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Optimization of amaranths–teff–barley flour blending ratios for better nutritional and sensory acceptability of injera

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Abstract: This study was conducted to optimize the compositions of amaranths, teff and barley flour blending ratios for better nutritional and sensory acceptability of injera. Ten formulations of composite flour were determined using D-optimal constrained mixture design with the aid of MINITAB17 software package. The ingredients were in the range of 40–100%, 0–60% and 0–20% for teff, amaranths and barley, respectively. Proximate and mineral analysis of injera was done using standard methods, and sensory evaluation was made using 5-point hedonic scales. Results of the study showed a significant difference (p < 0.05) in protein, calorie, fiber, calcium, iron, zinc and sensory quality of injera as the compositions of ingredients were changed. Levels of protein and gross energy increased with the increased proportion of amaranths, and addition of barley increased the carbohydrate value of injera. Calcium, iron and zinc contents of injera increased with the increment of amaranths and teff. Overall optimum point protein (11.84–14.60%), carbohydrate (74.39–79.71%), gross energy (363.68–381.22 kcal/100 g, iron

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PUBLIC INTEREST STATEMENT

Teff injera that is most preferred and consumed by majority of Ethiopians now gets preference in other parts of the world due to its gluten-free nature. However, the low productivity and relatively high cost makes teff less available and affordable by all society. Hence, considering underutilized grains like amaranth and less expensive like barley where most grown under uncertain and extreme climatic and soil conditions as a substitute or blending and optimization is vital. However, limited information is available on amaranths–teff–barley flour optimization for injera preparation. The current study aimed at exploring the proximate composition, mineral and sensory characteristics of injera made from a different blend of teff, barley and amaranth. Optimal formulation proportion in proximate and mineral composition of injera was obtained by blending teff flour with amaranths and barely flour up to a level of 60% and 10%, respectively. Therefore, the baking industry can use this optimum formulation of amaranths, teff and barley flour for preparation of injera.
29.34–42.44 mg/100 g, calcium 177.42 –430.47 mg/100 g) was found in a range of 40–77.5% for teff, 12.5–60% for amaranths and 0–10% for barley. Acceptability was decreased with increase in the proportion of amaranths and barley. The overall optimum point was found in a range of Amaranths (12.5–60%), barely (0–10%) and teff (40–77.5%) flours. Therefore, the blending of teff, amaranths, and barley flours can improve the proximate and mineral composition of injera.

Subjects: Substitutes - Food Chemistry; Breads, Cereals & Dough; Product Development

Keywords: blend; Injera; nutritional value; optimal mixture; mineral content; proximate composition

1. Introduction

Injera is a fermented, pancake-like soft, circular flatbread similar to chapatti with small bubbly structures or eyes (honey-comb-like holes) on its top surface, which are produced due to the production and escape of CO₂ during fermentation and baking, respectively. It can be produced from various cereals depending on availability and abundance such as teff, barley sorghum, maize and wheat (Bultosa, 2007; Bultosa & Taylor, 2004; Umeta, West, & Fufa, 2005) or a combination of some of these cereals (Ashenafi, 2006). Although it is preferred to prepare injera from sole teff flour, wheat, barley, sorghum, millet, maize and rice products are also incorporated (Ashenafi, 2006).

Amaranths (Amaranthus caudatus L.) is easy to grow, gluten-free, nutrient-rich and under-utilized pseudo-cereal that can play an important role in actions against hunger and malnutrition. Amaranths grows in wide range of agro-climatic conditions. It is resistant to drought, heat and pests and easily adapts to new environments including some that are inhospitable to conventional cereal crops (Emire & Arega, 2012; Shubhpreet, Narpinder, & Rana, 2010). Utilization of underutilized crops that can yield under uncertain and extreme climatic and soil conditions can play a key role in mitigating food insecurity. Even though the crop is grown in many parts of Ethiopia, inclusion of its product in injera and other food products preparation is rare.

Barley (Hordeum vulgare) is also the most widely grown crop over broad environmental conditions and the most important cereal crop in Ethiopia. It has persisted as a major cereal crop through many centuries and it is the world’s important cereal crop after wheat, maize and rice. According to Abiyu, Woldegiorgis, and Haki (2013), good injera is soft, fluffy and able to be rolled without cracking. However, sole barley-product-based injera is not common in Ethiopia as it lacks these characteristics. As a result, inclusion of ingredients such as teff-based flour process for injera preparation may be worthy to improve the necessary characters.

