Research & Development
2025, Vol. 6, No. 2, pp. 39-52
https://doi.org/10.11648/j.rd.20250602.13

Research Article

Formulation and Characterization of Physico-Chemical and Functional Properties of Sorghum, Barley, and Potato Composite Flour for Injera Making

Faris Mohammed[1, *], Solomon Abera Habtegebriel[2]

[1]Food Engineering, Dilla University, Dilla, Ethiopia
[2]Food Technology and Process Engineering, Haramaya University, Haramaya, Ethiopia

Abstract

Combination of sorghum, barley, and potato flour to make injera is not common practice, and not much scientific research has been done on the subject. Therefore, the purpose of this study was to describe the physicochemical characteristics, functional characteristics, and mineral contents of sorghum, barley, and potato flour's combination. Using a single factorial design and several blending ratio levels, the experiment was conducted. We performed four treatments in triplicate. The percentages of each ingredients such as, barley were 15, 20, and 25 percent; potatoes were 5, 10, and 25 percent; and sorghum were 80, 70, and 50 percent. The flours' functional properties included 56.50-69.33 percent disperse-ability, 8.24-11.17 g/g swelling power, 1.98-2.44 g/g water absorption capacity, and 0.80-1.25 g/g oil absorption capacity. The percentage of remained particle size increased from (0.66 to 0.80 percent) to 49.82, 49.88, and 54.32 percent, while the mesh size fell from 500 µm to 125 µm. The angle of repose was 28.63 to 44.30 degree, while the bulk density ranged from 0.60 to 0.85 g/ml. In terms of moisture content, fat, protein, fiber, ash content, carbohydrate, and total energy, the flours' respective proximate compositions were 11.99-12.75 percent, 2.72-3.06 percent, 15.33-16.27 percent, 5.47-5.98 percent, 1.77-2.14 percent, 60.90-61.59 percent, and 332.16-336.34 of Kcal/100g. The mineral concentrations of the flours were 7.34-38.90, 7.43-16.87, and 4.91-6.34 mg/100g for calcium, iron, and zinc, respectively.

Keywords

Barley Flour, Characterization, Composite Flour, Formulation, Nutrient, Potato Flour, Sorghum Flour

1. Introduction

1.1. Background

Sorghum grain is a prominent cereal crop for most of the countries in the world. Sorghum is characterized by its ability to produce grain in places with shortage of water supply and characterized by drought [1]. The nutrient components in sorghum grain are about 74% CHO, 1.2% ashes, 4.2% fat, 12.3% protein and 1.7% crude fiber [2]. On the other hand, the active compound found in sorghum has a disadvantage on the functionality of food products. For instance, tannin compounds affect color, texture and give bitter taste to *injera* and phytic acid impairs bioavailability of minerals [3].

*Corresponding author: asmafaris16@gmail.com (Faris Mohammed)

Received: 14 April 2025; **Accepted:** 27 April 2025; **Published:** 6 June 2025

Furthermore, inadequate dietary fiber intake in sorghum grain may be associated with high plasma cholesterol that relates to heart disease [4]. Barley is a cereal grain and found fourth level of world's cereal production sharing 12% of the total. It consists of high fiber content, which is very important in improving textures and gives lightness to bakery products as well as it used to reduce cholesterol in our body [5].

Potato (*Solanum tuberosum L.*), which is harvested as a fresh vegetable, is the world's fifth ranked crop in terms of production [6]. It is a root crop and currently at high production rate and so extensively dominating a wide range of farming land [7]. This root crop product consists of minerals and is high in resistant starch, which is very useful in colon fixation and digestion systems. Furthermore, lysine protein which is absent from grain crops and it helps the body to absorb minerals is found in potatoes. Potatoes are also characterized by having high moisture retention, which may improve the texture of baked food products [7-9].

Blending of flours is simply the combination of two or more flours of cereal grains that aim for nutritional improvements and gaining the overall acceptability of a food product.

Foods which may be produced from flours of different cereal and root crops can provide better nutrient and dietary diversity [10]. According to [11], blending flour for *injera* making is possible with a minimum cost.

For instance, barley flour combined with *teff* flour can be used to make low cost, nutrient dense *injera*, thereby positively influencing food and nutritional problems [12]. Potato flour can be introduced to different food types to improve texture and moisture retention. The blending of potato and cereal flours is reasonable in formulation of the food product system. For instance, combining potato and wheat flours lowers the price of importing wheat and boosts the use of crops grown nearby [13].

To sum up, blending of flour and starchy root crops may improve the different physicochemical properties and functional properties of baked food products. Moreover, barley and potato are also highly nutritious and very important in alleviating food nutritional problems [14]. However, the practice of mixing cereals with potato flour to make injera is not very common, and there hasn't been much scientific study done on the characteristics of sorghum-barley-potato composite flour up to this point. In order to create and describe the physicochemical and functional qualities as well as the mineral contents of sorghum-barley-potato composite flours that are blended at varied ratios, this study was done. The sorghum (*muyra2*), barley (*golden eye*), and potato (*bubbu*) were considered for experimental analysis.

1.2. Objective

1.2.1. General Objective

The formulation and characterization of composite flours of sorghum (*muyra2*), barley (golden eye) and potato (*bubbu*) for production of baked bread, which have been consumed in Hararghe, Oromia Region, Ethiopia.

1.2.2. Specific Objective

1. To quantify physicochemical and functional properties of sorghum, barley, and potato flours.
2. To determine mineral contents of sorghum-barley-potato composite.

2. Materials and Methods

2.1. Experimental Site

The experimental works such as functional properties, mineral contents, physico-chemical properties of sorghum-barley-potato composite flours were conducted at Department of Food Science and Post-harvest Technology Laboratory, Haramaya University. Crude protein, crude fat and fiber analysis was carried out at Animal Nutrition Laboratory, School of Animal Science, Haramaya University.

2.2. Experimental Material

Twenty five kilograms of fresh potato (*bubbu)* varieties, which was released in 2001, and twelve kilograms of sorghum grain (*muyra2*) variety, which was released in 2000, was collected from Haramaya University Agricultural Research Center (HUARC). Six kilograms of barley grain, (*golden eye)* varieties, which was released in 2012, collected from Fadis Agricultural Research Center (FARC).

2.3. The Equipment and Chemicals Used for Experiments

The equipment were used such as desiccator, oven drying, beaker, stirrer, measurement balance, muffle furnace, grinder, blender, tongue, fork, crucible glove, filter paper etc. the chemicals were used such as HCl, H2SO3, ether, petroleum ether, hexane, Ortho-phosphoric acid, NaOH, KOH, lanthanum solution, boric acid, sunflower oil.

2.4. Experimental Plan

The experiments were conducted in single factors factorial design of multiple levels. Blending ratios (B) had four levels which were denoted by (B0, B1, B2, and B3). The 100% of sorghum flour was used as a control unit and denoted by B0. The experimental treatment was carried out in triplicate.

Table 1. Experimental plan.

Blending Ratios	Treatments		
	1	2	3
B0	B01	B02	B03
B1	B11	B12	B13
B2	B21	B22	B23
B3	B31	B32	B33

Where:
B1 = Blending Ratio of 80:15:5 of sorghum, barley, and potato, respectively
B2 = Blending Ratio of 70:20:10 of sorghum, barley, and potato, respectively
B3 = Blending ratio of 50:25:25 of sorghum, barley, and potato, respectively.

2.5. Preparation of Sample

2.5.1. Sorghum Flour

The preparation of sorghum flour was done in a public milling house which was found in Bate. Ten kilograms (12 kg) of Sorghum grains (*Muyra2* varieties) were cleaned by methods of dry cleaning to get rid of rocks and other extraneous objects. Then, it got wet in clean water to remove unwanted material, which was not eliminated by dry cleaning methods. After that, it was dried in the sun for 30 min. A disc mill was used to grind the dry and weighed sorghum into flour. Before milling the actual sample, 2 kg of sorghum grain was milled to remove remnants of previous flour from the flour mill to prevent contamination. Before being used for additional processing and analysis, the flour sample was sealed, placed in polyethylene bags, and kept at room temperature (25 ℃) [15].

