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Relation among Proximate Compositions, Rheological Properties and Injera Making Quality of Millet Varieties

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Abstract

The rheological, baking and eating quality of foods are depends on the relationship among the proximate and starch compositions of flour. In the present study four finger millet varieties (Axum, Padet, Tadese and Tesema), one pearl millet variety (Kola-1) and one tef variety (Qucnho) which was used as control were considered for investigation. The aim of this study was to evaluate the relationship between the chemical compositions and rheological properties of flours for injera making quality. A significant ($p<0.05$) variations were observed among the five millet flours and Quncho in their proximate compositions and starch components. The highest contents of crude protein (11.62%), crude fat (6.42%), iron (61.7 mg/kg) and zinc (53.55 mg/kg) and the lowest contents of ash (1.72%), carbohydrate (55.37%), amylose (17.5%) and calcium (0.02%) were noticed for Kola-1 compared to finger millet cultivars. Pasting properties were positively correlated with starch and amylose contents, and negatively correlated with fat content. Injera making quality was positively correlated with fat and protein contents and negatively correlated with starch content. The result indicated that the highest the protein content the more preferred injera quality. In its consumer acceptance, injera made from Kola-1 was preferred similar with the control.

Keywords: Millet; Tef; Starch; Amylose; Rheological property; Injera

Introduction

Genetic and environmental factors play a major role in determining grain composition. On the other hand, the nutrient profiles, physic-functional and rheological properties of grain flours affect product making quality and quantity. Several authors reported that the nutrient compositions of cereals depend on genotype and environmental factors [1-3]. Among these are soil factors, such as pH, available nutrients, texture, organic matter content and soil-water relationships; weather and climatic factors, including temperature, rainfall, variety, part of the grain; postharvest handling and storage; and fertilizer applications and cultural practices and method of processing applied [4]. Goswami et al. analyzed a number of pearl millet varieties of African, American and Indian origin and observed that variations in protein, fat, total ash, calcium, phosphorus and iron were large [5].

Because the world depends on baked products for a large part of its food requirements, flour quality assumes high importance. The chemical composition and characteristics of grain flour affects its subsequent product quality. Contents of protein, vitamins, minerals, and essential amino acids are important in addition to the food value in calories. It is important to produce strains that are resistant to disease and give high crop yields as well as fulfill the requirements of the miller and baker. Baking quality is influenced by rheological properties of flour which determines the physical characteristics such as dough volume and sensory attributes. Many studies have revealed the relationship among the chemical composition, rheological properties and product making quality. Konik et al. have related starch viscosity, together with other non-starch four quality parameters, to noodle eating quality [6]. A high protein content is directly related to loaf volume of bread and the ability to absorb and retain a large quantity of water as this indicates the baking quality of flours and is a function of water absorption capacity [7,8]. There is however limited information on the correlation amid the chemical composition and rheological properties of millet grain flours with injera making quality, which staple food of Ethiopians and neighboring countries. Thus, this study aimed to investigate the effect of millets variety and its chemical compositions on the sensory quality of injera.

Materials and Methods

Material collection and sample preparation

In this study five samples of released millet varieties (4 finger millet and one pearl millet) namely Padet, Tessema, Tadesse, Aksum and Kola-1 grown in 2018/2019 season were collected from Melkassa Agricultural Research Center. One tef variety called Quncho was received from Debrezeit Agricultural Research Center and used as control.

Proximate composition determination

The proximate compositions such as moisture, crude fat, crude protein and ash of whole millet (finger and pearl) grain flours were analyzed according to the Approved Method of the Association of Official Analytical Chemists, Method 95.40, Method 948.22, Method 950.48, Method 923.03, respectively. For moisture content, an accurately weighed (3 g) sample was placed in an aluminum pan and dried in an oven at 105 °C to a constant weight. For crude fat/lipid content the samples were oven dried to remove the moisture. 3 g of flour sample was defatted in a Soxhlet apparatus using petroleum ether as the solvent (flour-to-solvent ratio of 1:10 w/v) for eight hours. Defatted samples were dried in an oven at 60 °C to remove residual traces of petroleum ether, and the samples were weighed to calculate lipid content.