Teff (Eragrostis tef) is a cereal crop widely cultivated in Ethiopia mainly to process its grain flour into injera (Bultosa, Hamaker, & Bemiller, 2008). Its grain is superior to other cereal grains in preparation of Injera, which is most, preferred and consumed daily by the majority of Ethiopian people (Bekabil, Befekadu, Rupert, & Tareke, 2011; Yetneberk, De Kock, Rooney, & Taylor, 2004). As it is gluten-free, it is also an option for persons with problems of gluten sensitivity (Bultosa, 2007). However, the low productivity and relatively high cost make teff less available and affordable by all society of the country and consumed in urban areas where household income is relatively higher (Berhane, Paulos, Tafere, & Tamru, 2011; Yetneberk et al., 2004).

Blending improves nutrient composition and overall acceptability of food products. Using teff flour as an ingredient for other easily available and relatively low-cost cereal-based products could be important for food security, especially in the developing countries. Since malnutrition is a major
problem in Ethiopia, improving the nutritional quality of injera can help to reduce the problem. Nevertheless, limited information is available on amaranths flour use as an ingredient of injera preparation with other common grains. Thus, the purpose of this research was to prepare injera form blends of amaranths, teff and barley flour and evaluate the proximate, mineral composition and sensory characteristics of injera.

2. Materials and methods

2.1. Collection of materials and sample flour preparation

Experimental materials used for laboratory analysis consisted of amaranths grain which was pale-white color collected from Konso, southern region of Ethiopia; teff (variety DZ-01–354) and barley (variety Himblili) seeds that were obtained from Debre Zeit Agricultural Research Center and Holeta Research Center, Ethiopia, respectively. Sample grains were ground to flours using stainless steel pin miller (China) to pass through a 0.5-mm-mesh screen, and milled samples were then packed in polyethylene bags and stored at room temperature.

Preparation of amaranths flour was done according to the procedures of Emire and Arega (2012) and Mugalavai (2013) with some modifications, and preparation of teff was according to the procedures outlined by Bultosa (2007) and Girma, Bultosa, and Bussa (2013). The grains were manually cleaned by siftings and winnowing to make it free from chaffs, dust and other impurities. Then, the grains were sorted and steeped for 24 h by soaking in warm water (50°C) in order to improve the cleaning operation and obtain a higher quality product. Moreover, steeping was done to facilitate physical and biochemical changes such as swelling of grains, degradation of soluble carbohydrates and removal of some pigments, microorganisms and bitter substances from the grain. After steeping, water was removed and seeds were placed in a dark place for 24 h at room temperature in order to get the optimum germination effect. The grains of both amaranths and teff were sun-dried and roasted until the moisture content reached 11% and milled using a stainless steel mill. The barley grain was checked for any sign of disease, sprout, physical damage and general suitability to the experiment. Then, it was prepared by sorting/cleaning, decorticating, sun-dried and milled (0.5-mm-mesh screen), sieved. Finally, all samples were packed in airtight polythene bags and stored at room temperature until it was needed for chemical analysis (Figure 1).

Figure 1. Flow diagram for the preparation of composite flour.
2.2. Composite flour formulation and experimental design

This study was carried out to find an appropriate ratio of three components, namely, amaranths, barley and teff grains processed into flour to subsequently prepare injera with optimum nutritional content. D-optimal mixture design was used to find the appropriate ratio. For the three components, the design yielded 10 possible formulations (Table 1) based on the lower and upper limits. Constrained region in the simplex coordinate system was defined by the limits of $0 \leq X_1 \leq 60$, $0 \leq X_2 \leq 20$, $40 \leq X_3 \leq 100$. $X_1 = \text{amaranth}$, $X_2 = \text{barley}$ and $X_3 = \text{teff flour}$. Numbers 1–10 represent the 10 formulations and correspond to the numbers in Table 1. Ranges of those ingredients were determined based on the procedure outlined by Bultosa (2007), Emire and Arega (2012) and Mugalavai (2013). Composite flour was formulated by blending the three basic ingredients using computer software called Design-Expert®, version 8, Stat-Ease software. The simplex design plot for the three components of mixture formulations is presented in Figure 2.

