Berhan International Research Journal of Science and Humanities (BIRJSH), 2022, 6(1), 38 - 47

Journal homepage: www.journals.dbu.et *ISSN: 2414-2794*

Evaluation of Functional Properties of Five Finger Millet Varieties and Their Flour Grown in *Mecha* District, Ethiopia

Ayalew Demissew*, Ayenew Meresa, Kiber Temesgen

Amhara Regional Agricultural Research Institute, Bahir Dar Food Science and Post-harvest Handling Research Center

Abstract

In this study functional properties of five finger millet grains and their flour were evaluated. Finger millets are staple food grains originated from Ethiopia. It is a gluten-free grain with smallest glycemic index and maximum nutritional content. Although finger millets have high nutrient value, it is neglected and underutilized grain not only in Ethiopia but also in the world. The grain is also rich sources of minerals such as calcium which is vital for growth and development of human being. Finger millet is also rich sources of essential amino acids like methionine, tryptophan and lysine. So in this study imperative physicochemical property of five finger millet grains and their flours were investigated. Pertinent physical properties of the grain like aspect ratio, thousand grain weight, true density, bulk density, porosity, sample volume, surface area, sphericity, dimensional properties and moisture content of grain finger millet varieties were analyzed. Bulk density, dispersibility, water absorption capacity and viscosity of five finger millet flours were evaluated. *Neche-deke* finger millet variety grain was significantly higher at ($p < 0.05$) than other grains in terms of weight, bulk density, true density, aspect ratio and sphericity. The research output provides basic information for engineers and food processors for designing and manufacturing of processing equipment's for finger millet and for new food product development from the grain.

Keywords: Bulk density, Dispersibility, Physical property, Viscosity

*Corresponding author email: *ayalewdemissew@yahoo.com*

Article information: Received 15 March 2022; Revised 16 October 2022; Accepted 25 November 2022

Introduction

Finger millet is a staple cereal crop and originated from Ethiopia. Finger millet ranks fourth after sorgum, foxtail and pearl millet in terms of production in dry land regions (Shiihii *et al.*, 2011). Now a day's finger millet is becoming a staple food grain in developing countries mostly in Asian and African courtiers. Finger millet is a gluten free grain having a minimal glycemic index with having superior nutritional content. But the grain is neglected and underutilized crop (Saleh *et al.*, 2013). The grains are rich sources of minerals such as calcium which is vital for growth and development of human-being in general and also strengthening bone and teeth. Finger millet is also rich sources of essential amino acids, such as methionine, tryptophan and lysine (Abdullah *et al*., 2012). Grains of finger millet varieties are different in shape, size and color (Jideani, 2012). Major physical properties of finger millet include moisture content, thousand grain weight, porosity, bulk density, aspect ratio true density, sample volume, sample surface area and perpendicular dimensions (Vadivoo *et al*., 1998). Functional properties of cereal grains are the fundamental physicochemical properties that reflect the complex interaction between the structure, molecular components, and composition and physicochemical properties of food components. The functional property of food is defined as physical, chemical and/or organoleptic properties of food. Examples of functional properties of food include viscosity, foaming capacity, water absorption capacity, dispersibility, bulk density, oil absorption capacity and swelling capacity (Walter *et al*., 2002).There for in this study physical properties of five finger millet grains and functional properties of their flours were evaluated so that food processing equipment manufacturers and food processors would have an access on basic information of functional properties of finger millet varieties.

Materials and Methods

Sample collection and preparation

Different finger millet cultivars (*Neche-deke*, *Neche*, *Tikure*, *Keye* and *Gebesema*) were collected from local market at *Mecha woreda*, western Amhara region, Ethiopia. Foreign materials were removed from the grains by traditional winnowing method using "*sefede*" and then immersed in clean water and finally dried in direct sun drying. The grain samples were randomly selected and 20 replicates were performed for dimensional properties (length, width and thickness). determination of other physical properties such as moisture content, thousand grain weight, bulk density, true density, porosity, aspect ratio, sample volume and sample surface area were performed in triplicates for each grains. Functional properties of these grain flours such as water activity, dispersibility, bulk density, colour attributes and viscosity were also performed in triplicates.

Preparation of flours

The sorted samples were then dried up to a moisture content of 12%. All samples were milled and sieved at 200µm Amhara Regional Agricultural Research Institute

Grain Laboratory, Bahir Dar, Ethiopia. The samples were then packed and sealed in a polythene bag. All the experiments were conducted at Bahir Dar food Science and Post-Harvest Handling Research Center and Ethiopian Health and Nutrition Research Institute laboratories.

