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The Study of Functional and Rheological Properties of Teff [*Eragrostis Teff* (Zucc.) Trotter] Grain Flour Varieties

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Abstract: This study was conducted to generate information on some functional and rheological properties of teff [*Eragrostis teff (Zucc.) Trotter*] grain Flour varieties. Six teff varieties namely Quncho (DZ-Cr-387), Felagot (DZ-Cr-442), Tesfa (DZ-Cr-457), Kora (DZ-Cr-438), Dukem (DZ-Cr-425) and Dagme (DZ-Cr-43Bvarieties) were considered and their selection was based on their recent year coverage area and the expected future expansion. Each variety was studied. *The highest value of functional properties of teff flours which included water and oil absorption capacity, swelling power, dispersibility and water solubility index of the teff flour were 0.99 g/g, 1.42 ml/g, 11.99%, 74% and 19.61% for DZ-Cr-387, DZ-Cr-438, DZ-Cr-438, DZ-Cr-438 & DZ-Cr-457 andDZ-Cr-438 varieties respectively. The pasting properties of the teff flour such as pasting temperature, peak time, peak viscosity, final viscosity, break down viscosity, trough and set back viscosity values had ranged from 76 to 80.33°C, 5.13 to 6.17 min, 880 to 1650cP, 1511 to 1721cP, 340.33 to 800cP, 540 to 880 and 370.33 to 971 cP. The farinograph values had ranged from 47.37 to 50.85%, 4.67 to 5.99 min, 3.62 to 4.24 min, 58.18 to 76.99 FU and 70.67 to 82.56 FU for water absorption, dough development time, dough stability time, mixing tolerance index and farinograph quality number respectively. There were significant ($P<0.05$) differences among the varieties except dough stability time.*

Keywords: Teff Grains and Flour, Pasting Properties, Functional Properties, Physical Properties, Rheological Properties

1. Introduction

Teff is a unique durable crop grown over a wide range of environmental conditions in Ethiopia and has been utilized as food and supplements for majority of the human diet in Ethiopia [1]. *Teff* is an ancient tropical cereal that has its center of origin and diversity in the northern Ethiopian highlands, from where it is believed to have been domesticated. In Ethiopia; it is a major food grain, mainly used to make *injera*, a traditional fermented Ethiopian pancake. *Teff* grain size is known to be extremely small with mean length ranging from0.61-1.17 mm and mean width ranging from 0.13-0.59 mm, which gives an average thousand kernel weight of 0.264 gram [1]. *Teff* grain anatomy studied by [2] indicates that the embryo, rich in protein and lipid, occupies a relatively large part of the grain. The aleurone layer is one cell thick and rich in protein lipid bodies. The testa is located within the pericarp and its thickness varies with the color of the grain. The testa of red *teff* is thicker than white *teff* and it is filled with pigmented material, suggested to be tannins or polyphenol compounds [3]. The *teff* grain proteins offer an excellent balance among the essential amino acids [4]. *Teff is* regarded as a "healthy food", suitable for its employment in novel foods such as baby foods and gluten-free based goods [5]. The attention to *teff has* been recently increased because of its health benefits. *Teff* has an attractive nutritional profile having significant levels of minerals including calcium, iron, magnesium, phosphorus, potassium, and zinc. Also, *teff* is rich in vitamins, such as thiamin (B1), riboflavin (B2), vitamin A and K. Furthermore, *teff* is high in proteins including all 8 essential amino acids that is superior in lysine than wheat or barley along with its high carbohydrate sand fiber contents. *Teff* is beneficial for those who are lactose intolerant since it is gluten-free. Red *teff* grains are greatly recommended for the improvement of osteoporosis and bone healing conditions [6].

Currently, consumer's preference towards baked goods with additional (functional and nutritional) value is increasing, forcing food industries to look for more natural nutrient-dense alternatives like grain *teff* flour for use by the people affected by celiac disease because it is a gluten free cereal grain with high potential. The growing demand for products from *teff* grain flour due to its nutritional and health benefits is raising the interest of modern food industries and bulk flour milling, flour handling and processing operations of this cereal grain is inevitable. Therefore generation of some information concerning of engineering properties of *teff* grain and its flour; to investigate and provide concise information and data on selected physical, functional, thermal and rheological properties of *teff* grain and its flour is considered to be important [7].