2.3. Preparation of injera from amaranths, teff, barley

Injera was prepared as per the procedure outlined by Bultosa (2007) as well as Yetneberk et al. (2004) with slight modifications (Figure 3). The procedure involves cleaning, milling, preparation of dough and fermentation of the dough after adding a starter culture (a fermented dough from previous batch) with 1: 1.6 w/v (Yetneberk et al., 2004) and fermenting at room temperature for 24–72 h. After fermentation, 10% of the sediment was mixed with water (1:3) and cooked for

### Table 1. Formulations of composite flour from amaranths, barley and teff flour for injera preparation

| Run order | %     |
|-----------|-------|
|           | Amaranths | Barley | Teff  |
| 1         | 60.00    | 0.00   | 40.00 |
| 2         | 0.00     | 20.00  | 80.00 |
| 3         | 12.50    | 10.00  | 77.50 |
| 4         | 30.00    | 0.00   | 70.00 |
| 5         | 32.50    | 15.00  | 52.50 |
| 6         | 42.50    | 5.00   | 52.50 |
| 7         | 0.00     | 0.00   | 100.00|
| 8         | 0.00     | 10.00  | 90.00 |
| 9         | 40.0     | 20.0   | 40.0  |
| 10        | 20.0     | 20.0   | 60.0  |

Figure 2. Simplex design plots for the three-component mixture formulations.
2–3 minutes with the objective of gelatinization (cooking) primarily to bring about the cohesiveness of dough and secondly to get ride of the easily fermentable carbohydrate from injera. Then, gelatinized batter (Absit) were cooled to room temperature and added back to the fermenting dough. After fermentation for 0.5–1 h, bubbles were formed, indicating the end point. Additional water was added to fermented dough to bring to correct batter consistency. About 500 g of fermented batter was poured in a circular manner on a hot clay griddle, covered, and baked for 3–4 minutes (Bultosa & Taylor, 2004; Yetneberk et al., 2004). Lower and upper limits of ingredients used in the mixture design were with a range of 40–100%, 0–60% and 0–20% for teff, amaranths and barley, respectively.

2.4. Proximate composition analysis
Proximate composition of each Injera prepared from different levels of the composite flour was determined. All analyses were performed in duplicate.

**Moisture content**: moisture of the samples were determined by dry air oven method according to AOAC (2005) method 925.10.

**Crude protein content** was determined using Semi-Micro Kjeldal Method according to the AOAC (2005) method 991.20.
Crude fat content: composite flour and individual ingredient flour was determined by Soxhlet extraction according to AOAC (2005) method.

Ash content: ash content of the injera samples were determined by AOAC (2005) method.

Crude fiber content: after digesting injera samples of 1.5 g by refluxing 1.25% boiling sulfuric acid and 28% boiling potassium hydroxide, then it was filtered, washed, dried, and combustion fresh sample was done according to AOAC (2000) method to determine crude fiber.

Total carbohydrate: Total carbohydrate content was determined by difference rather than being analyzed directly. It was determined by subtracting moisture content, crude protein, total ash and crude fat from the total weight of the sample (Onyeike, Olungwe, & Uwakwe, 1995).

Gross energy: Gross energy of composite flour sample was calculated according to the method developed by (Onyeike et al., 1995).

2.5. Mineral analysis
Mineral analysis (Ca, Zn and Fe) were determined by Atomic Absorption Spectrophotometer (autosampler AA 6800, Japan) method as per the AOAC (2005) method. One gram of composite flour and individual ingredient sample was ash and weighed. The white ash was treated with 5 ml of 6N HCl and dried on a hot plate. A ml of 3N HCl was added and heated on the crucible on the hot plate until the solution flask then mixed with distilled water. Then, the solution was used to determine Ca, Zn and Fe. Standard stock solution of Ca, Zn and Fe was made by appropriate dilution. The sample and standard were atomized by reducing air-acetylene for Ca and oxidizing air-acetylene for Zn and Fe as the source of energy for atomization. For Fe content determination, absorbance was measured at 248.4 nm and Fe was estimated from a standard calibration curve prepared from analytical grade Fe with a range of 0, 2, 4, 6, 8 and 10 ml. For Zn content, it was estimated from a standard calibration curve with a range of 0, 0.5, 1.0, 1.5, 2.0 and 2.5 ml. For Ca content determination, absorbance was measured at 422.7 nm after addition of 2.5 ml of LaCl3 to the sample solution and standard to suppress interferences. Calcium content was then estimated from standard solution of 0, 2, 4, 6, 8 and 10 ml prepared from CaCO3.

