Evaluation of Various Properties of Amaranthus (Genus Amaranthus L.) Based Composite Flour Blends for Preparation of Gluten-Free Biscuits

Muluken K. Kassa1*, Shimelis A. Emire2

1Department of Chemical Engineering, Institute of Technology, Hawassa University, P.O.Box 05, Hawassa, Ethiopia
2Department of Food Engineering, School of Chemical and Bioengineering, Addis Ababa University, P.O.Box 33381, Addis Ababa, Ethiopia

ARTICLE INFO

Article history:
Received: February 24, 2020
Accepted: September 8, 2020

Keywords:
composite flours
gluten-free
amaranthus
sorghum
finger millet

ABSTRACT

This research was conducted to investigate the pasting, rheological and functional properties, and gluten-free biscuit making potential of a composite flour prepared from grains of amaranthus, sorghum and finger millet. The formulation for the composite flour was obtained from D-optimal mixture design ratio using Design-Expert. The rheological and pasting properties of the composite flours were determined, while the proximate composition, physical dimensions, mineral concentration and sensory quality attributes of the biscuits were assessed. The results showed that there were significant (p<0.05) differences in the pasting profile of the control and amaranthus based composites flour except for pasting temperature. Water absorption capacity and water solubility index increased as the blending ratio of amaranthus flour increased, while oil absorption capacity decreased. The proximate composition evaluation 13.75, 2.04, 1.77 and 31.75% were found to be the highest values of the biscuit samples in terms of protein, crude fiber, ash and crude fat, respectively. Mineral analysis was carried out and there was a significant (p<0.05) difference in Fe, Ca, Zn and P content among the biscuit samples made from the composite flour blends. Similarly, the sensory evaluation indicated that there was a significant (p<0.05) differences in appearance, colour, texture, flavour and overall acceptability among the composite biscuit samples. However, the difference was insignificant (p>0.05) in crispiness of biscuit samples. In a nut shell this research revealed that a nutritionally dense gluten-free biscuits can be formulated without affecting the quality attributes of the biscuit. Thus, the composite flours can be used for the preparation of gluten free food products in Africa, where the crops have not been effectively utilized in food processing industries.

INTRODUCTION

Baking industry is considered to be one of the major segments of food processing in the present days and, because of their availability and reasonably good shelf life, baked products are gaining popularity. Wheat is a major cereal grain used for preparation of many baked goods. However, most of these foods are poor in terms of nutritional quality (Omobolanle et al., 2017). Baked products could be produced from cassava, sorghum, finger millet and other composite flours (Manley, 2000). A considerable attention has been given to the development of baked goods with better nutritional quality.

Amaranth is a pseudo-cereal with high nutritional value, particularly for its balanced amino acid content, dietary fiber content and antioxidant activity. Its nutritional quality have attracted the attention of researchers about the use of amaranth as functional ingredient (Cornejo et al., 2019). Grain amaranth can be used as seeds or flour to make products such as cookies, biscuits, and other bakery products (Muyonga...
et al., 2008). Beside its availability, amaranthus can also contribute to fighting malnutrition, especially in developing countries like Ethiopia. Sorghum has been utilized differently in different parts of Ethiopia and the grains are used in the preparation of porridge, infant food, and in the preparation of local beverages (Belton and Taylor, 2002). They are promising source of useful compounds because of their nutritional properties (Anonymous, 2016). In Ethiopia, finger millet is grown mainly as a sole crop in rotation with other annual crops, preferably legumes. Unleavened bread, thin-or thick porridge, fermented porridge, makingnjeru, “a flat leavened Ethiopian most widely used traditional food are some of the different food types prepared from finger millet (Belton and Taylor, 2002). The grain's protein content (7.4%) is comparable to that of rice (7.5%). Finger millet is also a rich source of minerals (Desai et al., 2010; Tsehaye et al., 2006).