2. Literature Review

2.1. Farinograph

Farinograph is used to measure the evolution of dough under specific kneading conditions after it was brought to standard consistency of 500 F. U. The principle of Farinograph operation is based on the resistance of dough to the kneader shaft. The resistant moment to the kneader shaft has increasing variation when mixing the components, hydrating of flour particles, dough formation and development, up to a maximum value, close to the value of dough normal consistency. Then, the variation of moment to the shaft, respectively dough consistency remain approximately constant, in the stability phase of the dough which can be maintained for longer or shorter time depending on the characteristics of flour. Graphic recording of the moment (dough consistency) during kneading with the farinograph device is called Farinograph [8]. The farinograph test is one of the most commonly used flour quality tests in the world. The results are used as parameters in formulation to estimate the amount of water required to make dough, to evaluate the effects of ingredients on mixing properties, to evaluate flour blending requirements, and to check flour uniformity. The results are also used to predict processing effects, including mixing requirements for dough development, tolerance to over mixing, and dough consistency during production. Farinograph results are also useful for predicting finished product texture characteristics. For example, strong dough mixing properties are related to firm product texture [9].

Water absorption is the amount of water required to center the farinograph curve on the 500 Brabender units (BU) line. This relates to the amount of water needed for a flour to be optimally processed into end products. Water absorption is expressed as a percentage [10].

Peak Time indicates dough development time; beginning at the moment water is addeduntil the dough reaches maximum consistency. This gives an indication of optimummixing time under standardized conditions. Peak time is expressed in minutes. Arrival Time is the time when the top of the curve touches the 500-BU line. Thisindicates the rate of flour hydration (the rate at which the water is taken up by the flour). Arrival time is expressed in minutes.

Departure Time is the time when the top of the curve leaves the 500-BU line. Thisindicates the time when the dough is beginning to break down and is an indication ofdough consistency during processing. Departure time is expressed in minutes. Stability Time is the difference in time between arrival time and departure time. Thisindicates the time the dough maintains maximum consistency and is a good indication ofdough strength. Stability time is expressed in minutes.

Mixing Tolerance Indexis the difference in BU value at the top of the curve atpeak time and the value at the top of the curve 5 minutes after the peak. This indicates thedegree of softening during mixing. Mixing tolerance index is expressed in Brabender units (BU). Weak gluten flour has a lower water absorption and shorter stability time thanstrong gluten flour adapted from AACC, 2000.

Farinograph quality numberis the point of the curve in which the curve hasdecreased by 30 FU after the maximum (based on the line of the diagram). Thus weakflour weakens early and quickly giving low quality number. Strong flour weakens lateand slowly indicting a high quality number [11].

2.2. Pasting Properties

This property is very important to know the flour or starch characteristics of a cereal orstarchy product. They are useful to predict the behavior of the flour in baking and brewing process [12]. Pasting properties of starch are the phenomena involving granular cooking, swelling, and total disruption of granules. It has been used to quantify cold-swelling of 'cooked' component, raw component that paste's during test and overall viscosity that indicates degree of starch dextrinization [13]. The pasting properties are important indices in predicting the pasting behavior during and after cooking, [14]. The pasting character predicts the processing qualities (cooking temperature and time, thickening ability, temperature, pressure, shear induce viscosity breakdowns, gelling and reterogradation tendencies over the storage durations) of starch based raw material food ingredients. The pasting character is fundamentally determined by the starch granule composition and its nature (ultra-structures) and is influenced by the non-starch flour components [1]. For example to determine these characteristics, it is necessary to use a Rapid Visco Analyzers, and the main characteristics are:

Pasting temperature. It indicates the minimum temperature required to cook starch [15].

Peak viscosity is the maximum viscosity attained by gelatinized starch during heating in water. It indicates the water binding capacity of the starch granule [16].

Breakdown viscosity is measurement of the vulnerability or susceptibility of the cooked starch to disintegration. The high breakdown in viscosity will reduce the ability of the starch sample to withstand heating and shear stress during cooking.