2.6. Sensory evaluation
Appearance, color, aroma, taste, texture and overall acceptability of injera was evaluated by 50 panelists (25 female and 25 male) using 5-point hedonic scales. Relative importance of each factor was compared numerically on a scale of 1–5, i.e. from very poor to excellent. Samples were presented turn by turn in identical containers and coded with three-digit random numbers to find out the most suitable preferable injera. Potable water was provided to rinse the mouth between evaluations and covered cups was also provided when panelists would not wish to swallow the samples (Olaoye, Onilude, & Oladoye, 2007).

2.7. Statistical analysis
A statistical software package (Design-Expert®, version 8.0, Stat-Ease) was used for the generation test of formulation, and MINITAB17 software package was used for data analysis, construction of contour plot, response surface plot and overlaid plot of the results. These formulations were obtained based on a constrained mixture D-optimal design. The statistical significance of the terms in the regression equations was examined by analysis of variance for each response and the significance test level was set at 5% ($p < 0.05$). The fitted models for all the parameters were generated as three-dimensional response surfaces as well as contour plots.
3. Results and discussion

3.1. Proximate composition

3.1.1. Moisture content

Significant difference (\(p < 0.05\)) was shown in moisture content of injera products (Table 2). Within an increment in barley flour proportion of up to 20%, an increase in moisture content from 5.82% to 7.59% was observed in the product (Table 3). Perhaps, an increase in moisture content could be due to the high water-binding capacity of the starch in the barley flour. The low moisture content was obtained from a high proportion of amaranths flour. Similarly, Shevkani, Singh, Kaur, and Rana (2014) reported that amaranths flour has high water-absorption properties. Moisture contents of all injera and the ingredients were within FAO/WHO-recommended safe limit (<10%). However, an increase in moisture content beyond the safe limit may not be good news as high moisture content in foods has shown to encourage microbial growth (Temple, Badamosi, Ladeji, & Solomon, 1996).

3.1.2. Ash content

The ash content indicates an estimate of the total mineral content in a given quantity of food substance (Mezgebo, Belachew, & Satheesh, 2018; Mishra & Chandra, 2012). A result in Table 2 depicts that ash content of injera sample and interaction between amaranths and barley was significantly different (\(p < 0.01\)). The ash contents of the injera sample varied between 1.85% and 3.69% (Table 3) and its content increased with the level of barley and amaranths in the composite flour. Similar to this, Mezgebo et al. (2018) also showed increment of ash as the red-teff was blended with soybean and papaya fruit flour. This increase in ash content could be due to high mineral compositions of amaranths and teff. Table 6 shows the linear regression model of ash with all three variables.

3.1.3. Crude fiber content

The fiber content of injera was significantly affected by amaranth-steff and barley-teff mix (Table 2). Fiber content of injera from 10 different formulations varied between 3.09% and 9.29% (Table 3). Relatively higher fiber content was observed in a sample of injera prepared from 60% amaranths and 40% teff. Fiber content of injera showed an increasing trend with a parallel increase in the proportion of amaranths flour. This could be attributed to the high fiber content of amaranths as compared to teff and barley. The linear regression model with three variables in Equation 4 depicts the crude fiber content. In harmony with the current findings, Vitali, Klarić, and Dragojević (2011) reported that an increase in fiber content of wheat flour was seen with increased addition of amaranths flour. Similarly, Teutonico and Knorr (1985) reported that incorporating amaranths resulted in twice as much fiber as corn and oats, and three times as much as wheat. Therefore, this is vital for many countries like Ethiopia, where amaranths is underutilized.