Determination of physical and functional properties

Moisture content on wet basis: The moisture content was determined according to a method (AACC, 2000).

Dimensional properties: Three different dimensional properties (mm) were determined by measuring the length (L), width (W) and thickness (T) of the grains using digital caliper at an accuracy of 0.001 mm according to method followed by (Mpotokwane *et al*., 2008).

Geometric mean diameter: The geometric mean diameter (mm) was determined according to (Mpotokwane *et al*., 2008).

Arithmetic mean diameter: Arithmetic mean diameter (mm) of the sample was determined by a method (Mpotokwane *et al*., 2008).

Thousand grain weight: Thousand grain weights were determined according to a method by (Sangamithra *et al*., 2016).

Bulk density: Bulk density (kg/m^3) was determined according to a method by (Vanrnamkhasti *et al*., 2008).

True density: The true density (kg/m^3) was determined by a method followed by (Karababa and Coşkuner, 2013).

Sphericity: The sphericity of the grains was determined according to a method followed by (Hamdani *et al.,* 2014).

Surface area: The surface area (mm^2) of the grains was calculated according to a method (Karababa and Coşkuner, 2013).

Aspect ratio: The aspect ratio (%) was calculated according to a method used by (Karababa, and Coşkuner, 2013).

Porosity: Porosity of grains was calculated according to a method by (Karababa and Coşkuner, 2013).

Sample volume: The volume (mm^3) of the grains was calculated using a method used by (Karababa and Coşkuner, 2013).

Water absorption capacity: Water absorption capacity of samples was determined by a method (Sawant *et al*, 2013).

Bulk density: Bulk density of the flours were determined a method by (Mandge *et al*., 2014).

Determination of dispersibility: Dispersibility of samples were determined a method by (Olapade *et al*., 2014).

Viscosity: Viscosity of samples was determined by a method according (Krishnan *et al*., 2011).

Data analysis

The data were subjected to analysis of variance (ANOVA) and means were separated using the Duncan multiple range test. Significance will be accepted at 95% confidence interval ($p < 0.05$).

Results and Discussion

Moisture content

Moisture content of five finger millet grains (*Neche-deke*, *Neche*, *Tikure*, *Keye* and *Gebesem*a) were found in the ranges from 8.04% to 10.24% while moisture content of the flours were ranging from 7.18% to 8.69%. *Tikure* and *Key*e finger millet grains moisture content showed a significant difference at ($p < 0.05$) for both grains and flours as compared to Neche-*deke*, *Neche* and *Gebesema* finger millet. The moisture content of finger millet grains found in this experiment was found minimum as compared to a report by (Saleh *et al*., 2013). From all the grains *Neche-deke* had highest moisture content while *Tikure* finger millet grain had the lowest moisture content. Moisture content is an important factor that directs the physical properties of grain. It is also excellent indicator as to whether the grains can be stored for a long or short period where the higher the moisture content, the shorter the storage life of the grain (Goswami *et al*., 2015).

Dimensional properties

The experimental mean results of the length, width and thickness of the five grain samples were found in range between 1.78 to 1.45mm for length, 1.56 to 1.31mm for width and 1.45 to 1.28mm for thickness as shown in table-one below. The result found was completely different form the finding and report by (Hamdani *et al*., 2014). This large difference may arise from agro-ecology and variety variation. Length values were significantly higher ($p< 0.05$) for *Tikure* finger millet grain while the rest four grains were not significantly different. Width values for *Tekure* cultivar was also significantly higher ($p<0.05$) while others were not significantly different at ($p>0.05$). Thickness values for *Tikure* finger millet were significantly higher when compared with other cultivars at ($p<0.05$). The geometric mean diameter for all grain samples were found in a range from 3.21 mm to 1.95mm while the arithmetic mean diameters range from 3.45mm to 1.85 mm. Similar values were reported by (Adebowale *et al*., 2012) concerning with geometric and arithmetic mean diameters.