Trough viscosity is related to the ability of the starch paste to form a gel after cooling. Gelation occurs with junction zone formation mostly through hydrogen bonding, re-associating the hydrated and dispersed starch molecules, and can vary with the botanical sources of the starch, amylose content and formation of amylose-lipid complexes, amount of water, other ingredients like proteins and temperature of cooling [17]. High-amylose (linear) starches re-associate more readily than high amylopectin branched starches.

Setback viscosity is a measure of recrystallization of gelatinized starch during cooling. High setback value gave lower reterogradation during cooling and the lower staling rate of the products made from the starch.

Final viscosityindicates the abilityof the starch to form a viscous paste [18].

3. Materials and Methods

3.1. Experimental Site

These experiments were done at Wolkite University, College of Engineering and Technology in Food Process Engineering Laboratory.

3.2. Experimental Materials

The six-*teff* varieties of Quncho (DZ-Cr-387), Felagot (DZ-Cr-442), Tesfa (DZ-Cr-457), Kora (DZ-Cr-438), Dukem (DZ-Cr-425) and Dagme (DZ-Cr-43B) were obtained from Debre Zeit Agricultural Research Center of the Ethiopian Institute of Agricultural Research (EIAR). These *teff* varieties were released by the National *teff* Improvement Program of the Ethiopian Institute of Agricultural Research (EIAR). The six *teff* varieties were selected based on the color, popularity among the *teff* grain consumers and the *teff* grain farming community, high yield, and that some are released recently [19].

Table 1. *Teff Grain Varieties.*

No	Variety name	Common name	Seed color	Year of release
1	DZ-Cr-387	Quncho	Very White	2017
2	DZ-Cr-442	Felagot	Red	2017
3	DZ-Cr-457	Tesfa	Pale White	2017
4	DZ-Cr-438	Kora	White	2014
5	DZ-Cr-425	Dukem	White	2016
6	DZ-Cr-43B	Dagme	White	2016

3.3. Statistical Analysis

Data was analyzed by the analysis of variance (ANOVA) procedures using statically analysis of software (SAS) for windows version 9.0. Least significant differences (LSD) are using for Fisher mean comparison tests. Significance is accepting at ($P< 0.05$)

4. Results and Discussions

Table 2. *Functional Properties of Teff Flour.*

Varieties	WAC (g/g)	OAC (ml/g)	SP (%)	DIS (%)	WSI (%)
DZ-Cr-387	0.99 ± 0.01^{a}	1.27 ± 0.01^{c}	10.24 ± 0.27^{c}	73.67 ± 1.53^{ba}	19.61 ± 0.18^{b}
DZ-Cr-442	0.98 ± 0.01^{ba}	1.18 ± 0.01^{e}	8.37 ± 0.13^{e}	72.00 ± 1.00^{b}	17.44 ± 0.12^{e}
DZ-Cr-457	0.96 ± 0.01^{b}	1.24 ± 0.01^{d}	8.88 ± 0.36^{d}	74.00 ± 1.00^{a}	18.69 ± 0.34^{c}
DZ-Cr-438	0.89 ± 0.01^{d}	1.42 ± 0.01^{a}	11.99 ± 0.12^{a}	74.00 ± 1.00^{a}	19.99 ± 0.22^{a}
DZ-Cr-425	0.91 ± 0.01^{d}	1.08 ± 0.02^{f}	10.91 ± 0.39^{b}	73.00 ± 1.00^{ba}	19.51 ± 0.18^{b}
DZ-Cr-43B	0.93 ± 0.01^{c}	1.32 ± 0.01^{b}	9.21 ± 0.22^{d}	72.00 ± 1.00^{b}	17.96 ± 0.06^{d}
LSD	0.02	0.02	0.47	1.97	0.36
CV	1.28	0.79	2.69	1.51	0.49

Note: WAC=Water absorption capacities, OAC=Oil absorption capacity, SP=Swelling power, DIS=Dispersability, WSI=Water Solubility index.
Within a column, values with different superscript lettershave significant ($P<0.05$) differences.