| Regression       | Moisture | Fiber | Protein | Fat | Ash    | Carbohydrate | Energy | Calcium | Iron | Zinc | Color | Flavor | Texture | Taste | Acceptability |
|------------------|----------|-------|---------|-----|--------|--------------|--------|---------|------|------|-------|--------|---------|-------|---------------|
| Linear           | 0.03     | 0.01  | 0.00    | 0.01| 0.00   | 0.00         | 0.01   | 0.00    | 0.45 | 0.01 | 0.01  | 0.00   | 0.23    | 0.00  | 0.00          |
| Quadratic        | 0.06     | 0.02  | 0.00    | 0.11| 0.00   | 0.09         | 0.07   | 0.03    | 0.06 | 0.36 | 0.00  | 0.92   | 0.13    | 0.01  |               |
| Amar × barley    | 0.02     | 0.16  | 0.01    | 0.26| 0.00   | 0.05         | 0.29   | 0.04    | 0.31 | 0.16 | 0.16  | 0.57   | 0.04    | 0.64  |               |
| Amar × teff      | 0.12     | 0.01  | 0.96    | 0.31| 0.00   | 0.13         | 0.44   | 0.04    | 0.02 | 0.19 | 0.17  | 0.00   | 0.85    | 0.22  | 0.00          |
| Barley × teff    | 0.17     | 0.12  | 0.60    | 0.57| 0.00   | 0.05         | 0.09   | 0.06    | 0.18 | 0.02 | 0.49  | 0.03   | 0.55    | 0.06  | 0.67          |
Table 3. Measured proximate composition and energy of injera prepared from amaranths, barley and teff products

| Injera components (%) | Proximate composition (%) | Energy (kcal/100 g) |
|-----------------------|---------------------------|---------------------|
| Injera components (%) | Moisture | Fiber | Protein | Fat | Ash | Carbohydrate | |
| Amaranths | Barley | Teff | | | | | |
| 60 | 0 | 40 | 4.97 | 9.29 | 14.60 | 2.7 | 3.34 | 74.388 | 380.25 |
| 0 | 20 | 80 | 7.58 | 3.88 | 11.53 | 1.24 | 3.05 | 76.599 | 363.68 |
| 12.5 | 10 | 77.5 | 6.23 | 5.22 | 11.84 | 1.06 | 1.85 | 79.02 | 372.98 |
| 30 | 0 | 70 | 5.81 | 7.51 | 12.64 | 1.49 | 2.92 | 77.74 | 374.95 |
| 32.5 | 15 | 52.5 | 6.79 | 6.95 | 12.91 | 1.57 | 2.73 | 76.00 | 369.77 |
| 42.5 | 5 | 52.5 | 6.21 | 8.83 | 13.45 | 2.07 | 2.6 | 75.68 | 374.43 |
| 0 | 0 | 100 | 5.82 | 3.51 | 10.62 | 1.02 | 3.2 | 79.34 | 374.81 |
| 0 | 10 | 90 | 6.45 | 3.09 | 11.04 | 0.74 | 2.06 | 79.71 | 369.00 |
| 40 | 20 | 40 | 7.59 | 8.30 | 13.40 | 1.44 | 3.69 | 73.89 | 362.07 |
| 20 | 20 | 60 | 6.71 | 6.85 | 12.48 | 1.54 | 2.99 | 76.28 | 368.91 |
3.1.4. Crude protein
The protein content of samples ranged from 10.62% to 14.60% (Table 3). Interaction between amaranths-teff and barley-teff had shown a significant difference (p < 0.05) in protein content (Table 2). Protein content of injera sample was increased with an increased proportion of amaranths flour, which could be due to the high amount of protein in amaranths flour. In fact, amaranths has an attractive protein source due to its high content of essential amino acids, especially lysine and methionine, which are limited quantities in cereal grains (Amare et al., 2015; Caselato-Sousa & Amaya-Farfán, 2012). Similarly, with increasing barley flour, an increase in protein content of injera was observed. Irrespective of other ingredients, the protein content of the teff was lower when considered separately. However, an increase in the protein content was observed when injera was prepared from blends of ingredients like barley and teff in addition to amaranths flour. Hence, the combination of grain proteins would provide better overall essential amino acid balance, helping to overcome the world protein calorie malnutrition problem (Livingstone, Feng, & Malleshi, 1993). Particularly, this is important for Ethiopians where injera is the major staple food prepared mostly from sole teff flour unless it is not accessible and costly. Above and beyond, amaranths- and teff-based injera can be a good source of protein for those who are gluten-sensitive.

3.1.5. Crude fat
Fat content showed a highly significant difference (p < 0.01) in the linear model, and significant difference (p < 0.05) in the fat content of injera was observed between amaranths with teff interaction (Table 2). The fat content of the developed injera varied from 0.74% to 2.7% (Table 3) in injera prepared from 10% barley with 90% teff and 60% amaranths with 40% teff, respectively. As barley ingredient increased, the crude fat decreased. Martirosyan, Miroshnichenko, Kulakova, Pogojeva, and Zoloedov (2007) reported that inclusion of amaranths oil in the diet contributes to an increase in the concentration of polyunsaturated fatty acids and effective natural antioxidant supplement capable of protecting cellular membranes against oxidative damage. Hence, high fat content in the injera comprising of a high amount of amaranths followed by teff may be attributed to their high fat composition. Similarly, Michaelsen et al. (2011) also reported that teff has a favorable fatty acid composition compared with other staple foods. Mezgebo et al. (2018) also agreed that dietary fats function in increasing palatability of food by absorbing and retaining flavors.