Amaranth, sorghum, and finger millet are all gluten-free cereal grains and are considered to be better alternatives for those who have been suffering from celiac disease or gluten – sensitive enteropathy, which is the case for some grains like wheat, barley and rye. But, the processing of these grain flours into baked products has several limitations as the grains lack these storage protein (gliadins and glutenin), which is responsible for gelatinization of flour and is considered to be one of the qualities of baked products as it influences elasticity, chewiness etc. These characteristics of baked products are mainly expressed by the rheological and pasting properties of the flour (Adeyemi and Ogazi, 1985; Belton and Taylor, 2002). Therefore, the aim of this research was to assess the rheological and pasting properties of composite flours prepared from grains of amaranthus, sorghum and finger millet, and the nutritional quality and sensory acceptability of biscuits developed thereafter.

Materials and methods

Raw material

Amaranthus grain (Amaranthus caudatus) samples were purchased directly from a local market in Konso, Ethiopia. Finger millet (Whitey/Necho variety) and sorghum (Melkam variety) samples were provided by Adet Agricultural Research Center and Melkassa Agricultural Research Centers of Ethiopia, respectively. The collected samples were transported to the laboratory in surface sterilized polythene bags. As described in Figure 1, the grains were sorted, cleaned and washed to remove immature seeds, sand and soil and sun dried for 24 hours. Wheat flour was collected from KOJI Food Processing PLC., Addis Ababa, Ethiopia and used as a control.

All grains were made into flour by dry milling process using a laboratory mill 120, version 2.2; model MF 3170, Hagersten, Sweden with a mesh size of 0.5 mm (Fig. 1). The prepared flours were separately stored in a polyethylene bags at 20 °C until further analysis. The composite flours were prepared by mixing amaranth flour with finger millet and sorghum flours at different level of ration. D-Optimal mixture ratio design was used to determine the optimum mixture formulation and a 10-run constrained D-optimal mixture experiment was generated using Design-Expert®, version 6.0.8, based on the lower and upper limits provided. For three components, the range of constrains was provided based on different literatures (Abdelghafoor et al., 2011; Schoenlechner et al., 2006; Vijayakumar and Mohankumar, 2009). Constrained region in the simplex coordinate system was defined by the limits of 50 ≤ X₁ ≤ 100, 0 ≤ X₂ ≤ 50, 0 ≤ X₃ ≤ 20,. X₁ = Amaranths, X₂ = sorghum and X₃ = finger millet flour. A wheat flour was used as a control, i.e. 100% wheat flour (w/w on flour basis) with total runs in this experiment were 11 runs (Table 1).

Biscuit preparation process

Biscuits were produced from the prepared composite flours using the standard AACC Method No.10.52 (AACC, 2000) and the baking process was as described by Karki et al. (2016). The dough was prepared in a laboratory manual dough mixer. Ingredients used for the preparation of biscuit samples, like margarine, sugar, sodium bicarbonate, salt and ammonium bicarbonate, were purchased from the local market in Addis Ababa, Ethiopia and prepared prior to the baking process. The recipe for the formulation of gluten-free biscuits was presented in Table 2.
### Table 1. D-optimal result for composite flour formulation

| Run | Code | Component 1 A: Amaranth % | Component 2 B: Sorghum % | Component 3 C: Finger millet % |
|-----|------|---------------------------|--------------------------|-------------------------------|
| 1   | C-01 | 100.00                    | 0.00                     | 0.00                          |
| 2   | C-02 | 50.00                     | 50.00                    | 0.00                          |
| 3   | C-03 | 80.00                     | 10.00                    | 10.00                         |
| 4   | C-04 | 50.00                     | 30.00                    | 20.00                         |
| 5   | C-05 | 60.00                     | 35.00                    | 20.00                         |
| 6   | C-06 | 65.00                     | 15.00                    | 20.00                         |
| 7   | C-07 | 80.00                     | 0.00                     | 20.00                         |
| 8   | C-08 | 75.00                     | 25.00                    | 0.00                          |
| 9   | C-09 | 50.00                     | 40.00                    | 10.00                         |
| 10  | C-10 | 90.00                     | 0.00                     | 10.00                         |