2.5.2. Preparation of Barley Flour

The preliminary preparation of barley grain was traditionally performed. The whole barley grain (golden eye variety) was assessed for any kind of defects and overall quality to the experimental analysis. Barley grain, which is free from defects and fulfills requirements for experimental work, was cleaned to remove unwanted material. This was done by a dry cleaning method followed by wet cleaning. Then, cleaned barley grain was conditioned or tempered for about 4 hours to 16% of moisture content. Then it was traditionally decorticated by a mortar and pestle to remove the hulls from the barley kernel. After that, drying was done by sun drying for about 45 min and separation of barley kernel from hull was done by winnowing. The prepared barley kernel was milled by a disc mill. For additional processing and experimental investigation, barley flour was sealed in polyethylene bags and kept at room temperature [16].

2.5.3. Preparation of Potato Flour

Twenty five kilograms (25 kg) of potato tuber (*bubbu* variety) was selected for the experiment, and the basic flour processing were: cleaning/sorting, peeling, slicing, blanching, cooling, drying, crushing/milling and screening of final flours [17].

2.6. Proximate Analysis of Flours of Sorghum, Barley, Potato and Composite *Injera* and Total Energy

2.6.1. Moisture Content

$$\text{Moisture Content (\%)} = \left(\frac{W2-W3}{W1}\right) * 100 \quad (1)$$

The prepared flour's level of moisture was determined based on [18] official method 925.09. The empty moisture test dish was weighed (W1). After being weighed (W2), the sample was dried for approximately six hours at 60 ℃ before being chilled in a desiccator to room temperature. The test dish and dried sample were weighed and represented by W3. The proportion of moisture in the flour's was then calculated as follows:

Where W1 represents the mass of the dish, W2 represents the mass of the sample and container, and W3 represents the mass of the sample and container upon drying (g).

2.6.2. Crude Fat

The crude fat in the flour sample was evaluated by the soxhlet method of extraction following the procedures of [18] official method 979.09. Before being siphoned and returned to the boiling flask, the hexane solvent was poured to the extraction chamber and completely encircled the sample. These were done for 5-10 min. The soxhlet, extraction thimble, extraction chamber and desiccators are all equipment used for overall fat extraction [19]. After being cleaned and dried, the extraction chamber was weighed (W1). The cotton that was fat-free was coated. Another layer of fat-free cotton was placed over the extraction thimble that held the 2 g of sample (W), which had been weighed primarily. After that, the thimble was put inside the extraction chamber, and the extraction cylinder that had been cleaned and dried was taken out of the desiccator and put into the flask holder. The extraction cylinder was filled with roughly 50 mL of ether before being placed into the heating plank. For almost four hours, the extraction was conducted at 55 ℃. After being separated, the extraction cylinder was dried in an oven set to 70 ℃ for roughly half an hour. After that, it was put in a desiccator to chill for roughly half an hour. The extraction cylinder was finally taken out of the desiccator and weighed (W2). The crude fat percentage was computed as follows:

$$\text{Crude Fat (\%)} = \left(\frac{W2-W1}{W}\right) \times 100 \quad (2)$$

Where: W1 is the extraction cylinder's weight (g), W2 is the extraction cylinder's weight plus the weight of the dried crude fat (g), and W is the sample's weight in (g).

2.6.3. Crude Protein

The amount of protein was calculated using [18] official method 979.09. After weighing 0.5 g of the sample, 6 mL of an acid combination (5 percent concentrated Orthophosphoric acid and 95 percent sulfuric acid) was added to each digestion tube and thoroughly mixed. After that, 3.5 mL of 30% hydrogen peroxide was added until violet reactions were observed. Each tube was filled with 3 g of the catalyst combination (0.5 g of ground selenium and 100 g of potassium sulfate), which was left for roughly 10 minutes prior to digestion. After four hours, the digestion was carried out until a clear solution was achieved. By adding 25 mL of di-ionized water, the precipitation of sulfate in solution was prevented. Using 2% boric acid and 40% NaOH, the sample solution was digested and diluted before being distilled. After that, 0.1N HCl acid was used to titrate the distillate until a reddish hue developed. Crude protein's nitrogen value was calculated as follows:

$$\text{Nitrogen (\%)} = \left(\frac{VHCL*[HCl]}{Wo}\right) \times 14 \times 100 \quad (3)$$

Where: VHCl = Volume of HCl; W0 = Weight of sample

$$\text{Protein \%} = 6.25\times \%Nitrogen \quad (4)$$

2.6.4. Ash Content

The ash content was determined based on [18], the official approach 923.03. After being cleaned with distilled water, the dried porcelain crucible was put in a muffle furnace set to 550 degrees Celsius and burned for around 30 minutes. After that, the crucible was left to cool at ambient temperature for almost half an hour. Following the weighing of the crucible (M1), the cooled crucible, and three grams of sample (M2), the sample was completely burned in a fume hood until smoking stopped. The sample spent almost four hours at 550 degrees Celsius in a muffle furnace. Then, it was cooled for about 1 hour and weighed (M3).

$$\text{Total Ash (\%)} = \left(\frac{M3-M1}{M2-M1}\right) \times 100 \quad (5)$$

Where (M2-M1) is the sample weight on a dry basis and (M3-M1) is the ash weight.

2.6.5. Crude Fiber Analysis

The analysis of crude fiber content was conducted using the standard method of [18]. A new sample weighing 3 g (W1) was put into a 700 mL beaker. After adding roughly 200 mL of 1.25 percent H2SO4, it simmered for about half an hour. After adding roughly 20 mL of 20% KOH, the mixture was cooked for an additional 30 minutes. The residue in the crucible was cleaned with hot distilled water and then filtered twice. The residue was filtered once more after being cleaned with 1% H2SO4 and then rinsed with 1% KOH. Lastly, water-free acetone was used to wash the residue. After being dried for approximately two hours at 130 degrees Celsius in an oven dryer, the crucible containing the sample was cooled for approximately half an hour in a desiccator before being weighed (W2). After being heated to 550 degrees Celsius for approximately 30 minutes in a muffle furnace, the crucible was cooled in a desiccator and its contents were weighed (W3). This is how the crude fiber was calculated.

$$\text{Fiber content (\%)} = \left(\frac{W3-W2}{W1}\right) \times 100 \quad (6)$$

Where: The weight of the crucible containing the sample after oven drying is W2, the weight of the crucible containing the sample after ashing is W3, and W1 is the weight of the fresh sample.

2.6.6. Utilizable Carbohydrate

The amount of usable carbohydrate was calculated as follows:

$$\text{\%Utilizable Carbohydrate= 100\% - (\%Moisture + \%Protein + \%Fat + \%Crude Fiber + \%Ash)} \quad (7)$$

2.6.7. Total Energy Content

The conversion of 4, 9, and 4 kcal per gram of crude protein, crude fat, and carbohydrate, respectively, yielded the total energy [20].

$$\text{Total Energy (Kcal/100g)} = [9 * \%Fat + 4 * \%Protein + 4 * \%Carbohydrate] \quad (8)$$

2.7. Mineral Contents

2.7.1. Iron

Iron was evaluated by the Atomic absorption spectrophotometer method [21]. After being pre-ignited at 550 ℃, the crucible was cooled in a desiccator. The weight of each crucible was recorded after the empty crucible was weighed and coded with a number. After weighing, roughly 3 g of the material was put into a crucible. The sample in a crucible was heated at 550 ℃ in a muffle furnace for approximately four hours, or until ashing developed. After cooling in a desiccator, the crucible and ash were weighed together, and the outcome was once more noted. Five milliliters of diluted 0.1M HCl were used to dissolve the ash. After that, the solution was transferred to a volumetric flask using premium filter paper. After being re-dissolved in 20 milliliters of 1M HCl, the residue was filtered into 100 milliliter volumetric flasks. Then it was read by the Atomic absorption spectrophotometer (510 nm). Iron content was computed as:

$$Iron\ Content\ \left(\frac{mg}{100}\right) = \frac{C \times DF \times 10}{Sample\ massing(db.)} \quad (9)$$

Where C stands for sample concentration in parts per million, DF for dilution factor, and 10 for conversion factor when evaluating 10 milliliters out of 100 milliliters.