$$\text{Lipid (\%)} = \frac{[(\text{Initial wt of full fat flour (g)} - \text{Final wt of defatted flour (g)}] \times 100}{\text{Initial wt (as is) of full fat flour (g)}}$$

For protein content, the micro-Kjeldahl method was used to determine the total proteins using 1 g of sample and 1 g catalyst. 5 ml sulfuric acid was added and the samples digested for 3 hrs. After digestion, the samples were distilled in the presence of boric acid and finally titrated with 0.1 N HCl and the volume used for titration was recorded. Sample nitrogen content was calculated using the formula:

$$\%N = \frac{(V_t - V_b) * N * V_1 * 0.014 * 100}{V_2 * m}$$

where, Vt, Vb, V1, V2 represents volume of titrant, blank, total volume of sample prepared and volume of sample used for titration respectively and m represents mass of sample.

Protein(%)=total N(%) x 6.25 (conversion factor for millets).

An accurately weighed sample (2.5 g) was placed in a ceramic crucible to determine the ash content and subjected to ashing in a muffle furnace maintained at 550 °C until a constant final weight for ash was achieved. Total carbohydrate content was determined by using colorimetric method. The crude fiber content was determined gravimetrically after acid hydrolysis using 0.128 M sulphuric acid and basic hydrolysis using 0.882 M sodium hydroxide. Energy values was calculated by multiplying the amounts of carbohydrate and protein, and fat by the factors of 4 Kcal and 9 Kcal g^{-1} respectively.

Total starch and amylose contents determination

Total starch was determined using a revised version of Fehling's test for reducing sugars. A duplicate (1 g) of samples were weighed into a conical flask and 5 ml concentrated sulfuric acid was added. The samples were boiled and digested for 3 hours with a frequent shaking. After the contents were cooled, neutralized with NaOH and then deproteinized with 7 ml lead acetate and 20 ml sodium acetate and filtered to 100 ml volumetric flask. Then, each 5 ml of Fehling's Solution A and B was put into a 100 Erlenmeyer flask and 15 ml of the filtered sample was added. After 3 drops of the methylene blue solution was added, the content was boiled on an electric stove for two minutes till the blue color of solution disappears. Finally, the total starch content was calculated using the formula:

$$\%\text{starch} = \frac{T}{S} \cdot DR \cdot \frac{100}{1000} \cdot 0{,}9$$

where:

- T: Concentration (mg/100 mL) of invert sugar in test solution, obtained by reference to the appended Lane-Eynon's Table [invert sugar (without sucrose)].
- S: Weight (mg) of sample.
- DR: Dilution Rate

Amylose content was determined by the method of Cagampang et al. [9]. For amylose content, 0.05 g (triplicate) finely ground flours were weighed into tube and 0.5 ml of 95% ethanol was added and mixed. Then 9.5 ml 1N NaOH was added, vortexed and 100 µl of sample was transferred into 25 ml volumetric flask and distilled water was added to a half. And then, 250 µl of 30% HCl and 250 µl of KI were added and filled to a mark with distilled water and finally, absorbance was measured at 580 nm. A blank sample containing 100 µl 1N NaOH was used.

Pasting properties

Pasting properties of flours were studied by using Rapid Visco Analyzer (RVA) as described by Maninder et al. [10]. Viscosity profiles of flours were recorded using flours suspensions (3%; 28 g total weight). Flour sample (3.5 g) was weighed into a dried empty canister; 25 mL of distilled water was dispensed into the canister containing the sample. The mixture was thoroughly stirred, and the canister was fitted into the RVA as per manufacturer's instructions. A programmed heating and cooling cycle from 50 °C to 95 °C was used, where the suspension was held at 50 °C for 1 min, heated at a uniform rate to 95 °C for 8 min and then held at 95 °C for 5 min before cooling to 50 °C within 8 min, and finally held at 50 °C for 1 min. The pasting profiles such as Peak Viscosity (PV), Breakdown Viscosity (BDV), Setback Viscosity (SBV) and Final Viscosity (FV) were recorded and determined with the aid of Thermocline for Windows Software connected to a computer. Stability ratio ((ratio of trough to peak viscosity) and retrogradation rate (ratio of setback to peak viscosity) also calculated.