Table 1. Dimensional properties of five finger millet grains

Dimensions (mm)	*Neche-deke*	*Neche*	*Gebesema*	*Tikure*	*Keye*
Length	$1.45^{a}\pm0.03$	$1.53^{b}\pm0.09$	$1.56^{c}\pm0.18$	$1.78^{e}\pm0.12$	$1.51^{e}\pm0.02$
Thickness	$1.31^{a}\pm0.01$	$1.42^{b}\pm0.10$	$1.34^{e}\pm0.12$	$1.56^{d}\pm0.08$	$1.52^{c}\pm0.05$
Width	$1.28^{a}\pm0.05$	$1.31^{d}\pm0.06$	$1.33^{d}\pm0.13$	$1.45^{a}\pm0.15$	$1.35^{d}\pm0.10$
GMD	$1.95^{c}\pm0.01$	$2.32^{b}\pm0.91$	$2.41^{b}\pm0.2$	$3.21^{a}\pm0.01$	$2.83^{a}\pm0.02$
AMD	$1.85^{d}\pm0.07$	$3.22^{e}\pm0.20$	$3.32^{e}\pm0.04$	$3.45^{c}\pm0.07$	$2.89^{a}\pm0.01$

**The mean ± standard deviation, n=20, Values followed by the same letters in the same row are not significantly different (p > 0.05), GMD= Geometric mean diameter and AMD= Arithmetic mean diameter*

Physical and functional properties of grains

The highest mean result for thousand grain weight was obtained from *Neche-deke* cultivar which is 825.6gm and the lowest mean result for thousand grain weight was 536.8gmfrom *Tikure* finger millet cultivar as shown in the table-two below. *Neche-deke* was significantly different at ($p<0.05$) for thousand grain weight as compared to other finger millet grains. The experimental result disagrees with the findings and report by (Balasubramanian and Viswanathan, 2010). These researchers reported that thousand grain weightswere185.8g at a moisture content of 11.1 to 25%. Contradicting result was also reported by (Siwela *et al*., 2007). Bulk density of finger millet grains were found in a range from 1093.6 to 1351.6 kg/m^3 respectively, with *Neche-deke* showing the highest bulk density and *Gebesema* cultivar showing the lowest. In terms of true density *Neche-deke* finger millet cultivar had significantly highest ($p<0.05$) true density of 1751.6 kg/m^3 while *Gebesema* finger millet cultivar had the lowest value of 1415.8 kg/m^3. Similar results were reported on true density of finger millet grains by (Balasubramanian and Viswanathan, 2010). The findings were ranged from 884.4 to 1988.7 kg/m^3 at a moisture content of 11.1 to 25%.). Bulk density is an essential factor that determines the grade and test weight of the grains during drying, storage and processing. It helps for storage and processing since size and shape of the grains were indicating high quality and better production of grains into flours.

Table 2. Physical properties of finger millet grains

Physical properties	*Neche-deke*	*Neche*	*Gebesema*	*Tikure*	*Keye*
1000 grain weight(wt.g)	825.6^{a}±10.2	703.4^{c}±5.2	689.7^{c} ±9.2	536.8^{b}±12.5	598.7^{e}±20.3
Bulk density (Kg/m^3)	1351.6^{a}±16.5	1253.7^{c}±12.6	1093.6^{c}±18.3	1131.9^{b}±20.5	1200.5^{e}±15.6
True density (Kg/m^3)	1751.6^{a}±20	1532.3^{b}±15.9	1415.8^{c}±18.4	1567.1^{c}±17.2	1498.7^{d}±17.2
Sphericity (%)	95.43^{a}±0.7	90.23^{b}±0.08	85.45^{c}±0.07	79.75^{c}±0.2	83.23^{c}±0.1
Porosity (%)	22.51^{a}±1.2	24.32^{a}±1.5	30.51^{a}±2.5	27.35^{e}±2.1	28.91^{b}±1.8
Aspect ratio (%)	96.21^{a}±0.08	86.35^{a}±0.06	81.57^{a}±0.02	78.55^{e}±0.07	80.75^{a}±0.04
Volume (mm^3)	0.84^{a}±1.2	1.03^{a}±0.08	1.12^{a}±0.2	1.32^{e}± 0.1	0.92^{a}±0.07
Surface area (mm^2)	5.73^{a}±0.09	5.96^{e}±0.3	6.03^{e}±0.02	6.97^{d}±0.06	6.21^{e}±0.06

**The mean ± standard deviation, n=3 and Values followed by the same letters in the same row are not significantly different (p >0.05).*