2.7.2. Zinc

The same procedure to iron analysis was followed. Zinc content was computed as:

$$\text{Zink}(ppm)\left(\frac{mg}{100g}\right) = \frac{(Cs-Cb)V \times D}{S} \quad (10)$$

Where: Cs = Concentration of analyte, Cb = Concentration of blank, V = Initial volume (100 ml), D = Dilution factor and S = Mass of the sample (g)

2.7.3. Calcium

The same procedure to Iron was followed.

Sample was weighed and charred on a hot plate, and then it was ashed. The sample was cooled and a few drops of strong HCl were added if ashing could not be finished. The sample was dried and re-ashed again. After that, 5 mL of strong HCl was used to break it up and dissolve it. Using a steam bath, the solution was cooked and then evaporated. After dissolving the residue in HCl once more, the mixture was filtered into a volumetric flask. After washing, the paper and residue were diluted to the 100 mL threshold. A stock solution of lanthanum (La) was added. Next, a typical calcium solution was made. Lastly, an absorption spectrophotometer was used to measure the absorbance of the sample and the standard solution at 422.1 nm. Calcium content was computed as:

$$Calcium\ (ppm)\left(\frac{mg}{100g}\right) = \frac{(Cs - Cb)V \times D}{S} \quad (11)$$

Where Cs is the concentration of the analyte, Cb is the blank's concentration, initial volume, D is the dilution factor, and S is the sample's mass (g).

2.8. Determination of Physical Properties of Flours

2.8.1. Particle Size Distribution

After being weighed, the flour samples were put in series to the top sieve (500 µm, 300 µm, 250 µm, 150 µm, and 125 µm). About fifteen minutes were spent shaking the column. At the end of shaking, material on each of the sieves were weighed [22]. The percentage of sample retained on the sieve was computed as:

$$Percentage\ of\ sample\ retained\ (\%) = \frac{Wsieve}{W\ total} \times 100 \quad (12)$$

Where: Wsieve = Weight of the sample retained on the sieve, Wtotal = Total weight of the sample

The percentage the sample was passed through the sieve was computed as:

Percentage of passed flour = 100% - Percentage of sample retained on the sieve.

2.8.2. Bulk Density

The empty test tube was weighed (W1) and its volume (V) was known. The sample was added to the test tube and tapped until constant volume was obtained [23]. Finally, the test tube plus tapped sample was weighed together for each sample (W2). Then bulk densities were computed as:

$$\text{Bulk Density (g/g)} = \frac{W2-W1}{V} \quad (13)$$

Where: W1 = Weight of empty test tube, W2 = Weight of sample plus test tube, V = Volume of test tube

2.8.3. Angle of Repose

Using one end, a cylinder with both ends open was set on a level surface. The flour sample was filled into the cylinder. The flour then slid down, creating a conical pile, while the cylinder was gradually raised off the surface. Measurements were made of the heap's diameter at the base and height at the top [24]. The height and diameter of the heap's summit were then measured and noted. The angle of repose was finally calculated as follows:

$$\text{Angle of repose } (\varphi o) = tan^{-1}\left(\frac{2h}{d}\right) \quad (14)$$

Where d is the heap base's diameter and h is the heap's

height.

2.9. Evaluation of the Functional Characteristics of Blended Flours of Sorghum, Barley, and Potato

2.9.1. Water Absorption Capacity

The empty test tube was coded and weighed and recorded (W1). After being weighed, the 1 g sample was put into a test tube (W2). The test tube was then filled with roughly 10 mL of distilled water. After that, it shook for almost three minutes. After it was shaken well, it was placed in centrifuges at 400 rpm in the centrifuge tube and stirred six times at 10 min time intervals. After the sample was centrifuged the supernatant was decanted then re-weighed (W3). Then, the percentage of water absorption capacity was computed as follows [24].

$$\text{WAC } (\%) = \frac{W3-(W1+W2)}{W1} * 100 \quad (15)$$

Where W1 is the weight of the test tube when it is empty, W2 is the weight of the sample, and W3 is the weight of the residue in the centrifuged tube.

2.9.2. Oil Absorption Capacity

Oil absorption capacity was calculated using the procedure outlined by [25]. The empty 25 mL centrifuge tube's weight was determined (W1). In the centrifuge tube, 10 mL of oil was mixed with 1 g of weighed flour (W0). After swirling for roughly five minutes, it was centrifuged for ten minutes at 400 rpm. The distinct oil was decanted as the supernatant. Lastly, the sediment and centrifuge tube weights were noted (W2). The following formula was used to determine the oil absorption capability.

$$OAC\ (\frac{g}{g}) = \frac{W2-(W0+W1)}{W0} \quad (16)$$

Where W0 is the sample's weight, W1 is the empty centrifuge tube's weight, and W2 is the empty centrifuge tube's weight plus the sediment's weight.

2.9.3. Disperse Ability

After weighing roughly 10 g of the sample, it was put into a 100 mL measuring cylinder and filled to the brim with distilled water. After stirring, it was left to settle for almost two hours [26]. Ultimately, the ability to disseminate was calculated as follows:

$$\text{Disperse ability= 100 ml - volume settled particle} \quad (17)$$

2.9.4. Swelling Power and Solubility

After weighing the 3 g sample, distilled water was poured to the centrifuge tube. A glass rod was used to swirl the tube while it was submerged in a hot water bath with a thermostat. After being taken out and allowed to cool, the tube was centrifuged. After being moved to a crucible, the supernatant was evaporated over a steam bath and dried in an oven. The crucible was then weighed in order to determine the swelling power [27]. After the supernatant was dried, the weight difference provided the weight of the soluble material, which was then used to compute the percentage solubility, which is the weight of the soluble material divided by the dry weight of the starch. The power of swelling was calculated as follows:

$$\text{Power of Swelling (g/g)} = \frac{Wet\ sediment\ weight}{Mass\ flour\ sample} \quad (18)$$

The solubility of the material was given as:

$$Solubility\ (g/g) = \frac{Mass\ of\ soluble\ material}{Mass\ of\ flour\ sample} \quad (19)$$

2.10. Statistical Analysis

Following data collection, SAS 9.1 software was used as a statistical analysis tool to perform analysis of variance (ANOVA) among the treatments. Mean values were used to compare the data. All significant treatment effects in the observed parameters (P = 0.05) were compared using LSD. The analysis of the treatment was done in triplicate.

3. Results and Discussion

3.1. Physical Characteristics of Sorghum, Barley, Potato and Blend Flours

3.1.1. Particle Size Distribution of Blended Flours

The distribution of particle sizes of sorghum, potato and barley flour are presented in Table 2. The percentage of particle size above 500 µm was very low and ranged from 0.66 to 0.80% of potato and sorghum flour, respectively with the significant difference at (P<0.05) between them. Similar trends prevailed in the sample above 300 µm particle size and had significant differences. The scored result varied between 2.43 and 3.02% of potato and sorghum flour, respectively.

Table 2. Distribution of particle size of sorghum, barley, and potato flour.