Injera processing

Injera was prepared using standardized injera making procedure [11]. The procedure involved milling whole millet grain into a flour, preparation of a dough, and fermentation of the dough by adding yeast and fermenting at room temperature for 48 hr. 25% of the fermented dough was thinned with 30 mL of water and cooked in 200 mL of boiling water for 1 min. The gelatinized batter was cooled to 45 °C at room temperature and added back to the fermenting dough. After thorough mixing, 100 mL of water was added and the batter was fermented at room temperature for 3 hr. Additional water (20 mL) was added to the fermented dough to bring to batter consistency. About 500 g of the fermented batter was poured in a circular manner on a 50 cm diameter hot clay griddle, covered, and baked for 2 min.

Data analysis

Data was analyzed using Minitab 16 statistical software package and Tukey's multiple comparison tests was used to determine the significance of differences among treatments at 95% confidence level. Each value was determined by at least duplicates. Results were given as mean ± standard deviation.

Results and Discussion

Proximate composition

The proximate compositions of flours and injera from millet varieties and control sample (Quncho) are indicated in Table 1. The analysis of variance showed that a significant ($p<0.05$) difference was demonstrated among millet varieties and within finger millet varieties. A crude fat content of millet flours ranged from 2.31% to 6.42%. The lowest and highest fat content was noticed in finger millet variety, Axum and pearl millet variety, Kola-1, respectively. Except for Axum, which showed a significant variation with Padet and Quncho, others finger millet varieties did not show significant disparity among them. Finger millet varieties showed a lowest crude fat content (2.31% to 2.99%) than pearl millet (6.42%). This difference might be due to genetics/varietal differences, environmental and pre-harvest agronomic practices like fertilizer application. Similar studies had been revealed that the crude fat content in finger millet varieties was in range of 1.3% to 1.8%. Antony et al. have reported a higher percentage (2.1%) of crude fat [12-14]. In addition, Hulse et al. revealed that the lipid content of millets was ranged from 1.5 to 4.8 g/100 g [15]. Several studies stated that among millets, the least lipid content has been reported in finger millet while the highest lipid content has been reported in pearl millet [11,16,17]. A study conducted by Abdalla et al. noticed that the oil content of ten pearl millet genotypes ranged from 2.7% to 7.1% [18].

The ash content of millet varieties was ranged from 1.1% to 2.39%, the lowest for Tadese. Ash content was significantly differed between finger millet and pearl millet varieties. A flour from Padet had the highest ash content with statistically non-significant ($p>0.05$) difference with Axum and Tesema varieties, and Quncho whereas those from Tadese (1.1%) and Kola-1 (1.72%) showed lower ash content with statistically significant difference in between. Similar study conducted by Ali et al. reported that the ash content of pearl millet cultivars was in a range of 2.1% to 2.3% [19].

The moisture content of flours ranged from 9.17 to 10.11%, the highest for Tadese and the lowest for Quncho with non-significant ($p>0.05$) difference among millet varieties and control sample. The moisture content of injera determines the product shelf stability. The result showed that the moisture content of injera ranged from 60.22% to 66.76% wet weight basis. Quncho had a highest percent of water content, 66.76%. The moisture content of injera sample made from Kola-1 was significantly ($p<0.05$) different from others, but not Axum.

Variety	Flour							Injera	
	MC (%)	Protein (%)	Fat (%)	Fiber (%)	Ash (%)	CHO	Energy (Kcal)	MC (%)	Protein (%)
Axum	10.08 ± 0.40^{a}	6.74 ± 0.22^{c}	2.31 ± 0.03^{c}	1.87 ± 0.18^{c}	2.02 ± 0.09^{ab}	74.61 ± 0.33^{a}	346.19^{b}	62.39 ± 0.19^{bc}	7.72 ± 0.03^{c}
Kola-1	9.64 ± 0.22^{a}	11.62 ± 0.23^{a}	6.42 ± 0.00^{a}	1.86 ± 0.16^{c}	1.72 ± 0.04^{b}	55.37 ± 1.81^{d}	325.74^{c}	60.22 ± 0.15^{c}	12.65 ± 0.04^{a}
Padet	9.46 ± 0.20^{a}	6.43 ± 0.06^{c}	2.99 ± 0.24^{b}	3.47 ± 0.05^{a}	2.39 ± 0.09^{a}	75.24 ± 0.97^{a}	353.59^{a}	65.12 ± 0.58^{ab}	6.54 ± 0.03^{d}
Tadese	10.11 ± 0.31^{a}	7.94 ± 0.28^{b}	2.80 ± 0.21^{bc}	3.12 ± 0.15^{ab}	1.10 ± 0.02^{c}	64.34 ± 0.82^{c}	312.28^{e}	64.18 ± 0.43^{ab}	7.97 ± 0.60^{c}
Tesema	9.33 ± 0.14^{a}	6.85 ± 0.03^{c}	2.66 ± 0.06^{bc}	1.39 ± 0.18^{c}	2.00 ± 0.18^{ab}	67.62 ± 0.53^{b}	321.82^{d}	65.89 ± 0.77^{a}	7.02 ± 0.13^{cd}
Quncho	9.17 ± 0.29^{a}	10.69 ± 0.09^{b}	3.22 ± 0.06^{b}	2.87 ± 0.15^{b}	2.66 ± 0.2^{a}	58.22 ± 1.46^{d}	304.62^{f}	66.76 ± 1.40^{a}	10.99 ± 0.37^{b}