4.1. Swelling Power

The measured swelling power of the teff flour is presented in Table 2. The values were 10.24, 8.37, 8.88, 11.99, 10.91 and 9.21% for the varieties Quncho (DZ-Cr-387), Felagot (DZ-Cr-442), Tesfa (DZ-Cr-457), Kora (DZ-Cr-438), Dukem (DZ-Cr-425) and Dagme (DZ-Cr-43B), respectively. There were significant ($P<0.05$) differences among the varieties, with Kora (DZ-Cr-438) having the highest value (11.99%) whereas, Felagot (DZ-Cr-442) the lowest value (8.37%). These results were found to be within range between 7.7 and 12.5% which were reported by [20]. They indicated swelling power is a measure of hydration capacity of starch, because the determination is a weight measure of swollen starch granules and their occluded water. Food eating quality is often connected with retention of water in the swollen starch granules [10]. Swelling power and solubility of starch granules also play an important role in contributing to the pasting and rheological behavior in most starchy products. Moorthy [21] reported that the swelling power of flour granules is an indication of the extent of associative forces within the granule. Swelling power is also related to the water absorption index of the starch-based flour during heating [12]. Therefore, the higher the swelling power, the higher the associate forces. The variation in the swelling power indicates the degree of exposure of the internal structure of the starch present in the flour to the action of water [13].

4.1.1. Water Absorption Capacity

The measured water absorption capacities of different teff flour are presented in Table 2. The values were 0.99, 0.98, 0.96, 0.89, 0.91 and 0.93g/g for the varieties Quncho (DZ-Cr-387), Felagot (DZ-Cr-442), Tesfa (DZ-Cr-457), Kora (DZ-Cr-438), Dukem (DZ-Cr-425) and Dagme (DZ-Cr-43B), respectively. There were significant (P< 0.05) differences among the varieties. Quncho (DZ-Cr-387) having the highest values (0.99 g/g) of water absorption among the varieties studied because Proteins (consist of subunits structure and dissociates on heating as observed by Granito [22]. Dev and Quensil, (1988) reported that protein subunit have more water binding sites (increase in the number of hydrophilic groups) which are the primary sites of water binding of protein. Kora (DZ-Cr-438) showed thelowest value (0.89 g/g). These results were foundin harmonywith previous studies conducted by [23]. The high water absorption capacity has been attributed to loose structure of starch polymers while low water absorption capacity value indicates the compactness of molecular structure [24].

4.1.2. Oil absorption Capacity

The oil absorption capacity results of different *teff* flours are presented in Table 1. There were significant (P< 0.05) differences among the varieties with values of 1.27, 1.18, 1.24, 1.42, 1.08 and 1.32 ml/g for Quncho (DZ-Cr-387), Felagot (DZ-Cr-442), Tesfa (DZ-Cr-457), Kora (DZ-Cr-438), Dukem (DZ-Cr-425) and Dagme (DZ-Cr-43B) *teff* varieties. Kora (DZ-Cr-438) having the highest value (1.42 ml/g) whereas Dukem (DZ-Cr-425) the lowest value (1.08 ml/g). These results were found to be within range between1.00 and1.55 ml/g) reported by [25]. Oil present food products improves their mouth feel and flavor retention. The oil binding capacity of food protein depends upon the intrinsic factors like amino acid composition, protein conformation and surface polarity or hydrophobicity. The ability of the proteins of the flour to bind with oil makes it useful in foodsystem where optimum oil absorption is desired. This makes the powder to have potentialfunctional uses in foods such as bakery products. The oil absorption capacity also makes the flour suitable in facilitating enhancement in flavor and mouth feel when used in food preparation. In addition fat increases the leavening power of the baking powder in the batter and improves the texture of the baked product.

4.1.3. Dispersbility

The property of Dispersability determines the tendency of flour to move apart from water molecule and shows its hydrophobic interaction. [26] Reported that water absorption is influenced by processing methods affecting starch gelatinization and swelling power. The measured Dispersability of different *teff* flour are Presented in Table 1. The values were 73.67, 72. 00, 74.00, 74.00, 73.00 and 72.00% for varieties Quncho (DZ-Cr-387), Felagot (DZ-Cr-442), Tesfa (DZ-Cr-457), Kora (DZ-Cr-438), Dukem DZ-Cr-425) and Dagme (DZ-Cr-43B), respectively. There were no significant (P>0.05) differences among the varieties. Present values were fairly compatible with results of Ashogbon and Akintayo, (2012), who reported values of 70.33-99.44% Dispersability for pearl millet flour [27].