### Table 2. Recipe for preparation of biscuit samples

| №  | Ingredients                  | Amount (g) |
|----|------------------------------|------------|
| 1  | Total flour                  | 200        |
| 2  | Grinded sugar                | 75         |
| 3  | Baking Soda/ Sodium bicarbonate | 5      |
| 4  | Ammonium bicarbonate         | 3          |
| 5  | Table salt                   | 3          |
| 6  | Margarine/Shortening         | 100        |
| 7  | Water                        | 75mL       |

As shown in Fig. 2, all ingredients except flour and sodium bicarbonate were added with continuous mixing during the preparation of dough from the composite flours and mixed more for about 10 min. The mixing process continued till the mixture turned to a homogenous creamy desired form. Then, the prepared composite flour and sodium bicarbonate were added to the dough and mixed continuously to form the final dough. Doughs were placed on a plate and a manual shaping machine was used to cut the dough to form desired shapes and sizes. The shaped dough pieces were baked in baking oven at about 210 °C for 15 min and then allowed to cool, packed in Ziploc bags and stored prior to analysis.

**Chemical analysis**

**Determination of pasting and rheological properties of composite flours**

Pasting property of composite flours was evaluated with Rapid Visco-Analyzer (RVA-4500) Perten instruments Pty. Ltd., Macquarie Park NSW,2012, Australia, according to method 76-21 of AACC (2000). Viscosity profile indices were recorded and obtained from a Thermocline for Windows (TCW) Version 3 software, provided with the RVA as described by Amoo et al. (2014) and Bourekoua et al. (2016).

The effect of different flour levels on dough rheology was determined according to Brabender ICC BIPEA 300 by using the Brabender® Farinograph®-E, model 810130 USB/230V/50-60Hz, Duisburg, Germany and results obtained as graphic output (farinograms) from a computer software provided with the Brabender Farinograph.

**Determination of functional properties of composite flours**

Water absorption capacity (WAC) of the samples was determined by using the method of Sulieman et al. (2019). The same procedure was repeated for oil absorption (Adebowale et al., 2005). WAC and OAC were expressed as the weight of sediment/initial weight of flour sample (g/g). The method of Awolu et al. (2015) was used to determine water solubility index of the flours. The swelling index (SI) was determined...
by using the method of Ezeocha and Okafor (2016) and expressed as the ratio of the final over the initial volume (mL/mL). The bulk density (BD) measurement was determined by measuring the material volume, which was compacted in a cylinder of 25 mL and the results were calculated as g/mL. The gluten content was determined according to the method of ICC (2000), standard No. 137/1, using perten gluten index®, version 1.0 E.N, Hagersten, Sweden, 2012.

**Determination of proximate composition of composite flour blends and biscuit**

The proximate composition of the flours and prepared biscuit samples were determined using the standard methods of AOAC (2000). The samples were analyzed for moisture, ash, crude fiber, crude protein, crude fat, and carbohydrates using the procedure described by AOAC (2000) method 925.09, 923.03, 962.09, 979.09 and 4.5.01, respectively. Determination of carbohydrate was carried out using estimation by difference. The heating value for the three groups of nutrients, which provide the body energy, was estimated in kJ by multiplying the percentage of crude protein, crude fat and carbohydrates by the energy values for gross nutrients conversion factors.