Note: a, b, c, d, e and f superscripts are significantly ($p<0.05$) different column wise within and between different millet cultivatars, n=2. MC-moisture content; CHO-carbohydrate.

Table 1: Proximate composition and energy value of flours and injera.

Among finger millet varieties, the lower moisture content was noticed in injera made from Axum. On the other side, no significant difference was observed between Padet, Tadese, Tesema and Quncho and similarly between Axum and Kola-1. This difference in moisture content could attributed because of the chemical and functional properties of the varieties. Similar result was reported that the moisture content of fresh injera samples (as soon as it was baked) varied from 62%-65% [20]. According to these authors the three types of fungal species belonging to the genera of Penicillium, *Aspergillus* (*Aspergillus niger*) and *Rhizopus* species were responsible for injera spoilage, although their extent of growth varied depending on temperature. From this point of view, it's possible to predict that injera made from Quncho might be spoiled faster due to the action of spoilage microorganisms, particularly mould.

Protein, a large biomolecules consisting of one or more long chains of amino acid residues is another constituent of millet flour and was ranged from 6.43% to 11.62%, the highest for Kola-1 and the lowest for Padet with statistically significant difference ($p<0.05$) among varieties. Finger millet varieties showed a lowest protein content and Tadese had the highest crude protein content (7.93%) and was significantly varied among them. A highest protein content was observed in Kola-1 and Quncho varieties in both flours and injera with a significant difference in between. Large variations in protein content, from 6 to 21 percent, have been observed [21]. On contrary, Monteiro et al. reported the protein content of 14 varieties of Italian millet in a range of 11.13% to 18.75% [22]. Finger millet is poor in protein content compared with other common cereals. Both genetic and environmental factors appear to have an important role in determining the protein content of finger millet [23].

The protein content of injera was ranged from 6.15% to 12.65%, which corresponds to Padet and Kola-1 varieties, respectively. A significant difference was demonstrated between injera from millet varieties and control sample in their crude protein content. Kola-1 (12.65%) was statistically differed in its protein content. Injera made from Axum, Tadese and Tesema varieties did not show statistical difference at p<0.05. Compared to flours, an increment in protein content was observed in injera (Figure 1). This might be due to enzymes that could be produced by the yeast during fermentation and enzymes can be considered as proteins.

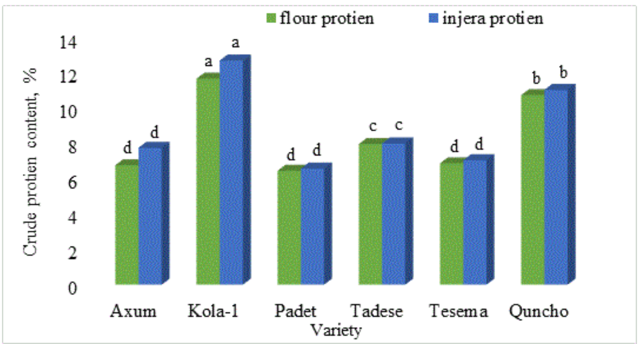

Figure 1: Protein content of flour and injera (p>0.05).