4.1.4. Water Solubility Index

Water solubility index is important parameter often used as an indicator of degradation of molecularcomponents. WSI measures the amount of soluble components released from theprotein and other molecules after extrusion. The water solubility index results of *teff* flours are presented in Table 1. The values were 19.61, 17.44, 18.69, 19.99, 19.51 and 17.96% for varieties Quncho (DZ-Cr-387), Felagot (DZ-Cr-442), Tesfa (DZ-Cr-457), Kora (DZ-Cr-438), Dukem (DZ-Cr-425) and Dagme (DZ-Cr-43B), respectively withsignificant (P<0.05) differences among the varieties. Kora (DZ-Cr-438) hadthe highestvalue of 19.99% whereas Felagot (DZ-Cr-442) the lowest value of (17.44%) water solubility index among the varieties. These results were found to be within the range between14.39 and20.33% which was reported by [28] for cassava flour. The low water solubility index offlour could be attributed to the possibility of amylase complex with especially lipids in flour starch preventing it from dissolving in solution. Other factors could be the high stability of flour starch amylopectin structure; hence, preventing it from possible degradation during heating [29].

Table 3. *Pasting Properties of Flour.*

Varieties	PT (°C)	Pt. (min)	PV.(cP)	FV (cP.)	BD (cP.)	TV (cP)	SB (cP.)
DZ-Cr-387	76.00 ± 1.00^{b}	5.20 ± 0.10^{c}	1640.33 ± 2.0^{b}	1614 ± 2.00^{c}	$800.\pm4.00^{a}$	840 ± 2.00^{b}	774 ± 0.00^{b}
DZ-Cr-442	80.33 ± 1.53^{a}	5.50 ± 0.10^{b}	900.33 ± 1.53^{e}	1568 ± 2.00^{d}	340.33 ± 2.51^{e}	602.0 ± 2.00^{e}	967.33 ± 1.15^{a}
DZ-Cr-457	79.00 ± 1.00^{a}	5.17 ± 0.03^{c}	1250 ± 7.81^{c}	1721.67 ± 1.52^{a}	541.00 ± 1.00^{b}	880.0 ± 1.00^{a}	370.33 ± 3.30^{c}
DZ-Cr-438	70.00 ± 1.00^{c}	5.13 ± 0.06^{c}	880.0 ± 1.00^{f}	1511.33 ± 1.53^{f}	360.33 ± 0.57^{d}	540.0 ± 1.00^{f}	971.00 ± 2.65^{a}
DZ-Cr-425	80.33 ± 1.53^{a}	5.17 ± 0.06^{c}	1650.33 ± 1.53^{a}	1558.67 ± 1.53^{e}	546.67 ± 8.50^{b}	623.77 ± 3.21^{d}	486.67 ± 5.70^{c}
DZ-Cr-43B	80.00 ± 1.00^{a}	6.17 ± 0.03^{a}	1109 ± 1.00^{d}	1681.00 ± 1.00^{b}	458.00 ± 6.93^{c}	650 ± 1.00^{c}	925.67 ± 3.70^{a}
LSD	2.14	0.13	6.21	2.91	8.71	3.35	4.12
CV	1.55	1.38	0.28	0.10	0.96	0.27	10.47

4.2. Pasting Temperatures

The measured pasting temperatures of the teff flours dough are presented in Table 3. There were significant (P<0.05) differences. Varieties, Felagot, Tesfa, Dukem and Dagme exhibited pasting temperatures of 80.33, 79.00, 80.33 and

80.00°C, respectively with no significant differences among them. Their values is found to be statistically higher than the 76.00°C belonging to variety Quncho which in turn is statically higher than the lowest value 70.00°C of variety Kora. Pasting temperature of different flour varies due to various sizes of the *teff* starch granules. Larger *teff* flour granules are associated with lower pasting temperature and high swelling properties [30]. In this observation, Dukem (DZ-Cr-425) and Felagot (DZ-Cr-442) flour had smaller granules size than the other varieties, thus may have contributed to the higher pasting temperature. Higher pasting temperature also indicates a greater structural rigidity of the flour [31]. The Pasting temperature found in this work is somehow similar to the reported RVA pasting temperatures between 64.1°C and 90.8°C for five *teff* flour starches [32].