The porosity results obtained varied from 22.51 to 30.51%. The highest porosity value was found at *Gebesema* grain while *Neche-deke* finger millet cultivar had lowest value. Our finding also coincides with the report by (Al-Mahasneh and Rababah, 2007). Different porosity value was also reported by (Jain and Bal, 1997) which was ranging from 32.5 to 63.7% with having 11.1 to 25% moisture content. Nearly similar porosity was presented by (Zewdu and Solomon, 2007) but it was done for *Teff*. The mean results of aspect ratio of the grain found in a range from 78.55 to 96.21% where *Neche-deke* finger millet grain was found to have a highest percentage while lowest percentage was *Tikure* cultivar. Contradicting and lowest value by (Adebowale *et al*., 2012) was discovered and reported as 59.62% of aspect ratio at a moisture content of 10%. Very different values of aspect ratio were also reported by (Markowski *et al*., 2013). In our experimental result the mean results of sphericity ranged from 79.75 to 95.43 %. The highest result was obtained on *Neche-deke* cultivar and the lowest result on *Tikure* cultivar. Similar finding was also reported by (Baryeh, 2002). The surface area mean results of this study varied from 5.73 to 6.97 mm^2 in which the highest result was obtained from *Tikure* cultivar and the lowest result *from Neche-deke* cultivar. Our finding also coincides with the finding and the report by (Adebowale *et al*., 2012).The mean sample volume of the samples studied varied from 1.17 to 0.88 mm^3, respectively. The highest result was obtained from *Gebesema* and lowest results from *Tikure* cultivar. Similar results which ranged from 3.79 to 5.79 mm^3 at a moisture content of 7.4% were also reported by (Jain and Bal, 1997).

Functional properties of flours

Table-three below shows the results of functional properties on finger millet flours such as bulk density, water absorption capacity, dispersibility, viscosity and micro-structure. The results of bulk density were highest on finger millet *Neche-deke* cultivar (0.99g/mL) and lowest on *Tikure* flour (0.86 g/mL). *Neche-deke* flour showed a significant difference at ($p<0.05$) higher as compared to *Gebesema* and *Tikure*. Similar result reported by (Dharmaraj *et al.*, 2015). Another similar report was also published by (Mandge, *et al*, 2014). Low bulk density of finger millet flour would be an advantage in the preparation of instant foods. Higher bulk density indicates that the flour can be used in food preparation while low bulk density flour is suitable to use in the preparation of weaning food formulation. Since *Tikure* finger millet flour had the least bulk density, it can be used in the preparation of the complementary foods. Water absorption capacity of finger millet flours ranged from 0.92 to 1.26 mL/g where *Neche-deke* flour had the highest value and black flour with the lowest value. *Neche-deke* showed a higher significant difference ($p<0.05$) in water absorption activity as compared to other finger millet samples.

Table 3. Functional properties of raw finger millet cultivar flours

Functional properties	***Neche-deke***	***Neche***	***Gebesema***	***Tikure***	***Keye***
WAC(ml/g)	$1.26^{a}\pm 0.31$	$0.98^{e}\pm 0.6$	$1.06^{b}\pm 0.02$	$0.92^{d}\pm0.02$	$0.95^{d}\pm0.04$
Bulk density (Kg/m^3)	$0.99^{a}\pm0.07$	$0.92^{e}\pm 0.02$	$0.89^{b}\pm0.07$	$0.86^{d}\pm0.03$	$0.93^{d}\pm0.02$
Viscosity, cold paste (cP)	$7.00^{a}\pm0.02$	$6.32^{b}\pm0.08$	$6.46^{d}\pm0.07$	$6.00^{e}\pm0.12$	$6.77^{c}\pm 0.09$
Viscosity, cooked paste (cP)	$134.21^{e}\pm0.02$	$234.12^{c}\pm0.23$	$46.74^{e}\pm0.03$	$59.67^{e}\pm 0.1$	$123.02^{c}\pm0.1$

**The mean ± standard deviation, n=3,Values followed by the same letters in the same row are not significantly different (p >0.05) and WAC= water absorption capacity*