**Determination of mineral composition of composite flour blends and biscuit**

The analyses for essential minerals were carried out by using atomic absorption spectrophotometric method. A sample of digest was used to determine some elements (calcium (Ca), iron (Fe) and Zinc (Zn)) on the atomic absorption spectrophotometer and phosphorus (P) on flame photometry. The digestion of the sample and minerals were quantified according to AOAC (2000). The digestion of the sample was analyzed by a panel of twenty trained panelists randomly selected from Addis Ababa Science and Technology University. The panelists were from both sexes, and from different ages. They were requested to taste each sample separately without comparing it with another sample. Sensory evaluation was performed 24 hours after baking, using a 9-hedonic scale of points, where 1 corresponds to the statements “I dislike it extremely” and 9 corresponds to “I like it extremely.” The samples were evaluated for desirability for appearance, colour, taste, crispness, flavour, texture, and overall acceptability of the baked samples. Coded product

samples was measured as average value of four individual biscuits with the help of an electronic analytical balance (PASS, FA-2004, Germany) of 0.01 g sensitivity.

The spread factor was determined by calculating the thickness and the diameter of the prepared samples according to AOAC (2000) method 10-50D. Spread ratio was calculated by dividing the average value of diameter by average value of thickness of biscuits (Sulieman et al., 2019).

**Determination of colour dimension of biscuit samples**

Color measurements, L* (lightness), a* (redness-greenness) and b* (yellowish-bluish), of the biscuit samples were carried out using a colour measuring instrument spectrophotometer (Model CM-600d, Konica Minolta, INC, Japan, 2012). The instrument was initially standardized (L*=90.29, a*=1.37, b*=0.06) using a white reference standard (white duplicating paper sheet, 80 g/m²).

**Determination of texture profile of biscuit samples**

The texture profile of baked biscuit samples was determined using a texture analyzer (TA1 Series texture Analysis Machine (TA1SH-203V, AMETEK® Test and Calibration Instruments, LLOYD Materials Testing, 2016, England) according to AOAC (2000). Biscuit hardness was measured by means of a cutting-shear test using a stainless steel probe, which runs perpendicular to the major dimension of the sample, placed on a slot surface (4 mm wide), at a constant head speed of 2 mm/s. The maximum force (N) required to shear the sample was taken as a measure of hardness. The distance at the maximum force was also recorded. All measurements were carried out in triplicate.

**Sensory evaluation of biscuit samples**

The evaluation and testing preferences of the baked biscuit samples were analyzed by a panel of twenty (20) semi-trained panelists randomly selected from Addis Ababa Science and Technology University. The panelists were from both sexes, and from different ages. They were requested to taste each sample separately without comparing it with another sample. Sensory evaluation was performed 24 hours after baking, using a 9-hedonic scale of points, where 1 corresponds to the statements “I dislike it extremely” and 9 corresponds to “I like it extremely.” The samples were evaluated for desirability for appearance, colour, taste, crispness, flavour, texture, and overall acceptability of the baked samples. Coded product
samples were arranged in a random order on white plates and served to the panelists. The panelists were given a 20 min orientation about the procedure of sensory evaluation. Potable water was provided to rinse the mouth between evaluations and covered cups were also provided if panelists did not wish to swallow the samples.

Experimental design and statistical analysis

The analyses were designed to use replication techniques for each treatment and determined by triplicate. Each treatment was repeated a number of times (three) to obtain a valid and more reliable estimate. The composite flours were formulated based on a constrained mixture D-optimal design using Design-Expert®, version 6.0.8 (Stat-Ease, Inc. 2021 East Hennepin Ave., Suite 480 Minneapolis, USA, 2002). The statistical analysis, means and standard deviation (SD) were calculated using SPSS statistical software. One way Analysis of Variance (ANOVA) was used for data analysis with a significance (p<0.05) difference for comparison of means.

Results and discussion

Pasting properties of a composite flours

Viscosity profile or pasting properties of the composite flour sample indices are presented in Table 3. There were no significant (p>0.05) differences in pasting temperatures between various treatments of composite flours and the control wheat flour, but in general, the pasting temperature in composite flours was lower than that of the control (100% wheat flour), which shows that the gluten in wheat flour held more water, so that some of the water is not available for starch, which resulted in the reduction of gelatinization. The reduced gelatinization temperature indicates the better availability of starch to amylolysis enzymes during baking process, which is desirable in baked products like bread, but not that significant for biscuits (Dautant et al., 2007).