4.2.1. Peak Time

The peak time results of *teff* flours are presented in Table 2. The time at which peak viscosity occurred in minutes is termed peak time [33]. The values were 5.20, 5.50, 5.17, 5.13, 5.17 and 6.17 min for varieties Quncho (DZ-Cr-387), Felagot (DZ-Cr-442), Tesfa (DZ-Cr-457), Kora (DZ-Cr-438), Dukem (DZ-Cr-425) and Dagme (DZ-Cr-43B), respectively. There were significant ($P<0.05$) differences among the varieties. Dagme (DZ-Cr-43B) having the highest value (6.17 min) followed by the 5.50 min of variety Felagot. The rest of the varieties had peak time values of 5.13 to 5.20 min with no significant ($P>0.05$) differences among them. These results showed slightly longer time thanthe RVA Pasting time reported (6.00-3.43 min) for *teff* flour by [32]. Short peak time observed in the flour may be due to reduced starch content. However, short peak time is indicative of its ability to cook fast.

4.2.2. Peak Viscosity

The peak viscosity results of *teff* flour values had ranged from 880 to 1650.33cp. Dukem (DZ-Cr-425) having the highestvalue (1650.33cP) whereas Kora (DZ-Cr-438) the lowest value (880cP). There were significant ($P < 0.05$) differences among the varieties. The peak viscosity is indicative of the strength of pastes, which are formed from gelatinization during processing in food applications. It also reflects the extent of granule swelling [34] and provides an indication of the viscous load likely to be encountered during mixing. The higher the peak viscosity the more is the swelling index, while low paste viscosity is indicative of higher solubility as a result of starch degradation or dextrinization [35]. The PV indicates the thickening ability and water holding capacity of the pasted flour and reflects the eating quality of the food products to be made as reported by [36]. The final viscosity results of the *teff* flours are presented in Table 3. The values had ranged from 1511.33 to 1721.67 cP Tesfa (DZ-Cr-457) having the highest value (1721.67cP) and Kora (DZ-Cr-438) the lowest value (1511.33 cP). There were significant ($P<0.05$) differences among the final viscositiesdue to the varieties. Final viscosities are important in determining ability of the flour sample to form a gel during processing andit is the most commonly used parameters to define a particular sample quality [12]. Final viscosity shows the ability of the material to form a viscous paste and it is mainly determined by the retro gradation of soluble amylose in the process of cooling.

4.2.3. Breakdown Viscosity

The measured breakdown viscosity of the *teff* flours are presented in Table 2. The values had ranged from 340.33 to 800 cP. There were significant ($P<0.05$) differences among the varieties. Quncho (DZ-Cr-387) had the highest value (800cP) while Felagot (DZ-Cr-442) the lowest value (340.33 cP). Quncho (DZ-Cr-387) breakdown viscosity larger than that of the other varieties. This means that these teff varieties showed the highest disintegration degree of the swollen systems and alignment of amylase and other linear components in the direction of shear while the lowest value of breakdown viscosity in Felagot (DZ-Cr-442). Breakdown viscosity reflects the stability of the paste during processing. The higher the breakdown in viscosity, the lower the ability of the starch in the flour samples to withstand heating and shear stress during [33]. It was also reported by [37] that high breakdown value indicates relative weakness of the swollen starch granules against hot shearing while low breakdown values indicate that the starch in question possesses cross-linking properties. The break down viscosity measures the differences between peak viscosity and trough viscosity achieved during the high temperature (80.33°C for 5.17 min) holding duration and shows the relative differences of shear thinning and degree of disintegration of the swollen systems. *Teff* flour starch pasting are shear tolerant and thus had a potential for use in foods processed under high shear conditions.