Factor	Particle size distribution of flours (%)				
	500 µm	300µm	250µm	150µm	125µm
Sorghum	0.68±0.08[a]	3.02±0.18[a]	15.20±0.40[a]	31.50±1.74[a]	49.88±2.10[a]
Barley	0.80±0.02a	2.73±0.17a	16.10±0.27a	30.52±0.85a	49.82±1.23a
Potato	0.66±0.06a	2.43±0.15ba	14.72±0.40ba	28.35±2.87a	54.32±2.68a
CV (%)	7.88	6.06	2.35	6.63	4.09
LSD	0.14	0.41	0.91	5.00	5.25

All values are mean ± standard deviation. Means within column with different superscript are significantly different at P<0.05. Where: CV = Coefficient of variation, LSD = Least significant difference.

For sorghum, barley, and potato flour, the percentage of particles larger than 250 µm likewise showed a significant difference (P<0.05). The values are ranged between 14.72 and 16.10% with the highest score for barley flour and lowest for potato flour. The percentage of particle size ranged from 0.2-6.7%, 2.90-56.20% and 31.10-44.5% of 500, 250, and 125µm, respectively, which is presented by [28] for *teff* flour. This outcome was consistent with the current research. However, there was no significant difference (P>0.05) in the percentage of particles larger than 150 µm between the sorghum, barley, and potato flours. The sorghum, barley, and potato flour scores are 31.50, 30.52, and 28.35 percent, respectively. Likewise, the fraction of particles larger than 150 µm did not differ significantly (P>0.05). The recorded values are 49.88, 49.82, and 54.30% of sorghum, barley, and potato flour respectively (Table 2).

The rate of water absorption during processing is influenced by the flour's particle size; finer particles result in faster water absorption [29]. Dough made with coarse flour was more rigid and resistant to flow and deformation [30]. More particles are held on the sieve during meshing because the smaller particle size increases the surface area available for surface cohesive forces to interact and friction to prevent flow [31].

3.1.2. Bulk Density of Flours

When deciding on the necessary packaging, handling materials, and applications for wet processing in the food business, bulk density is a crucial factor [32]. The bulk density data for each flour type are shown in Table 3. The values for barley, sorghum, and potato flour categories were 0.60, 0.81, and 0.85 g/mL, respectively, indicating significant differences (P<0.05). The potato's value exceeded the range of 0.66 to 0.72 g/ml as reported by [33] and in agreement with the 0.79 to 0.89 g/mL of early findings reported by [34]. The 0.60 g/mL for the barley found in this study was in agreement with the 0.63 to 0.72 g/mL reported by [35].

The bulk densities of the composite flours were 0.71, 0.76, and 0.79 g/ml for B1, B2, and B3, respectively. The latter two were not significantly (P>0.05) different from each other but statistically higher than the former, probably because of more percentage of potato in the mixture.

3.1.3. Angle of Repose

Table 3 displays the angle of repose data for each of the three varieties of flour. The sorghum and potato flours' 38.74 and 38.24 degrees did not differ substantially (P>0.05), although they are both much higher than the barley flour's 33.40 degree. The composite flours on the other hand exhibited statistically different values with 28.63, 33.06, and 44.30 degrees for B1, B2 and B3 blending ratios, respectively. According to earlier research, when the moisture content increases, so does the flour's angle of repose [36].

Table 3. Angle of repose and bulk density of sorghum, barley, potato, and blending flours.

Flour Type	BD (g/mL)	AR (˚)
Sorghum	0.81±0.01[a]	38.74±0.66[b]
Barley	0.60±0.01[c]	33.40±0.41[c]
Potato	0.85±0.02[a]	38.24±0.49[b]
Blending Ratio		
B1	0.71±0.03[b]	28.63±0.87[d]
B2	0.76±0.00[ba]	33.06±0.74[c]
B3	0.79±0.01[a]	44.30±0.55[a]
CV (%)	2.10	1.63
LSD	0.04	1.75

All values are mean ± standard deviation. Means within a column with the different superscript letter are significantly different at P<0.05. Where: CV = Coefficient of variation, LSD = Least significant difference, BD = Bulk density, AR = Angle of repose B1, B2, B3 = Blending ratios.

3.2. Functional Properties of Sorghum, Barley, Potato and Blend Flours

Table 4 displays the functional property values of the potato, barley, and sorghum flours and their blends made for the study. In order to correlate and measure the complicated relationship between the structure, composition, physicochemical characteristics, and molecular conformation of dietary components with the type of surroundings, functional properties are crucial physicochemical characteristics [35].

3.2.1. Water Absorption Capacity of Blended Flour

The flour's ability to retain water against gravity, including physically trapped and bound water, is known as its water absorption capacity [37]. It is crucial for product uniformity and bulking in baking applications [38].

Table 4. *Functional property of sorghum, barley, potato, and blended flour.*

Flour Type	WAC (g/g)	OAC (g/g)	DA (%)	SP (g/g)
Sorghum	2.04 ±0.09^{b}	0.84 ± 0.06^{a}	67.17 ±0.76^{a}	9.23 ±0.21^{b}
Barley	2.19 ±0.06^{b}	0.13 ±0.05^{c}	56.50 ±1.32^{b}	11.17 ±0.24^{a}
Potato	2.12 ±0.05^{b}	0.09 ±0.05^{c}	66.33 ±1.53^{a}	8.24 ±0.25^{c}
Blending Ratio				
B1	2.44 ±0.10^{a}	0.95 ± 0.04^{a}	68.50 ±1.80^{a}	9.59 ±0.17^{b}
B2	2.09 ±0.03^{b}	0.86 ±0.06^{a}	69.33 ±1.53^{a}	9.64 ±0.30^{b}
B3	1.98 ±0.04^{bc}	0.80 ±0.04^{ba}	68.50 ±1.50^{a}	9.37 ±0.33^{b}
CV (%)	3.05	5.34	2.19	2.68
LSD	0.18	0.11`	3.96	0.70

All values are mean ± standard deviation. Means within a column with the different superscript letter are significantly different at P<0.05. Where: CV = Coefficient of variance, LSD = Least significant difference, BR = Blending ratio, WAC = Water absorption capacity, OAC = Oil absorption capacity, DA = Disperse ability, SP = Swelling power.

The mouthfeel, texture, and consistency of flour products are all influenced by WAC and OAC [39]. The water absorption capacity data of sorghum, barley, potato flours and their blends, are presented in Table 4. Statistically no significant difference was observed for water absorption capacity, among unblended flours and having values between 2.04 and 2.19 g/g. On the other hand, significant differences were observed among the composite flours with the highest value (2.44 g/g) being observed for samples with 80% sorghum, 15% barley, and 5% potato level whereas the lowest value (1.98 g/g) was observed for those with 50% sorghum, 25% each of the barley and potato blend. The flours used in this study had water absorption capacities ranging from 1.33 to 2.00 g/g of fermented sorghum, cocoyam, and germinated pigeon flours, which were comparable to previous results reported by [38]. This result, also in line with previous findings, ranged from 0.82 to 2.88 g/g which were recorded for wheat and *jering* seed composite flours by [39]. The WAC of blended flour was higher than that of sorghum flour; this was due to decrease in fat content as barley-potato flour mixture is increased as indicated in data of current work. The fat is characterized by hydrophobic nature and so it's one of the factors which may affect the WAC of bakery food [40]. As a result, some meals, such as bakery goods, are made with flour that has a high WAC. As a result, flour with a high WAC may have more hydrophilic ingredients, like polysaccharides [33].