3.1.6. Total carbohydrate
The carbohydrate content of injera varied between 73.89% and 79.71% (Table 3). Highly significant differences (p < 0.01) were observed in respect of the carbohydrate content of injera due to the interaction of teff and barley (Table 2). The lowest carbohydrate content (73.89%) recorded in injera obtained from blends of amaranths 40%, barley 20% and teff 40%, while the highest (79.71%) recorded in injera formulated from amaranths 0%, barley 10% and teff 90% (Table 3). This finding indicates that the carbohydrate content increased linearly with the proportion of teff and barley flours. This is because of the high amount of carbohydrate found in teff and barley flour. Baye (2014) also reported teff as a starchy cereal. Similar to these findings, Cherie, Ziegler, Fekadu Gemede, and Zewdu Woldegiorgis (2018) reported that proximate composition of injera for protein, fat and carbohydrate increases progressively as the proportion of maize increases in teff–maize–rice injera formulation.

3.1.7. Gross energy
The gross energy of Injera samples varied from 362.07 to 380.25 kcal/100 g (Table 3). A significant difference (p < 0.05) was observed in the gross energy content of the injera sample for barley and teff interaction, in the linear model (Table 2). The highest gross energy content (380.25 kcal/100 g) was observed in injera samples prepared from a combination of amaranths 60% and teff 40% and lowest energy content (362.07 kcal/100 g) was observed in injera samples prepared from a blend of amaranths 40%, barley 20% and teff 40%. This result indicates that the energy content of injera samples prepared from a formula consisting of high proportion of amaranths flour may be
attributed to the high fat content of amaranths flour. The regression model for gross energy is shown in Table 6 as indicated in a linear model with three variables.

### 3.2. Mineral content (calcium, iron and zinc)

#### 3.2.1. Calcium, iron and zinc content

The calcium content of injera showed significant ($p < 0.05$) difference in amaranths–barley and amaranths–teff blend (Table 2). Similarly, significant ($p < 0.05$) variation in iron content was observed in amaranths–teff composite flour whereas variation in zinc content was observed in amaranths–barley and barley–teff (Table 2). In the samples from the different blends, calcium content varied between 82.49 and 430.47 mg/100 g, iron content varied between 10.75 and 40.34 mg/100 g and zinc content varied from 1.44 to 4.35 mg/100 g (Table 4).

Calcium, iron and zinc contents of injera increase with the increment of amaranths and teff. Calcium content of injera increased with the increment of amaranths proportion in the sample, which may be due to the higher amount of calcium in the amaranths flour. Actually, calcium was the most abundant mineral among the investigated elements. Similarly, Vitali et al. (2011) reported that amaranths is an excellent source of calcium, iron and magnesium. Incorporation of amaranths to different grains for improving mineral content was reported (Bultosa, 2007; Emire & Arega, 2012) to improve the mineral composition.

### 3.3. Sensory evaluation

Sensory qualities are important criteria that make the product to be consumed pleasant. The mean consumer acceptance scores indicated acceptability of injera for color, flavor, taste, texture and overall acceptability with the numerical value that ranged 1.64–5.00, 1.68–4.38, 1.98–4.67, 1.64–5.00 and 1.72–4.54, respectively (Table 5). Vision plays a major role in sensory analysis and appearance of food, and it can have a major effect on its acceptability (Kikafunda, Abenakyo, & Lukwago, 2006).

