.4) was observed in the sample made using 5% *P. edulis*, 5% maize, and 90% red teff. However, the lowest score (4.2) was observed in the maximum addition of *P. edulis* (15%). The result recorded from sensory panellists also showed that supplementing maize flour had a more positive effect than *P. edulis* flour on the colour of composite injera (Figure 3).

The aroma of injera formulated from the maximum proportion of *P. edulis* ratios got better (6.58) compared to the addition of teff and maize. However, the lowest score (5.25) was observed in the ratio of 80% teff, 15% maize, and 5% *P. edulis*. The blending ratio of composite flours was significantly ($p < 0.05$) different in terms of the aroma of composite injera. The findings highlighted that supplementation of Teff by *P. edulis* flour increased consumer acceptance of aroma as scored by a panellist. The results depicted that utilization of underutilized *P. edulis* flour plays a significant role in improving aromas. The regression model (Table 6) for the aroma of injera depicted that *P. edulis* had positive impact to increase aroma of composite injera.

The mean score of injera evaluated by panellists ranged from 4.66 to 5.92 (Table 5). The panellists' value highlighted that supplementing 5% *P. edulis* and 10% maize flours to teff-maize flours for injera making was moderately liked (5.92). However, supplemented injera with 15% *P. edulis* flour was rated as neither like nor dislike (4.66).

Food acceptance is heavily influenced by texture. The result obtained in this study showed that the texture values of injera were significantly ($p < 0.05$) influenced by the blend proportion of maize and *P. edulis* flours. The findings highlighted that a preference for liking the texture of teff injera increased from 4.25 to 6.42 with decreasing the percentage of *P. edulis* and increasing maize flour in the composite injera. The softness of teff might be related to smaller granule sizes of teff starch 2–6 μm in diameter, as Bultosa et al. (2002) reported. In addition to this, the granule size of teff starch is lower than maize starch granule size (15–20 μm) (Singh et al., 2014) and *P. edulis* starch granule size (14.6 μm –190.4 μm) (Hellemans et al., 2017).

The blending ratio of composite flours had a significant ($p < 0.05$) difference among composite injera of appearance, rollability, and several injera eyes. Increasing the proportion of *P. edulis* flour in the preparation of injera could affect the top and bottom surface, rollability, and the number of eyes of injera and reduce the scores given by panellists when compared with the control sample of injera. Similar results were reported for injera prepared from composite cassava-teff (Tadesse, 2016).

Panellists evaluated the composite injera's overall acceptability, ranging from 4.67 to 6.25 (Table 5). The result shows that the overall acceptability of the developed injera increased with a minimum proportion of *P. edulis* flour and the maximum proportion of blanched teff and maize flour in the formulation.

3.1.6. Overall optimum of injera formulation based on proximate and sensory evaluation

The overall numerical optimization of injera revealed that the best results were found in the blend ratio of 13.09% maize, 9.32% *P. edulis*, and 77.59% teff flours with a desirability value of 0.66 with significant improvement of protein, fat, energy, and overall acceptance of consumer's preference. The superimposition of overlay plot regions of interest of blended injera was ranged for protein (10.7–10.8%), fat (2.62–2.80%), energy (388.3–391.9 kcal/100g), and overall acceptance of consumer's preference (5.5–6.3) (Figure 4).

4. Conclusion

This study investigated the effect of Oromo Dinich (*P. edulis*) flour supplemented on teff-maize composite injera's quality characteristics. The findings showed that the supplementation of more *P. edulis* flour proportion in the formulations gave better results in terms of crude fat, utilizable carbohydrate, gross energy, and low antinutrients content (tannin and phytic acid). Furthermore, adding more *P. edulis* flour in teff-based composite flours enhanced the total phenolic content and antioxidant capacity of the baked injera products. At the same time, the aroma of the composite injera products was significantly ($p < 0.05$) acceptable with increasing blending ratios of *Plectranthus edulis* flour in the formulation compared with only maize and teff flour. The overall numerical optimization result shows that using *P. edulis* flour up to 10% supplement with teff-maize composite flours resulted in acceptable injera

products in terms of nutritional composition and minor change of sensorial quality. Thus, supplementing underutilized and locally available *P. edulis* tuber flour with teff-maize flours significantly enhanced the nutritional potential of teff-based injera products besides increasing their availability among low-income families for solving food insecurity.

Declarations

Author contribution statement

Ayana Fekadu, Yetenayet B. Tola, Addisalem Hailu Taye, and Ebisa Olika Keyata: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data included in article/supp. material/referenced in article

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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