3.2.2. Oil Absorption Capacity of Flours

The ability of flour to absorb oil is known as its oil absorption capacity [41]. Food tastes may be better retained by flour with a high OAC content. They can be utilized to create food items with improved flavor and mouthfeel [42]. The oil absorption capacity of the flours exhibited significant (P<0.05) differences with values of 0.84, 0.09 and 0.13 g/g for sorghum, potato and barley, respectively. This could be attributed to the natural composition of the flours. The significant difference (P<0.05) were also seen in the OAC values of the various levels of barley and potato mixes with sorghum that are shown in Table 4. The range of the readings was 0.09 to 0.95 g/g. The combined proportion of 80% sorghum, 15% barley, and 5% potato flours produced the highest value for B1, whereas the potato flour sample produced the lowest value. In this study, the oil absorption capacity of blended flour was comparable to that of teff-taro

composite flour, which ranged from 0.9 to 1.45 g/g, which previously reported by [43] and lower than value ranged from 1.87-2.08 g/g for composite flour, which presented by [44]. Similarly, it was lower than 1.33 to 2.80 g/g recorded for blended, fermented sorghum and germinated pigeon flour reported by [38].

The protein content of dietary materials and the lipophilic nature of the granule surface of flours influence their functional qualities. Food protein consists of hydrophilic and hydrophobic parts and has an implication on oil absorption capacity of flour [35, 44].

3.2.3. Disperse Ability

A measure of how easily flour can be reconstituted into a fine-grained paste while being stirred is called disperse ability [45]. The ability of flour to disperse particles in water is another significant functional feature that can be used in a variety of culinary preparations. The data of dispersive ability of the flours considered in this study are presented in Table 4. The flours of pure sorghum and potato didn't show statistical difference (P>0.05) between them with values of 67.17 and 66.33%, both of which being significantly (P<0.05) greater than the 56.50% of the barley flour. Comparable outcomes were reported by [46], who showed that the dispersive-ability for wheat, maize, yam, cassava and cocoyam flours were 71.1, 68.1, 65.00, 69.00, and 60.30%, respectively. No significant difference (P>0.05) were noted among the blends of flours of sorghum, potato and barley, all showing disperse ability values of 68.50% for both of B1 and B3 as well as 69.33% for B2 of flour sample.

3.2.4. Swelling Power of Flour

Table 4 displays the flours' swelling power data. The unblended flours' swelling powers ranged from 8.24 g/g of potato flour to 9.23 g/g of sorghum and 11.17 g/g of barley flour, with a significant difference (P<0.05). These findings were more than the 2.57 to 5.75 g/g and 2.58 to 5.82 g/g measurements for white water yam and yellow yam flours, respectively, that were published by [47]. In contrast, the swelling power value in this work ranges from 8.24 to 11.17 g/g. This was consistent with earlier research findings that showed a range of 5.7 to 23.5 g/g, as reported by [48]. However, no significant difference was observed due to the blending ratio with values being between 9.37 and 9.64 g/g.

The capacity of starch to immobilize water and swells is known as swelling power [49]. Because it indicates the strength of the associative forces inside the flour of granules, the swelling power of flours affects food preparation [50]. The outer membranes of the starch granules in the flour rupture during the milling process and expand up in the form of a gel by absorbing water, which could be the cause of the increase in swelling power. The degree of crystalline packing of the starch granules in the flour is indicated by the swelling pattern [51]. In conclusion, dietary components including carbohydrate, fat, protein, ash, and fiber, as well as other additives like sugar and alcohol, always affect the functional qualities of flours and foods [52].

3.3. Proximate Composition of Blended Flours

Table 5. *Proximate composition and total energy of blended flours.*

BR	MC (wb%)	Fat (%)	CP (%)	CF (%)	Ash (%)	CHO (%)	Total Energy (kcal/100g)
B1	11.99 ± 0.27^{b}	3.06 ± 0.19^{a}	16.27 ± 0.25^{a}	5.98 ± 0.43^{a}	1.77 ± 0.04^{ba}	60.94 ± 0.59^{a}	336.34 ± 3.33^{a}
B2	12.63 ± 0.16^{ba}	2.94 ± 0.06^{a}	15.77 ± 0.25^{a}	5.93 ± 0.37^{a}	1.84 ± 0.16^{a}	60.90 ± 0.81^{a}	333.10 ± 2.85^{a}
B3	12.75 ± 0.28^{ba}	2.72 ± 0.28^{a}	15.33 ± 0.50^{a}	5.47 ± 0.50^{a}	2.14 ± 0.02^{a}	61.59 ± 1.07^{a}	332.16 ± 1.50^{a}
CV (%)	2.67	5.87	2.39	6.12	5.90	1.07	0.66
LSD	0.86	0.40	0.93	0.94	0.29	1.89	6.12

All values are in mean ± standard deviation. Means with in a column with the different superscript letter are significantly different at P<0.05. Where: CV = Coefficient of variance, LSD = Least significant difference; B1, B2, B3 = Blending ratios, MC = Moisture content, wb = Wet basis, CP = Crude protein, CF = Crude fiber, CHO = Utilizable carbohydrate.

Table 5 displays the proximate composition information for the three flours and their blends. Table 5 also shows that there were no significant (P>0.05) variations in the moisture content of the blended flours. For B1, B2, and B3, the moisture content values were 11.99%, 12.63, and 12.75 percent, respectively. The recorded data ranged between 11.99 and 12.75%. The previous result of moisture content (11.64%) of barley flour, which reported by [53] was in range of current study. The current result also in line with values ranged from 6.63-15.98% of earlier findings for potato, rice, cassava and

soybean flours, which was reported by [44] and higher than (4.48%) of early study for potato flour, reported by [54]. The high moisture content of the potato flour seemed to have contributed to the blends' increased moisture content.

The crude fat content of blending flours was no significant (P>0.05) difference (Table 5). The recorded data 3.06, 2.94, and 2.72% were observed for B1, B2, and B3. This value is between 2.72 and 3.06%. The result of earlier findings ranged from 1.63 to 1.79%, for sorghum flour, which reported by [55] was lower than that of the current study. It was a close range with the value ranging from 4.42 to 4.56% of sorghum flour which were reported by [56]. It observed that the high crude fat of the sorghum flour has played a role in raising those of the blends.

Similarly, there was no significant difference (P>0.05) in crude protein of blended flours (Table 5). The results ranged from 15.33 to 16.27%. These results were higher than the earlier work, ranging from 4.54 to 13.70%, those reported by [44] for potato, rice, cassava and soybean flour; as well as value ranged from 5.87 to 7.66% for potato varieties, which reported by [57]. The current study also indicated that the protein content, which was observed in blended flour, was higher than that of previous results, reported by different authors for sorghum flour.

Regarding the crude fiber no significant difference (P>0.05) was found between blended flour (Table 5). For B1, B2, and B3, the fiber level of the blended flour was 5.98, 5.93, and 5.47 percent, respectively. The obtained results in the current study were higher than values ranging from 3.48 to 4.48% of earlier work as reported by [54]. A higher fiber content does help flours retain and cling onto water better [52].

There was no significant difference (P>0.05) in the blended flours' ash content data (Table 5). The present investigation yielded data that varied between 1.77 and 2.14 percent. The previous result values 1.89% of ash content observed in sorghum flour was in range of current work, which reported by [56]. The increased percentage of barley and potato flour in the composite flours has contributed to lift the ash levels. These values were lower than the 2.50 to 3.00% observed for *teff*-barley composite flour, which was reported by [58].

Table 5 indicates that there were no significant (P>0.05) variations in the blended flour's carbohydrate content. For B1, B2, and B3, the recorded data values were 60.94, 60.90, and 61.59 percent, respectively. The carbohydrate content in this work is varied from 60.90 to 61.59%. These results were lower than the results of earlier work, 82.71% of sorghum flour, which was reported by [56]. Because blended flour has a high protein level, it may have a lower carbohydrate content in this study.

In regard to energy content there was no significant difference (P>0.05) between blended flour (Table 5). The composite flours had values of 336.34, 333.10, and 332.16 Kcal/100g recorded for B1, B2, and B3, respectively with no statistical difference between them. The results of the current study for energy content was higher than the results of earlier work ranged from 330.99 to 344.73 Kcal/100g, which was reported by [54] for blanched potato flour. However, it was lower than the value that ranged from 337.85 to 375.57 Kcal/100g, which was presented by [59] for finger millet, soybean, and sweet potato composite flour.