Amaranth–barley interaction and Amaranths–teff interaction in the quadratic model showed a highly significant difference ($p < 0.001$) in color (Table 2). Injera prepared from 100% teff (control) was the most preferred than others. The flavor of the injera samples showed a significant difference ($p < 0.05$) in the quadratic model and in the interaction between amaranths and teff, and a highly significant difference ($p < 0.01$) was observed between amaranths and barely interactions (Table 2). Acceptability of flavor was declined with the proportion of amaranths flour increases in the

### Table 4. Mineral content of injera as influenced by the blending ratio of teff, amaranths and barley flour

| Injera components (%) | Mineral contents (mg/100 g) |
|-----------------------|-----------------------------|
|                       | Ca  | Fe  | Zn  |
| Run                   |     |     |     |
| 1                     | 60  | 0   | 40  |
| 2                     | 0   | 20  | 80  |
| 3                     | 12.5| 10  | 77.5|
| 4                     | 30  | 0   | 70  |
| 5                     | 32.5| 15  | 52.5|
| 6                     | 42.5| 5   | 52.5|
| 7                     | 0   | 0   | 100 |
| 8                     | 0   | 10  | 90  |
| 9                     | 40  | 20  | 40  |
| 10                    | 20  | 20  | 60  |
Table 5. Sensory mean scores for samples (injera) evaluated by untrained panels

| Run | Amaranths (%) | Barley (%) | Teff (%) | Colour | Flavor | Texture | Taste | Overall acceptability |
|-----|---------------|------------|----------|--------|--------|---------|-------|-----------------------|
| 1   | 60.00         | 0.00       | 40.00    | 1.64   | 1.68   | 1.64    | 1.90  | 1.72                  |
| 2   | 0.00          | 20.00      | 80.00    | 4.21   | 4.23   | 5.00    | 4.49  | 4.09                  |
| 3   | 12.50         | 10.00      | 77.50    | 3.71   | 4.09   | 1.66    | 3.28  | 3.98                  |
| 4   | 30.00         | 0.00       | 70.00    | 3.90   | 3.99   | 4.21    | 3.70  | 4.01                  |
| 5   | 32.50         | 15.00      | 52.50    | 3.48   | 3.43   | 2.85    | 2.57  | 3.18                  |
| 6   | 42.50         | 5.00       | 52.50    | 2.36   | 3.09   | 2.85    | 2.31  | 2.63                  |
| 7   | 30.00         | 0.00       | 70.00    | 3.90   | 3.95   | 4.20    | 3.70  | 4.00                  |
| 8   | 0.00          | 0.00       | 100      | 5.00   | 4.38   | 5.00    | 4.67  | 4.53                  |
| 9   | 0.00          | 10.00      | 90.00    | 5.00   | 4.23   | 5.00    | 4.34  | 4.54                  |
| 10  | 40.00         | 20.00      | 40.00    | 2.41   | 2.86   | 2.73    | 2.35  | 2.26                  |
| 11  | 20.00         | 20.00      | 60.00    | 4.00   | 4.03   | 2.85    | 3.11  | 3.61                  |
| 12  | 60.00         | 0.00       | 40.00    | 1.64   | 1.68   | 1.64    | 1.98  | 1.82                  |
table 6. Regression models for proximate compositions, mineral content and sensory acceptability of injera prepared from amaranths, teff and barley

| Injera properties | Regression model | R² |
|-------------------|------------------|----|
| Moisture          | y = 3.342x₁ + 19.547x₂ + 5.904x₃ + 0.385x₁x₂ + 2.503x₁x₃ - 9.155x₂x₃ | 0.98 |
| Ash               | y = 7.71x₁ + 64.10x₂ + 3.07x₃ - 68.29x₁x₂ - 9.04x₁x₃ - 77.17x₂x₃ | 0.95 |
| Crude protein     | y = 17.29x₁ + 16.68x₂ + 10.62x₃ - 12.2x₁x₂ + 0.02x₁x₃ - 1.81x₂x₃ | 0.99 |
| Crude fibre       | y = 17.29x₁ + 16.68x₂ + 10.62x₃ - 12.2x₁x₂ + 0.02x₁x₃ - 1.81x₂x₃ | 0.99 |
| Crude fat         | y = 4.68x₁ + 10.02x₂ + 0.82x₃ - 18.96x₁x₂ - 2.06x₁x₃ - 9.07x₂x₃ | 0.94 |
| Carbohydrate      | y = 67.57x₁ - 10.35x₂ + 79.56x₃ + 99.07x₁x₂ + 8.58x₁x₃ + 97.21x₂x₃ | 0.96 |
| Gross energy      | y = 381.58x₁ + 115.52x₂ + 368.31x₃ + 176.84x₁x₂ + 15.86x₁x₃ + 299.98x₂x₃ | 0.91 |
| Calcium           | y = 1035x₁ + 6125x₂ + 138x₃ - 7877x₁x₂ - 10066x₁x₃ - 6940x₂x₃ | 0.94 |
| Iron              | y = 21.5x₁ - 232.5x₂ + 11.7x₃ + 272.3x₁x₂ + 95x₁x₃ + 370.8x₂x₃ | 0.93 |
| Zinc              | y = 116.3x₁ + 49.9x₂ + 78.2x₃ - 209.3x₁x₂ - 72.2x₁x₃ - 17.7x₂x₃ | 0.98 |
| Colour            | y = -2.89x₁ + 17.9x₂ + 5.08x₃ - 13.91x₁x₂ + 5.39x₁x₃ - 19.94x₂x₃ | 0.94 |
| Flavour           | y = -4.29x₁ + 13.39x₂ + 4.37x₃ - 6.68x₁x₂ + 10.49x₁x₃ - 12.09x₂x₃ | 0.99 |
| Texture           | y = 0.08x₁ + 26.87x₂ + 5.18x₃ - 29.35x₁x₂ - 12.22x₁x₃ - 30.73x₂x₃ | 0.84 |
| Taste             | y = -1.01x₁ + 39.16x₂ + 4.52x₃ - 90.97x₁x₂ + 3.26x₁x₃ - 44.01x₂x₃ | 0.95 |
| Overall acceptability | y = -3.615x₁ + 7.382x₂ + 4.547x₃ - 6.438x₁x₂ + 8.730x₁x₃ - 5.756x₂x₃ | 0.98 |