The results of trough viscosity values are displayed in Table 3. The values had ranged from 540 to 880cP. Tesfa (DZ-Cr-457) had the highest value (880cP) and Kora (DZ-Cr-438) the lowest value were (450cP). There were significant ($P<0.05$) differences among the varieties.

4.2.4. Setback Viscosity

The measured setback viscosity of the *teff* flours values are presented in Table 2. The values had ranged from 370.33 to 971cP. Kora (DZ-Cr-438) had the highest value (971cP) where as Tesfa (DZ-Cr-457) had lowest value (370.33cP). There were significant ($P<0.05$) differences among the varieties. The SBpredicts the degree of gelatin and the gradual reterogradation tendencies on cooling and storage of the *teff* flour starch pasted system. *Teff* starch was known to have less thickening ability, shear tolerance and slow setback than commercial normal maize starch reported by [1] on the RVA pasting and similar is also seen in the Bra bender amyl graph pasting. *Teff* starches were also known to have slow reterogradation tendencies on the refrigeration and freeze storages and freeze-thaw cycle treatments than the maize starches [38]. The remarkably lower SV of the *teff* flours with respect to wheat and rice flours is related to amylase retro gradation and confirm that *teff* flours retrograde extent than other cereals. Such lower reterogradation tendency in the *teff* flours could make them to be advantageous in formulation of different food products [1].

Farinograph Test

Table 4. *Farinograph Test.*

Varieties	WA (%)	DDT (min)	DST (min)	MIT (FU.)	FQN (FU.)
DZ-Cr-387	47.37±0.33^{b}	4.67±0.28^{d}	3.99±0.12^{a}	68.69±0.34^{c}	77.94±0.32^{c}
DZ-Cr-442	50.11±0.11^{a}	5.28±0.38^{b}	3.64±0.16^{a}	74.58±0.97^{b}	77.47±0.59^{c}
DZ-Cr-457	48.14±0.39^{b}	5.03±0.07^{b}	3.62±1.64^{a}	76.99±0.13^{a}	70.67±0.66^{e}
DZ-Cr-438	48.14±0.22^{b}	4.78±0.07^{b}	4.24±0.64^{a}	59.12±0.11^{d}	76.07±0.65^{d}
DZ-Cr-425	50.15±0.95^{a}	5.99±0.12^{a}	3.84±0.05^{a}	58.82±0.35^{ed}	82.56±0.51^{a}
DZ-Cr-43B	50.85±0.45^{a}	5.19±0.29^{bc}	4.04±0.23^{a}	58.18±0.33^{e}	80.32±0.19^{b}
LSD	0.87	0.42	0.67	0.83	0.92
CV	0.99	4.55	9.73	0.71	0.67

Note: WA= Water absorption, DDT= Dough development time, DST= Dough stability time, MTI=Mixing tolerance index, FQN= Farinograph quality number. Within a column, values with different superscriptletters havesignificant (P<0.05) differences.

4.3. Water Absorption

Water absorption is the point chosen by the baking industry which represents a target water-to-flour ratio in bread dough. It is important to determine taste and texture of flour and dough performance during proofing and baking. The measured water absorption capacity of the different *teff* flours dough is presented in Table 3. The values were 47.37, 50.11, 48.14, 48.14, 50.15 and 50.85% for varieties Quncho (DZ-Cr-387), Felagot (DZ-Cr-442), Tesfa (DZ-Cr-457), Kora (DZ-Cr-438), Dukem (DZ-Cr-425) and Dagme (DZ-Cr-43B), respectively. There were significant (P< 0.05) differences among water absorption capacityof the varieties. Dagme (DZ-Cr-43B) had the highest value (50.85%) and Quncho DZ-Cr-387) having the lowest value (47.36%) [39]

4.3.1. Dough Development Time

Dough development time is the time from the first addition of water to the time the dough reaches the point of greatest torque. The measured of dough development time *teff* flours are presented in Table 3. There were significant (P<0.05) differences among the varieties on the dough development time of the teff flour dough. The longest time (5.99 min) was recorded for Dukem (DZ-Cr-425) whereas Quncho (DZ-Cr-387) having the shortest dough development time. The longest DDT for this flour could be due to the lowest fraction of teff flour dough in which resulted in the lowest gluten content which absorbs the water. Dough development time increases with the increase in the proteolytical degradation of protein [40]. This is also may be due to decrease in their gluten contents and weakening of protein network due to proteolytical activity of composite flour. These results were found to be the range between 4.5 and 6.5 min who reported by [41].