3.4. Mineral Contents of Sorghum, Barley, Potato and Blend Flours

Table 6 shows the mineral content of flours of sorghum (*muyra2*), barley (*golden eye*), potato (*bubbu*), and their mixtures. The results indicated that the zinc contents of B1, B2, and B3 were 5.42, 5.88, and 4.91 mg/100g, respectively, with no significant difference (P>0.05). The range in this investigation was greater than the teff flour value of 1.47 mg/100g provided by [60] and comparable with (4.72 mg/100g), which was reported by [59] for barley flour.

Table 6 also shows, there was significant difference (P<0.05) in calcium content of blended flour. The obtained result ranged from 8.64 to 11.68 mg/100g. The value 30.00 mg/100g of calcium content for sorghum flour, which was presented in previous work as reported [61] was higher than that of current study. On the other hand, the range of current result is higher in calcium content than 3.36 to 4.14 mg/100g, which is reported by [55] for sorghum flour. This shows that the calcium content observed in blended flour of current data was preferable and acceptable for *injera* making (Table 6).

Additionally, the iron content of the blended flour showed no significant variation (P>0.05), with an intermediate value of 11.78 mg/100g of B3. Table 6 shows that the value is between 11.78 and 14.59 mg/100g. The range of current study was higher than 6.29 mg/100g of iron content of barley flour, which was reported by [53].

Table 6. *Mineral contents of sorghum, barley, potato, and blending flour (mg/100g).*

Factor	Minerals		
	Zn	Ca^{2+}	Fe^{3+}
B1	5.42 ± 0.20^{a}	8.64 ± 0.35^{b}	14.59 ± 1.23^{a}
B2	5.88 ± 0.84^{a}	9.17 ± 0.48^{b}	11.92 ± 1.63^{a}
B3	4.91 ± 0.16^{a}	11.68 ± 0.26^{a}	11.78 ± 1.01^{ba}
CV (%)	8.08	3.68	7.62
LSD	2.07	1.53	2.70

All values are mean ± standard deviation. Values within the same column with different superscript letters are significantly different from each other at P<0.05. Where**:** CV = Coefficient of variance, LSD = Least significant difference, Zn = Zinc, Ca^{2+} = Calcium, Fe^{3+} = Iron, B1, B2, B3 = Blending ratios.

4. Summary, Conclusions and Recommendations

4.1. Summary

In this study, blended flours made from sorghum, barley, and potatoes were examined for their proximate composition, mineral content, functional characteristics, particle size distribution, angle of repose, and bulk density.

Three blending ratios of sorghum-barley-potato were B1, B2, and B3 (80:15:5, 70:20:10, and 50:25:25, respectively were considered for the study. 100% sorghum flour served as the control unit.

The bulk density and angle of repose of sorghum, barley, and potato flour, as well as their combined flour, were 0.60 to 0.85 g/ml and 28.63 to 44.30 degrees, respectively, as well as particle size distribution of flours in percentage of retained was increased from (0.66- 0.80%) to (49.82-49.88%) as mesh size decreased from 500 µm to 125 µm, respectively. The functional characteristics of composite flours that were examined included solubility, swelling power, disperse ability, and the ability to absorb water and oil. The highest value (2.44 g/g) and lowest value (1.98 g/g) of water absorption capacity were observed in B1 (80% sorghum, 15% barley, and 5% potato flours), and B3 (50% sorghum, 25% barley and 25% potato flours), respectively. The oil absorption capacity ranged between 0.09 and 0.95 g/g were obtained in potato and B1 flours, respectively. Regarding swelling power, the highest value (11.17 g/g) and lowest value (8.24 g/g) were recorded for barley and potato flours, respectively. The disperse ability of flours ranged between 56.50 and 69.33% were taken for barley and B2 flours, respectively with no statistical difference between blending flours

The proximate composition of flours were 8.79-13.43% moisture, 0.97-3.76% fat, 4.69-17.60% crude protein, 4.00-6.28% crude fiber, 1.40-2.14% ash, 59.79-79.42% carbohydrate, and 318.16-350.91 Kcal/100g total energy content. Similarly, the physical properties of sorghum, barley, potato and their blending flours such as bulk density and angle of repose were 0.60-0.85 g/ml and 28.63-44.30 degree, respectively. For flours containing minerals including iron, calcium, and zinc, the scores were 3.19 - 6.34 mg/100g, 7.34-38.90 mg/100g, and 7.43-16.87 mg/100g, respectively.

4. 2. Conclusions

The combination of flours of sorghum, barley and potato were practicable for the improvements of nutritional and functional properties of baked food, which has been highly consumed in Hararghe, Oromia Region, Ethiopia. However, there was a limited scientific study done on this blended flour and its food product. The current study has done on the formulation and characterization of sorghum-barley-potato blended flour so as to improve the nutritional quality besides other food quality of sorghum based injera. The sorghum, barley, and potato flour was used as ingredients. The physical properties were analyzed in current work and recorded data showed that they were improved when compared with that of sorghum flour, which was recorded in earlier work. Similarly, functional properties, proximate composition, and mineral contents of blended flour were increased when compared with the results of previous work scored for similar parameters in sorghum flour. However, crude fat, CHO, and calcium content of blended flour in current work were lower than that of control samples of earlier work. The blending ratio of B3 was the best combination, when compared with the control sample because both nutritional and mineral contents were improved. The limitation of this study was the shortage of experimental instruments and the laboratory equipment with old versions as well as the current condition in the country were the major constraint while performing this research.

4.3. Recommendations

Study storage condition, shelf life, selection of packaging material, which enable good handling and sauce absorption index of sorghum-barley-potato composite flour is recommended for the coming studies.

Since they were not included in this paper, more research should be done to assess the blended flour's pasting qualities as well as its anti-nutrient content, such as its oxalate level.

Abbreviations

AACC	American Association of Cereal Chemist
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemist
CHO	Utilizable Carbohydrate
FARC	Fedis Agricultural Research Center
HUARC	Haramaya University Agricultural Research Center
LSD	Least Significant Different
OAC	Oil Absorption Capacity
SAS	Statistical Analysis System
WAC	Water Absorption Capacity

Acknowledgments

I want to thank Allah first and foremost for giving me the grace and strength to finish studying. Second, I would like to sincerely thank my advisor, Dr. Eng. Solomon Abera, for providing me with the chance to benefit from his extensive knowledge and expertise. Thirdly, Dilla University has my sincere gratitude and thanks for providing me with financial assistance. Finally, my sincere gratitude goes to my family, friends, and everyone else who helped me out in any way they could.

Author Contributions

Faris Mohammed: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Visualization, Writing - original draft, Writing - review & editing

Solomon Abera Habtegebriel: Project administration, Supervision, Validation, Visualization, Advising and approving.

Funding

This work is not supported by any external body.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] C. V Ratnavathi and V. V Komala, *Sorghum Grain Quality*. 2016. [Online]. Available: https://doi.org/10.1016/B978-0-12-803157-5.00001-0

[2] Y. Mihretie, "The Effect of Blending Ratio of Tef [Eragrostis Tef (Zucc) Trotter], Sorghum (Sorghum bicolor (L.) Moench) and F... Related papers," *J. Nutr. Food Sci.*, vol. 7, 2017. [Online]. Available: https://doi.org/10.4172/2155-9600.1000583

[3] J. M. Awika, "Sorghum: Its unique nutritional and health-promoting attributes," in *Gluten-free ancient grains*, Elsevier, 2017, pp. 21-54. [Online]. Available: https://doi.org/10.1016/B978-0-08-100866-9.00003-0

[4] G. H. McIntosh, R. K. Newman, and C. W. Newman, "Barley foods and their influence on cholesterol metabolism," *World Rev. Nutr. Diet*, vol. 77, pp. 89-108, 1995. [Online]. Available: https://doi.org/10.1159/000424467

[5] B. Dahina, "Volume 5 Issue 3 [Year - 2014] ISSN 2319 - 9202 Role of Gluten protein in the food products of living beings and its effect on their body both physicochemical and metabolically reactions Praveen Kumar CASIRJ Volume 5 Issue 3 [Year - 2014] ISSN 2319 -," vol. 5, no. 3, pp. 65-83, 2014.