Water absorption capacity of flours was found under range of 1.26 to 0.92. Similar result was found and reported by (Olapade *et al.*, 2014). The water absorption capacity of flour or isolate is a useful indicator for determining if the flour can be incorporated into aqueous food formulations, especially those involving dough handling. Lower water absorption activity is suitable for making thinner gruels and also indicates the amount of water available for gelatinization (Giami, 1993). High water absorption activity values indicate loose structure of starch polymers while low values indicate the compactness of the structure (Adebowale *et al*., 2012). The dispersibility (%) of finger millet flour was higher on *Neche-deke* finger millet (96.03) while lower values were obtained from *Tikure* sample (86.73). *Neche-deke* finger millet was significantly different in dispersibility as compared to *Gebesema* and *Tikure* finger millet flours. The findings of this study were similar to those by (Olapade *et al*., 2014) who reported dispersibility ranging from 68 to 70.67% in cassava-bambara flours. The values of dispersibility may help produce fine constituent dough during mixing. The cold viscosity paste of the flour samples ranged from 6.00 to 7.00cP while cooked viscosity ranged from 59.67 to 346.74cP, respectively. *Gebesema* finger millet flour for cold and cooked paste was significantly higher ($p<0.05$) as compared to *Neche-deke* and *Tikure* finger millet flours. These results are similar to those of who studied the cold and cooked viscosity pastes of native, hydrothermal and decorticated finger millet. It is also indicated that cold viscosity paste not measured on native finger millet but measured on hydrothermally treated and decorticated finger millet were 11 and 22cP. Finger millet seed coat, (Krishnan, 2012) obtained results ranging from 12.0 to 21.0cP for cold viscosity paste while the cooked viscosity ranged from 48.0 to 248.0cP.

Conclusion

Neche-deke finger millet grain and flour was significantly higher in moisture content, water absorption capacity, bulk density, dispersibility, thousand grain weight, true density, aspect ratio and sphericity as compared to other finger millet varieties and their flours. *Neche-deke* finger millet flour was found important and convent for food processors to develop new food products. It is also found pertinent for consumption in urban areas especially by people who suffer from chronic diseases such as celiac disease. This basic information would also be used by design and manufacturing engineers for production of appropriated storage, processing and packing for finger millet grains and their flours. Additionally, the size and shape such as geometric mean diameter and sphericity properties of the finger millet grains required to be identified by manufacturers as they have a say in designing enhanced equipment appropriate for grain and other food processing operations. *Tikure* finger millet cultivar also recommended for the formulation of infant foods.

Acknowledment

The authors are grateful to Amhara Regional Agricultural Research Institute for financial and material support.

Conflict of interest

The authors declare that there is no conflict of interest.

References

AACC, (2000). In D. E. Bruns (Ed.). *Official methods of analysis* (10th ed). St Paul, MN: American Association of Cereal Chemists.

Abdullah, M. H. R. O., Ch'ng, P. E., &Yunus, N. A. (2012). Some physical properties of musk lime (*Citrus Microcarpa*). *International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering*, 6(12), 1122–1125.

Adebowale, A. A., Adegoke, M. T., Sanni, S. A., Adegunwa, M. O., & Fetuga, G. O. (2012). Functional properties and biscuit making potentials of sorghum-wheat flour composite. *Journal of Food Technology*, 7(6), 372–379.

Adebowale, A. A., Fetuga, G. O., Apata, C. B., & Sannai, L. O. (2012). Effect of variety and initial moisture content on physical properties of improved millet grains. *Nigerian Food Journal*, 30(1), 5–10.

Akpata, M. L., & Akubor, P. I. (1999). Chemical composition and selected functional properties of sweet orange (Citrus sinensis) seed flour. Plant Foods for Human Nutrition, 54, 353–362.

Al-Mahasneh, M. A., &Rababah, T. M. (2007). Effect of moisture content on some physical properties of green wheat. *Journal of Food Engineering*, 79, 1467–1473.

Balasubramanian, S., & Viswanathan, R. (2010). Influence of moisture content on physical properties of minor millets. *Journal of Food Science*, 47(3), 279–284.

Baryeh, E. A. (2002). Physical properties millets. *Journal of Food Engineering*, 51, 39–46.

Dharmaraj, U., Meera, M. S., Yella Reddy, S. Y., & Malleshi, N. G. (2015). Influence ofhydrothermal processing on functional properties and grain morphology of finger millet. *Journal of Food Science and Technology*, 52(3), 1361–1371.

Giami, S. Y. (1993). Effect of processing on the proximate composition and functional properties of cowpea (*Vigna unquiculata*) flour. *Food Chemistry*, 47, 153–158.

Goswami, D., Manikantan, M. R., Gupta, R. K., & Vishwakarma, R. K. (2015). Moisture dependent selected postharvest engineering properties of ragi (*Eleusinecoracana*) grown in Northern Hills of India. *Journal of Postharvest Technology*, 3(3), 082–088.