A range of 1.39% to 3.47% flours crude fiber content was noticed with statistical difference between them, the highest percent for Padet and lowest content for Tesema. Padet and Tadese, which had a highest percentage (3.47% and 3.12%) of crude fiber and similarly Axum, Kola-1 and Tesema did not show a significant difference among them. The present study agreed with Hulse et al. reported that the protein, fat, ash, crude fiber and carbohydrate content of finger millet and pearl millet were 7.7 g to 11.8 g; 1.5 g to 4.8 g; 2.2 g to 2.6 g and 67 g to 72 g per 100 g edible portion, respectively. According to this study, finger millet had the lowest content in protein and fat, and the highest content in ash, crude fiber and carbohydrate than pearl millet variety. Similar result has been reported by Siroha et al. that the protein content of pearl millet cultivars flour ranged 9.7% to 11.3% [24]. Shimels et al. reported the protein and moisture contents of Padet and Tadese were 9.86% and 7.61%, and 9.39% and 9.71%, respectively.

Abdalla et al. reported that the crude protein, fat, ash, crude fiber, starch and dry matter content of ten pearl millet genotypes were ranged from 8.5% to 15.1%, 2.7% to 7.1%, 1.6% to 2.4%, 2.6% to 4.0%, 59% to 70% and 88% to 91%, respectively. A study by Ali et al. found about 92.5% dry matter, 2.1% ash, 2.8% crude fiber, 7.8% crude fat, 13.6% crude protein, and 63.2% starch in pearl millet. FAO reported the protein, carbohydrate, fat, crude fiber, ash and energy content for finger millet were 7.3 g, 72 g, 1.3 g, 3.6 g, 2.7 g and 336 Kcal; and for pearl millet 11.6 g, 67.5 g, 5 g, 1.2 g, 2.3 g and 363 Kcal, respectively [25]. Oshodi et al. revealed that the moisture, protein, fat, ash crude fiber and carbohydrate content of pearl millet 10.2%, 11.4%, 7.6%, 1.8%, 3.1% and 56.9%, respectively [26]. Ravindran et al. reported that the moisture, crude protein, crude fat, fiber, ash and carbohydrate contents of finger millet varieties were in a range of 12.13 to 12.54%, 9.2 to 10.6%, 1.5 to 1.6%, 4.2 to 4.5%, 2.5 to 3.1% and 81.1 to 81.8%, respectively [27].

Starch and reducing sugar

The reducing sugar (RS), total starch (TS), amylose and amylopectin contents of millet and tef grain flours are shown in Table 2. A reducing sugar is a sugar that contains a free aldehyde or ketone group and acts as a reducing agent. Reducing sugars can react with other constituents of the food, like amino acids, to change the color and taste of the food. Starch is a major storage form of carbohydrate in millets. A range of 66.78% to 82.2% for reducing sugar and 60.11% to 73.98% for starch contents were noticed in all treatments. A significant difference was observed between and within millet varieties. Kola-1 showed the lowest RS (66.78%) and TS (60.11%) contents and was differed significantly (p<0.05) from Tadese and Tesema varieties. Tadese had the highest contents of RS (82.2%) and TS (73.98%) with non-significant (p>0.05) difference with Padet and Tesema varieties. Quncho was statistically similar in its RS and TS contents with all the investigated millet varieties.

Variety	Reducing sugar, %	Total starch, %	Amylose, %	Amylopectin, %
Axum	70.52 ± 3.31^{bc}	63.47 ± 2.99^{bc}	19.52 ± 0.31^{b}	80.48 ± 0.31^{b}
Kola-1	66.78 ± 2.92^{c}	60.11 ± 2.63^{c}	17.5 ± 0.3^{c}	82.5 ± 0.3^{a}
Padet	72.51 ± 0.51^{abc}	65.26 ± 0.46^{abc}	20.87 ± 0.2^{a}	79.13 ± 0.2^{c}
Tadese	82.21 ± 3.38^{a}	73.98 ± 3.04^{a}	18.64 ± 0.35^{b}	81.35 ± 0.35^{b}
Tesema	78.81 ± 3.48^{ab}	70.93 ± 3.13^{ab}	18.98 ± 0.3^{b}	81.01 ± 0.3^{b}
Quncho	72.51 ± 0.51^{abc}	65.26 ± 0.46^{abc}	19.25 ± 0.4^{b}	80.74 ± 0.4^{b}
Note: a, b, c superscripts are significantly (p<0.05) different column wise within and between different millet cultivars, n=2. All results are in wet basis.				