[6] G. Bobo, C. Arroqui, and P. Virseda, "Natural plant extracts as inhibitors of potato polyphenol oxidase : The green tea case study," *LWT*, vol. 153, p. 112467, 2022. [Online]. Available: https://doi.org/10.1016/j.lwt.2021.112467

[7] D. K. Singh, P. Raigond, and P. Kharumnuid, "Potatoes : The Food for Nutritional Security," vol. 2, no. 3, pp. 498-501, 2020.

[8] C. E. Larder, M. Abergel, S. Kubow, and D. J. Donnelly, "Freeze-drying affects the starch digestibility of cooked potato tubers," *Food Res. Int.*, vol. 103, pp. 208-214, 2018. [Online]. Available: https://doi.org/10.1016/j.foodres.2017.10.034

[9] M. Belay, W. Mohammed, and K. Adare, "Potato (Solanum tuberosum L.) Growth, tuber yield and quality as influenced by blended NPS fertilizer and farmyard manure," vol. 13, no. 1, pp. 45-55, 2022.

[10] L. Woldemariam, G. Mamo, and F. Woldeyes, "Effect of Barely (Hordeum Vulgare L.) and Potato (Solanum Tuberosum L.) Blending Ratios on Injera in North Shewa Zone, Ethiopia," 2022. https://doi.org/10.21203/rs.3.rs-1803824/v1

[11] S. Neela and S. W. Fanta, "Injera (An ethnic, traditional staple food of Ethiopia): A review on traditional practice to scientific developments," *J. Ethn. Foods*, vol. 7, no. 1, p. 32, 2020. https://doi.org/10.1186/s42779-020-00069-x

[12] K. Biadge, "Evaluation of Injera prepared from composite flour of Teff and Barley variety," *J. Food Sci. Nutr. Ther.*, vol. 6, no. 1, pp. 038-040, 2020. https://doi.org/10.17352/jfsnt.000025

[13] N. Yuliana, S. Nurdjanah, S. Setyani, and D. Novianti, "Improving properties of sweet potato composite flour: Influence of lactic fermentation," in *AIP Conference Proceedings*, AIP Publishing LLC, 2017, p. 20040. https://doi.org/10.1063/1.4985431

[14] M. Banti, T. Atlaw, and B. Agza, "Injera Making Quality Evaluation of Tef and Cassava Composite Flour," vol. 8, no. 6, pp. 99-104, 2020. https://doi.0rg/10.11648/j.bio.20200806.11

[15] E. K. Alawode, M. A. Idowu, A. A. Adeola, E. K. Oke, and S. A. Omoniyi, "Some quality attributes of complementary food produced from flour blends of orange fleshed sweetpotato, sorghum, and soybean," *Croat. J. Food Sci. Technol.*, vol. 9, no. 2, pp. 122-129, 2017. https://doi.org/10.17508/cjfst.2017.9.2.06

[16] J. Mohammed, S. Seleshi, F. Nega, and M. Lee, "Revisit Ethiopian traditional barley-based food," *J. Ethn. Food*, no. June, pp. 1-7, 2016. https://doi.org/10.1016/j.jef.2016.06.001

[17] Z. Zhang, C. C. Wheatley, and H. Corke, "Biochemical changes during storage of sweet potato roots differing in dry matter content," *Postharvest Biol. Technol.*, vol. 24, no. 3, pp. 317-325, 2002. https://doi.org/10.1016/S0925-5214(01)00149-1

[18] AOAC, "Official Methods 925.09," *Assoc. Off. Anal. Chem.*, vol. 1, no. Official Analytical Int, pp. 1-1213, 2000.

[19] W. Horwitz, *Official methods of analysis of AOAC International. Volume I, agricultural chemicals, contaminants, drugs/edited by William Horwitz.* Gaithersburg (Maryland): AOAC International, 1997. 2010.

[20] T. T. T. Nguyen, G. Loiseau, C. Icard-Verni ère, I. Rochette, S. Tr èche, and J.-P. Guyot, "Effect of fermentation by amylolytic lactic acid bacteria, in process combinations, on characteristics of rice/soybean slurries: A new method for preparing high energy density complementary foods for young children," *Food Chem.*, vol. 100, no. 2, pp. 623-631, 2007. https://doi.org/10.1016/j.foodchem.2005.09.080

[21] AACC, *Approved methods of the American association of cereal chemists*, vol. 1. Amer Assn of Cereal Chemists, 2000.

[22] S. Y. Sonaye and D. R. N. Baxi, "Particle size measurement and analysis of flour," *Int. J. Eng. Res. Appl.*, vol. 2, no. 3, pp. 1839-1842, 2012.

[23] M. A. Tufa, K. Urga, G. T. Woldesemayat, and B. G. Mitiku, "Development and nutritional assessment of complementary foods from fermented cereals and soybean," *J. Food Sci. Nutr.*, vol. 2, no. 2, pp. 1-8, 2016. https://doi.org/10.24966/FSN-1076/100014

[24] J. L. Jane *et al.*, "Effects of amylopectin branch chain length and amylose content on the gelatinization and pasting properties of starch," *Cereal Chem.*, vol. 76, p. 629, 1999. https://doi.org/10.1094/CCHEM.1999.76.5.629

[25] Y. A. Adebowale, I. A. Adeyemi, and A. A. Oshodi, "Functional and physicochemical properties of flours of six Mucuna species," *African J. Biotechnol.*, vol. 4, no. 12, pp. 1461-1468, 2005.

[26] O. Oluwole *et al.*, "Some functional properties of flours from commonly consumed selected Nigerian Food Crops," *Int. J. Agric. Food Sci.*, vol. 1, no. 5, pp. 92-98, 2016.

[27] L. M. Nwokocha and P. A. Williams, "New starches: Physicochemical properties of sweetsop (Annona squamosa) and soursop (Annona muricata) starches," *Carbohydr. Polym.*, vol. 78, no. 3, pp. 462-468, 2009. https://doi.org/10.1016/j.carbpol.2009.05.003

[28] Y. Assefa, S. Emire, M. Villanueva, W. Abebe, and F. Ronda, "Influence of Milling Type on Tef Injera Quality," 2003. https://doi.org/10.1016/j.foodchem.2018.05.126

[29] O. O. Oladunmoye, O. C. Aworh, B. Maziya‐Dixon, O. L. Eruka Inure, and G. N. Elemo, "Chemical and functional properties of cassava starch, durum wheat semolina flour, and their blends," *Food Sci. Nutr.*, vol. 2, no. 2, pp. 132-138, 2014. https://doi.org/10.1002/fsn3.83

[30] A. Lazaridou, A. Marinopoulou, and C. G. Biliaderis, "Impact of flour particle size and hydrothermal treatment on dough rheology and quality of barley rusks," *Food Hydrocoll.*, vol. 87, no. August 2018, pp. 561-569, 2019. https://doi.org/10.1016/j.foodhyd.2018.08.045

[31] J. J. Fitzpatrick, S. A. Barringer, and T. Iqbal, "Flow property measurement of food powders and sensitivity of Jenike's hopper design methodology to the measured values," *J. Food Eng.*, vol. 61, no. 3, pp. 399-405, 2004. https://doi.org/10.1016/S0260-8774 (03)00147-X

[32] M. I. Akpata and P. I. Akubor, "Chemical composition and selected functional properties of sweet orange (Citrus sinensis) seed flour," *Plant Foods Hum. Nutr.*, vol. 54, no. 4, pp. 353-362, 1999. https://doi.org/10.1023/A:1008153228280

[33] H. Mamat, N. Masri, and K. Zainol, "Functional properties of composite flour: a review," vol. 4, no. July, 2020. https://doi.org/10.26656/fr.2017.4 (6).419

[34] V. Ndungutse, P. M. N. Ngoda, H. Vasantha Kaalam, E. K. Shakala, and A. K. Faraj, "Processing quality of selected potato (Solanum tuberosum l.) Cultivars grown in Rwanda," *Potato J.*, vol. 46, no. 1, pp. 48-55, 2019.