Hamdani, A., Rather, S. A., Shah, A., Gani, A., Wani, S. M., Masoodi, F. A., & Gani, A. (2014). Physical properties of barley and oats cultivars grown in high altitude Himalayan regions of India. *Journal of Food Measurement and Characterization*, 8, 296–304.

Jain, R. K., & Bal, S. (1997). Properties of pearl millet. *Journal of Agricultural EngineeringResearch*, 66, 85–91.

Jideani, I. A. (2012). Digitariaexilis (acha/fonio), Digitariaiburua (iburu/fonio) and Eleusinecoracana (tamba/finger millet) - Non-conventional cereal grains with potentials.*Scientific Review and Essays*, 7(45), 3834–3843.

Karababa, E., &Coşkuner, Y. (2013). Physical properties of carob bean (*Ceratonia siliqua L.*): An industrial gum yielding crop. *Industrial Crops and Products*, 42, 440–446.

Krishnan, R., Dharmaraj, U., Sai Manohar, R., & Malleshi, N. G. (2011). Quality characteristics of biscuits prepared from finger millet seed coat based composite flour. *Food Chemistry*, 129, 499–506.

Mandge, H. M., Sharma, S., & Dar, B. N. (2014). Instant multigrain porridge: effect of cooking treatment on physicochemical and functional properties. *Journal of Food Science and Technology*, 51(1), 97–103.

Markowski, M., Zuk-Gołaszewska, K., & Kwiatkowski, D. (2013). Influence of variety on selected physical and mechanical properties of wheat. *Industrial Crops and Products*, 47, 113–117.

Mpotokwane, S. M., Gaditlhatlhelwe, E., Sebaka, A., & Jideani, V. A. (2008). Physical properties of Bambara groundnuts from Botswana. *Journal of Food Engineering*, 89, 93–98.

Olapade, A. A., Babalola, Y. O., & Aworth, O. C. (2014). Quality attributes of fufu (fermented cassava) flour supplemented with bambara flour. *International Food Research Journal*, 21(5), 2025–2032.

Saleh, S. M., Zhang, Q., Chen, J., & Shen, Q. (2013). Millet grains, Nutritional quality, processing and potential health benefits. *Comprehensive Reviews in Food Science and Technology*, 12, 281–295.

Sangamithra, A., Swamy, G. J., Sorna, P. R., Nandini, K., Kannan, K., Sasikala, S., &Suganya, P. (2016). Moisture dependent physical properties of maize kernels. *International Food Research Journal*, 23(1), 109–115.

Sawant, A. A., Thakor, N. J., Swami, S. B., & Divate, A. D. (2013). Physical and sensorycharacteristics of ready-to-eat food prepared from finger millet based composite mixer by extrusion. *Agricultural Engineering International Journal*, 15(1), 100–105.

Shiihii, S. U., Musa, H., Bhati, P. G., & Martins, E. (2011). Evaluation of physicochemical properties of Eleusinecoracana starch. *Nigerian Journal of Pharmaceutical Sciences*, 10(1), 91–102.

Siwela, M., Taylor, J. R. N., de Milliano, W. A. J., &Doudu, K. G. (2007). Occurrence andlocation of tannins in finger millet grain and antioxidant activity of different grain type. *Cereal Chemistry*, 84(2), 169–174.

Vadivoo, A. S., Joseph, R., & Ganesan, N. M. (1998). Genetic variability and diversity forprotein and calcium contents in finger millet [*Eleusinecoracana (L.)* Gaertn] in relation to grains color. *Plant Foods for Human Nutrition*, 52, 353–364.

Vanrnamkhasti, M. G., Mobli, H., Jafari, A., Keyhani, A. R., Soltanabadi, M. H., Rafiee, S., & Kheiralopour, K. (2008). Some physical properties of rough rice (*Oryza sativa L.*) grain. *Journal of Cereal Science*, 47, 496–501.

Walter, H.L, L., Fanny, C., Charles & R., Christian. (2002). Minerals and phytic acid interaction: is it a realproblem for human nutrition. *International Journal of Food Science and Technology 37*, 727-739.

Zewdu, A. D., & Solomon, W. K. (2007). Moisture-dependent physical properties of teff seed. *Biosystems Engineering*, 96(1), 57–63.