Table 2: Starch components and reducing sugar content of flours.

Axum had the lowest RS (70.52%) and RS (63.47%) among finger millet cultivars. This result agreed to Jambunathan et al. reported a range of 62.8% to 70.5% total starch and amylose from 21.9% to 28.8% for pearl millet genotypes. Yanez et al. reported the starch and amylose content of proso millet that contained 64% starch of which 29·1 % was amylose. In addition, Wankhede et al. revealed that the mean starch content finger millet varieties were 59.5% to 61.25% [28]. The large difference observed in amylose content might be due to varietal and agronomic practices.

A range of 17.5% to 20.87% and 79.13% to 82.5% amylose and amylopectin contents were obtained, respectively with a statistical difference between millet varieties and control sample. Kola-1 had the lowest percentage of amylose (17.5%) and the highest amylopectin content (82.5%). Finger millet varieties Axum, Tadese and Tesema did not show a significant variation in their amylose and amylopectin contents. Wankhede reported the amylose content of the starch in finger millet was 16% [29]. Relatively a higher amylose content within a range of 20% to 22% for five pearl millet starches was reported by Beleia et al. Bultosa et al. noticed the amylose content of 13 teff varieties in the range of 20% to 26% [30]. A range of 13.6% to 17.7% amylose content was reported for pearl millet cultivars [31]. Peak viscosity was positively correlated with starch (r=0.6) and amylose (r=0.71) contents and negatively correlated (r=-0.82) with fat content.

Amylopectin is the major component of millet starch, and its fine structure plays a critical role in the characteristics of starch. The relative proportion of amylose and amylopectin greatly influences the physicochemical properties of starch and therefore its technological and nutritional properties [32-35]. A higher amylose content is desirable in many human diets as amylose is usually more slowly digested [36]. For example, rice cooking quality in particular is largely determined by its amylose content [33,37]. Low amylose levels are associated with cohesive, tender and glossy cooked rice, whereas high amylose levels cause rice to absorb more water and consequently expand more during cooking, and the cooked grains tend to be dry, fluffy and separate [38]. Starch digestibility also linked to the amylose content. According to Hibberd et al. a starch digestibility was reported to be higher in low amylose content, i.e. waxy sorghum than in normal sorghum, corn and pearl millet grains [39].

Pasting property

The results of pasting properties of millet and control sample flours are shown in Table 3. A significant ($p<0.05$) difference was observed between millet varieties and control sample in their pasting temperature (PT). The highest and lowest PT was noticed for Quncho (83.2 °C) and Padet (75.02 °C), respectively. Among millet varieties, the pearl millet Kola-1 (77.4 °C) had the highest pasting temperature. PT provides the ability of starch to imbibe water and swell during cooking which indicated Padet to have the lowest capacity to absorb water. All finger millet cultivars were showed significant variation in their cooking temperature. The peak viscosity (PV) of flours was varied significantly and ranged from 855 to 3434 cP, the lowest for Kola-1 and the highest for Padet. Pearl millet was shown to have very high amylase activity, about ten times higher than that of wheat grain and this was probably responsible for the low peak viscosity observed. Tadese and Tesema were statistically similar in their PV [40]. Quncho showed the lowest PV compared to finger millet varieties. Fat (r=-0.81) and protein (r=-0.98) contents were negatively correlated with PV. Hoover et al. stated that granules with high peak viscosity have weaker cohesive forces within the granules than those with lower values and would disintegrate more easily [41]. The amylose-to-amylopectin ratio of starch greatly affects the starch pasting properties. In addition, pasting properties are greatly influenced by plant source, starch content, interaction among the components, and testing conditions [42]. Furthermore, proteins and lipids are involved in resistance to starch swelling [43].