4.3.2. Dough Stability

Dough stability time is the time in minutes during which the curve remains on 500 BU line. The measured dough stability time of the *teff* flours dough are displayed in Table 3. The values were 3.99, 3.64, 3.62, 4.24, 3.84 and 4.04 min for varieties Quncho (DZ-Cr-387), Felagot (DZ-Cr-387), Tesfa (DZCr-457), Kora (DZ-Cr-438), Dukem (DZ-Cr-425) and Dagme (DZ-Cr-43B), respectively. There were no significant (P>0.05) differences among the varieties [41].

4.3.3. Mixing Tolerance Index

Mixing tolerance index is used by bakers to determine the amount that dough was softening over a period of mixing. The mixing tolerance index results of the flours are shown in Table 3. The values were 68.69, 74.58, 76.99, 59.12, 58.82 and 58.18 FU for varieties Quncho (DZ-Cr-387), Felagot (DZ-Cr-442), Tesfa (DZ-Cr-457), Kora (DZ-Cr-438), Dukem (DZ-Cr-425) and Dagme (DZ-Cr-43B), respectively. There were significant (P<0.05) differences among the varieties. Tesfa (DZ-Cr-457) having the largest value (76.99 FU) whereas Dagme (DZ-Cr-43B) the shortest value (58.18 FU) of the varieties. These results were found to be the range between 44.23 and 80.21 FU reported by [42] *teff* flour blend with wheat flour dough.

4.3.4. Farinograph Quality Number

Farinograph quality number is the point of the curve in which the curve has decreased by 30 FU after the maximum (based on the line of the diagram). Thus weak flour weakens early and quickly giving low quality number. Strong flour weakens late and slowly indicting a high quality number. The farinograph quality number results of the *teff* flours dough are presented in Table 3. The values were 77.94, 77.47, 76.07, 70.67, 82.56 and 80.32 FU for varieties Quncho (DZ-Cr-387), Felagot (DZ-Cr-442), Tesfa (DZ-Cr-457), Kora DZ-Cr-438), Dukem (DZ-Cr-425) and Dagme (DZ-Cr-43B), respectively. There were significant (P<0.05) differences among the varieties. Dukem (DZ-Cr-425) having the highest value (82.56 FU) whereas Kora (DZ-Cr-438) the lowest value (70.67FU). These results were found to be within the range between 40 and 115 FU reported by [43] for blend both *teff* flour and soft wheat flour dough.

5. Conclusions

Teff is one of the major and indigenous cereal crops in Ethiopia. It is a unique durable crop grown over a wide range of environmental conditions in Ethiopia and has been utilized as food and supplements for majority of the human diet in Ethiopia. This study was conducted to generate information on some engineering properties of *teff [Eragrostis teff* (Zucc.) Trotter] grain and its flour. Six *teff* varieties namely Quncho (DZ-Cr-387), Felagot (DZ-Cr-442), Tesfa (DZ-Cr-457), Kora (DZ-Cr-438), Dukem (DZ-Cr-425) and Dagme (DZ-Cr-43B).

The results were reported as an average value of triplicate analysis of (mean ± SD) and were analyzed by Fisher's Least Significance Difference (LSD) method and at statistical significance of $P<0.05$. The functional and rheological properties of the flours and dough expected of the teff grains. The color data showed that the varieties vary in the color of their flours which could be reflected on the processed products. The whiteness values as well as the a* and b^* show that the white starch color is strongly diluted by the color of the non-white pigments found on the cover of the grains. This is also supported by the high fiber contents of the flours recorded in the study. All in all valuable information have been obtained about the teff grains that are of high importance in industrial processing of the grain to various products.

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