Formulation. This result may be observed due to the darker color of the amaranths flour. Similarly, Lorenz (1981) also indicated that the crumb color acquired slightly darker color as amaranths substitution increased.

Score of taste and texture showed a significant difference (p < 0.05) in the quadratic model of the components. A highly significant difference (p < 0.01) was also observed in the interaction between amaranths with teff and amaranths with barely (Table 2). Similarly, overall acceptability of injera showed a significant difference (p < 0.01) in the quadratic model of teff with barely and amaranths with teff interactions. Among the runs, 2, 4, 7, 8 and 9 were most accepted with the mean score (4.01–4.54) in their overall acceptability (Table 5). Panelists due to its crumb texture considered amaranths-based injera as less attractive and the textural problem was due to the absence of gluten. As the amaranths substitution increased, the texture score decreased. This result implied that when amaranths and barely flour increased in composite flour, the acceptability of the product decreased. This was because the dark color and nutty flavor of amaranths was pronounced as the percentage increased. This acceptability may depend on the color of the teff flour. Similarly, Yetneberk et al. (2004) also reported that injera from sorghum had poor sensory quality.

3.4. Optimal mixture composition of proximate, mineral composition and sensory evaluation

Acceptability of the overall optimum value for protein, carbohydrate, gross energy, iron and calcium varied in the range of 11.84–14.60%, 74.388–79.71%, 363.68–381.22 kcal/100 g, 29.34–42.44 mg/100 g, 177.42–430.47 mg/100 g, 3.19–4.54, respectively (Figure 4).

The white region in the (Figure. 4) indicates that an optimum combination of amaranths, teff and barely results in desirable attributes. The overall optimum point was found in amaranths 12.5–60%, teff 40–77.5% and barely 0–10%. The white region of Figure 5 shows the optimal sensory acceptability of the formula. The point of prediction shows that 0–32.5% amaranths, 52.5–100% teff and 0–15% barely were optimal for sensory evaluation. The optimal point for color, flavor, texture and overall acceptability varied between 3.713–5.00, 3.09–4.376, 2.85–5, 3.12–4.67 and 3.19–4.54, respectively.
4. Conclusion

The injera prepared from formulations of amaranths–teff–barley flour significantly influenced the moisture content, protein, mineral, fat, energy, crude fiber contents minerals like calcium, iron and zinc and sensory acceptability. Blending of amaranths flour up to a level of 60% would able to increase the protein, fat, energy as well as the crude fiber contents in the various combinations. The mineral content of injera increased with the increment of amaranths and teff mix. Besides, 32.5%, 52.5% and 15% were found as the optimal proportions for sensory optimization for amaranths, teff and barely flour mix, respectively. Generally, the optimum proportions were found as follows: amaranths, 12.5–60%; barely, 0–10% and teff, 40–77.5%. This could have significant implications for improving consumption of nutritionally acceptable injera from underutilized grains like amaranths.

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