Breakdown viscosity (BDV) of millet varieties varied significantly between 263 and 1730 cP, the lowest for Kola-1, which showed greater resistance to heat and shear and the highest BDV for Padet. All finger millet varieties were found to have higher BDV with non-significant variation among them, which showed lower resistance to shear and heat than Kola-1 and Quncho. The setback viscosity (SBV) differed significantly ($p<0.05$) and ranged from 540 to 2042 cP, the highest for Padet and the lowest for Kola-1. The higher the setback value, the lower the retro gradation during cooling and the lower the staling rate of the products made from the flour. Flours from Padet, Tadese and Tesema showed statistically similar SBV value. The final viscosity (FV) of the treatments ranged from 833.5 to 3746 cP. Tadese and Tesema cultivars did not show significant variation. Quncho was found to have lower BDV, SBV and FV than finger millet varieties but higher than the pearl millet variety, Kola-1.

Axum and Tadese showed the highest stability ratio (0.56) (ratio of trough to peak viscosities), which indicated most stable to shear and heat; whereas Kola-1 had the lowest stability ratio (0.34), revealed least stable. This could be attributed to increment of moisture content and as it increased the stability ratio. Stability ratio describes the resistance of starch paste to viscosity breakdown as shear is applied. Starches with a higher stability ratio has potential applications in heat processed products like soups. The retrogradation rate (the ratio of setback to peak viscosity) of flours from millet varieties and control sample ranged from 0.59 to 0.72. Quncho had the highest rate of retrogradation and there was no significant variation with Kola-1 and Padet varieties.

Variety	PT (°C)	PV	BDV	SBV	FV	SR	RR
Axum	76.72 ± 0.03^{c}	2860 ± 29.7^{d}	1587 ± 40.3^{a}	1682 ± 68.6^{b}	3337 ± 58^{c}	0.56 ± 0.02^{ab}	0.59 ± 0.02^{b}
Kola-1	77.4 ± 0.00^{b}	855 ± 7.1^{f}	263 ± 7.8^{c}	540 ± 38.2^{d}	833.5 ± 44.5^{e}	0.34 ± 0.01^{d}	0.63 ± 0.04^{ab}
Padet	75.02 ± 0.03^{f}	3434 ± 18.4^{a}	1676 ± 52.3^{a}	2042 ± 79.2^{a}	3746 ± 22.6^{a}	0.5 ± 0.01^{c}	0.59 ± 0.03^{b}
Tadese	76.62 ± 0.03^{d}	2984 ± 26.2^{c}	1715 ± 56.6^{a}	1852 ± 7.8^{ab}	3400 ± 62.2^{bc}	0.58 ± 0.01^{a}	0.62 ± 0.0^{b}
Tesema	75.9 ± 0.00^{e}	3201 ± 15.6^{b}	1607 ± 63.6^{a}	1872 ± 58^{ab}	3542 ± 44.5^{b}	0.51 ± 0.02^{bc}	0.59 ± 0.03^{b}
Quncho	83.2 ± 0.00^{a}	1554 ± 21.2^{e}	813 ± 21.2^{b}	1124 ± 29.7^{c}	1958 ± 12.7^{d}	0.54 ± 0.0^{abc}	0.72 ± 0.01^{a}

Note: a, b, c and d superscripts are significantly ($p<0.05$) different column wise by Tukey's Multiple Comparison Test within and between millet cultivars and control sample, n=2. PT, pasting temperature; PV, BDV, SBV and FV are peak, breakdown, final and setback viscosities, respectively; SR, stability ratio; RR, retrogradation rate.

Table 3: Pasting behavior (cP) and stability ratio of millet varieties and control sample flours.

Injera making quality

In this study, a nine-point hedonic scale was used (1=extremely dislike, 9=extremely like). Table 4 showed the results of sensory characteristics of injera from five millet varieties and tef injera which was used as control. In terms of eye distribution, aroma, taste and bitterness aftertaste no significant difference ($p>0.05$) were observed between and within millet varieties and control sample. Padet was rated lower in its injera eye distribution, number and size. Injera eye is a honeycomb like structure of the top surface of the product and it's formed during baking. Injera with a characteristic of white color, even eye distribution, less sourness and bitterness, rollable and less stick is preferred by consumers. This study revealed that injera eye distribution was positively correlated ($r=0.56$) with protein content and negatively correlated with starch content. Carbon dioxide gas production during fermentation play a fundamental role in injera eyes and this depends on the amount of free sugars present in the flour as it consumed by a yeast. Similar result was reported by Geleta et al. stated that injera quality was significantly and positively correlated with protein content ($r=0.94$) [44]. In addition, according to this author traits like starch content and amylose content did not show significant correlation with injera quality. Conversely, Yetneberk et al. stated injera eye was positively correlated with starch and negatively with protein contents. Rather it that results in carbon dioxide production. Tadese and Padet showed significantly a highest and lowest number of holes respectively, and Tesema had the lowest among finger millet varieties.