[35] R. Kumar, B. R. Singh, S. Chandra, and N. Chauhan, "Physico-chemical and functional properties of different flours used for preparation of cookies," vol. 10, no. February 2022, pp. 716-722, 2021.

[36] R. Kenghe, M. Jadhav, and C. Nimbalkar, "Physical Properties of Sorghum (Sorghum Bicolor) Grains As a Function of Moisture Content," *Int. J. Eng. Sci. Res. Technol.*, vol. 4, no. 10, pp. 496-504, 2015.

[37] J. C. Parajo, J. Sineiro, and H. Domı, "Functionality of oilseed protein products : A review," vol. 39, pp. 945-963, 2006. https://doi.org/10.1016/j.foodres.2006.07.002

[38] L. Okpala, E. Okoli, and E. Udensi, "Physico‐chemical and sensory properties of cookies made from blends of germinated pigeon pea, fermented sorghum, and cocoyam flours," *Food Sci. Nutr.*, vol. 1, no. 1, pp. 8-14, 2013. https://doi.org/10.1002/fsn3.2

[39] Y. F. Cheng and R. Bhat, *Functional, physicochemical and sensory properties of novel cookies produced by utilizing underutilized jering (Pithecellobium jiringa Jack.) legume flour*, vol. 14. Elsevier, 2016. https://doi.org/10.1016/j.fbio.2016.03.002

[40] A. A. Adebowale, L. O. Sanni, and S. O. Awonorin, "Effect of texture modifiers on the physicochemical and sensory properties of dried fufu," *Food Sci. Technol. Int.*, vol. 11, no. 5, pp. 373-382, 2005. https://doi.org/10.1177/1082013205058531

[41] A. O. Obadina, I. O. Ishola, I. O. Adekoya, A. G. Soares, C. W. P. de Carvalho, and H. T. Barboza, "Nutritional and physico-chemical properties of flour from native and roasted whole grain pearl millet (Pennisetum glaucum [L.]R. Br.)," *J. Cereal Sci.*, vol. 70, pp. 247-252, 2016. https://doi.org/10.1016/j.jcs.2016.06.005

[42] O. O. Awolu, P. M. Oluwaferanmi, O. I. Fafowora, and G. F. Oseyemi, "Optimization of the extrusion process for the production of ready-to-eat snack from rice, cassava and kersting's groundnut composite flours," *Lwt*, vol. 64, no. 1, pp. 18-24, 2015. https://doi.org/10.1016/j.lwt.2015.05.025

[43] M. Wegari, "Effects of Blending ratio and Fermentation time on Physicochemical and Sensory Acceptability of Teff-Taro Composite Flour Injera," 2022.

[44] N. Tharise, E. Julianti, and M. Nurminah, "Evaluation of physico-chemical and functional properties of composite flour from cassava, rice, potato, soybean and xanthan gum as alternatives to wheat flour," *Int. Food Res. J.*, vol. 21, no. 4, pp. 1641-1649, 2014.

[45] A. Adebowale, S. Sanni, and F. Oladapo, "Chemical, Functional and Sensory Properties of Instant Yam - Breadfruit Flour," *Niger. Food J.*, vol. 26, no. 1, 2009. https://doi.org/10.4314/nifoj.v26i1.47417

[46] O. Babatunde, A. Omotayo, A. Adewale, and O. Johnson, "Physical Properties of Nine Nigerian Staple Food Flours Related to Bulk Handling and Processing," vol. 10, no. 4, pp. 175-181, 2016.

[47] R. Rosida, T. Estiasih, and E. Sri Wahyuni, "Functional and pasting characteristics of modified water yam flour (Dioscorea alata).," *Int. Food Res. J.*, vol. 24, no. 5, 2017.

[48] A. J. Aina, K. O. Falade, J. O. Akingbala, and P. Titus, "Physicochemical properties of twenty-one Caribbean sweet potato cultivars," *Int. J. Food Sci. Technol.*, vol. 44, no. 9, pp. 1696-1704, 2009. https://doi.org/10.1111/j.1365-2621.2009.01941.x

[49] Z. O. Apotiola and J. F. Fashakin, "Evaluation O F Cookies from (Wheat, Yam, and Soybean) Blend," vol. 14, pp. 11-17, 2013.

[50] M. C. Ojinnaka and C. C. Nnorom, "Quality evaluation of wheat-cocoyam-soybean cookies," *Niger. J. Agric. Food Environ.* vol. 11, no. 3, pp. 123-129, 2015.

[51] A. Gani *et al.*, "Engineering and functional properties of four varieties of pulses and their correlative study," *J. Food Meas. Charact.*, vol. 9, pp. 347-358, 2015. https://doi.org/10.1007/s11694-015-9242-7

[52] C. G. Awuchi, "Proximate Composition and Functional Properties of Different Grain Flour Composites," *Int. J. Food Sci.*, vol. 2, no. 1, pp. 43-63, 2019.

[53] A. Dobhal and P. Awasthi, "Comparison of nutritional profile of barley flour and refined wheat flour," no. August, 2021.

[54] R. F. Nascimento and M. H. G. Canteri, "Effect of blanching on physicochemical characteristics of potato flour," *Hortic. Bras.* vol. 36, no. 4, pp. 461-465, 2018. https://doi.org/10.1590/s0102-053620180406

[55] L. Moench, D. Processing, N. A. Mohammed, I. A. M. Ahmed, E. E. Babiker, and A. Materials, "Nutritional Evaluation of Sorghum Flour (Sorghum," pp. 58-62, 2011.

[56] M. Tegeye, A. Kaur, J. Kaur, and H. Singh, "Value added convenience food from composite sorghum-maize-sweet potato flour blends," *Indian J. Agric. Sci.*, vol. 89, no. 11, pp. 1906-1910, 2019.

[57] A. S. Chemeda, G. Bultosa, and N. Dechassa, "Effect of Variety and Storage on the Tuber Quality of Potatoes Cultivated," vol. 7522, no. March, pp. 84-89, 2014. https://doi.org/10.4314/star.v3i1.14

[58] B. Kefale, "Evaluation of Injera Prepared from Composite Flour of Teff and Barley Variety Evaluation of Injera Prepared from Composite Flour of Teff and Barley Variety," no. July, 2022. https://doi.org/10.7176/FSQM/97-01

[59] M. Feyera, F. Dasa, and K. Kebero, "Formulation and Quality Evaluation of Finger Millet Based Composite Food Products," vol. 10, no. 3, pp. 59-65, 2021. https://doi.org/10.11648/j.ijnfs.20211003.11

[60] L. Yegrem, S. Abera, and M. Temesgen, "Nutritional composition and sensory quality of injera prepared from tef (Eragrostis tef (Zucc.) Trotter) complemented with lupine (Lupinus spp.)," 2021. https://doi.org/10.1080/23311932.2020.1862469

[61] G. Agern and R. Gibson, "Food Composition for Use in Ethiopia I," *ENI, Addis Ababa, Ethiopia*, 1968.