A significant ($p<0.05$) variation were noticed in color, rollability, adhesiveness and overall acceptance of injera. Quncho was perceived and preferred differently and rated higher in its overall acceptance (8.04). Conversely, injera made from Padet was rated lower in color (5.71) and overall acceptance (6.21). A positive correlation ($r=0.74$) was noticed between protein content and overall acceptability, and total starch and number of holes/eyes ($r=0.63$). From finger millet cultivars Padet was perceived lower in its injera eye distribution and color; and a highest score of bitterness aftertaste sensory attribute was for injera made from Axum (7.31) and Tesema (7.24) varieties with non-significant ($p>0.05$) variation in between. Bitterness aftertaste could be due to polyphenols in the grain.

Variety		Sensory attributes							
	Number of holes	Eye distribution	Color	Aroma	Taste	Bitterness aftertaste	Rollability	Adhesiveness	Overall acceptance
Axum	17503 ± 68b	7.49 ± 0.38a	8.01 ± 0.28a	7.38 ± 0.38a	7.49 ± 0.38a	7.31 ± 0.35a	7.35 ± 0.42ab	6.91 ± 0.45ab	7.05 ± 0.08bc
Kola-1	9756 ± 76e	7.28 ± 0.09ab	8.26 ± 0.38a	7.78 ± 0.17a	7.14 ± 0.20a	6.97 ± 0.04a	7.14 ± 0.21ab	6.79 ± 0.21ab	7.51 ± 0.11ab
Padet	10577 ± 66d	6.25 ± 0.05b	5.71 ± 1.07b	7.33 ± 0.11a	7.09 ± 0.28a	6.83 ± 0.09a	7.42 ± 0.18ab	6.84 ± 0.18ab	6.21 ± 0.11d
Tadese	18386 ± 5a	6.65 ± 0.15ab	7.40 ± 0.09ab	7.26 ± 0.37a	7.08 ± 0.03a	7.21 ± 0.28a	7.11 ± 0.17ab	6.495 ± 0.12ab	6.44 ± 0.12cd
Tesema	14688 ± 41c	6.57 ± 0.34ab	7.41 ± 0.57ab	7.48 ± 0.23a	7.11 ± 0.16a	7.24 ± 0.36a	7.04 ± 0.06b	6.48 ± 0.09b	7.14 ± 0.29b
Quncho	10376 ± 70d	7.35 ± 0.41ab	8.47 ± 0.08a	8.09 ± 0.21a	7.96 ± 0.05a	7.06 ± 0.57a	7.99 ± 0.16a	7.43 ± 0.18a	8.04 ± 0.22a

Table 4: Sensory characteristics of injera.

Rollability is one of important injera sensory attribute as it describes the ability of injera being rolled. The result showed that Quncho (7.99) and Tesema (7.04) had the highest and the lowest rollability with a significant difference among them. This difference might be due to retro gradation of starch components. Yetneberk et al. revealed that sorghum cultivar with floury endosperm, were characterized by soft and rollable injera. The degree of *adhesiveness* of injera during consumption is desirable to consumer acceptance and it's a quality of being stick to human sense organs while eating. Tesema showed the lowest degree of stickiness with non-significant difference among finger millet cultivars and was significantly ($p<0.05$) differed from Quncho.

Conclusion

A product making quality of millet grain flours depends on the inherent characteristics of the grain which might be affected by varietal differences, environment and agricultural practices. Finger millet cultivars exhibited the highest total starch and amylose and the lowest protein and crude fat contents than pearl millet (Kola-1) counterparts. Among finger millet cultivars, Padet had highest pasting profiles. The present study revealed that among millet varieties injera made from

Kola-1, Axum and Tesema varieties were more preferred in overall consumer acceptance with statistical difference among them and the result was comparable to a most preferred tef injera. As a recommendation, Kola-1 can substitute tef injera as it was perceived and rated statistically similar with Quncho.

Conflict of Interest

No

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