The results of the pasting characteristics indicated that the higher level of finger millet flour increased the peak viscosity (PV), break down viscosity (BDV), and setback ratio (SBR) of composite flours. This is due to the reduced presence and interaction of components like fat and protein from finger millet starch that increase the viscosity (Dautant et al., 2007). There was a change in the pasting profile of the composite flours compared with its 100% flour. It was found that the PV decreased as finger millet flour decreased, but the ratio of sorghum flour and amaranth flour only had a little effect on peak viscosity of composite flours and there was a significant (p<0.05) difference among the composite flours. According to Morris et al. (1997), the differences in the starch and protein composition of composite flours could affect pasting viscosity and properties.

The lower BDV was found in composite flours, as compared with the control wheat flour with the lowest (874cP) and the highest (2157cP) BDV exhibited for C-01 and 100% SF flour, respectively, showing a significant (p<0.05) difference among the composite flour blends. The decrease in BDV were shown as the amount of Amaranthus flour increased in the composite flour, which can be related with the protein damage in amaranthus flour in the involvement of heat.

Table 3. Pasting properties (Rapid visco-analyser parameters) of composite flour blends

| Samples       | PV (cP) | TV (cP) | BDV (cP) | FV (cP) | SBR  | PT (min) | P<temp. (°C) |
|---------------|---------|---------|----------|---------|------|----------|--------------|
| 100% SF*      | 3040    | 1962    | 1078     | 7184    | 5222 | 5.33     | 75.98        |
| 100% FMF      | 3939    | 1782    | 2157     | 4468    | 2686 | 5.60     | 76.42        |
| 100% WF       | 2648    | 1253    | 1395     | 3626    | 2373 | 5.40     | 78.56        |
| C-01          | 1967    | 1093    | 874      | 1639    | 546  | 5.49     | 76.20        |
| C-02          | 2199    | 1224    | 975      | 2344    | 1120 | 4.67     | 79.20        |
| C-03          | 2249    | 1146    | 1103     | 1885    | 739  | 4.33     | 76.75        |
| C-04          | 2305    | 1094    | 1211     | 2329    | 1235 | 5.01     | 78.80        |
| C-05          | 2265    | 1121    | 1053     | 2174    | 962  | 4.60     | 78.30        |
| C-06          | 2398    | 1067    | 1331     | 2022    | 955  | 4.47     | 76.75        |
| C-07          | 2432    | 1116    | 1316     | 1941    | 825  | 4.33     | 75.90        |
| C-08          | 2090    | 1129    | 961      | 1946    | 817  | 4.47     | 78.30        |
| C-09          | 2391    | 1177    | 1214     | 2422    | 1245 | 4.96     | 77.45        |
| C-10          | 2107    | 1091    | 1016     | 1718    | 627  | 5.04     | 76.65        |

*p100%SF: 100% Sorghum Flour, 100%FMF: 100% Finger Millet Flour, 100%WF: 100% Wheat Flour, samples coded with C-01 up to C-10 are composite flours obtained from D-optimal result for composite flour formulation and preparation of biscuit samples accordingly as presented in table 1; PV = Peak Viscosity, BDV = Breakdown Viscosity, TV = Trough Viscosity, SBR = setback ratio, FV = Final Viscosity, PT = Peak Time and P<temp.= Pasting temperature.
Generally, the decrease in BDV and FV values shown as the amount of amaranth flour increased, which indicates the ability of the flour to form a viscous paste or gel after cooking and cooling as well as the resistance of the paste to shear stress during stirring (Lee et al., 2012). Composite flours showed significantly lower setback ratio than that of wheat flour, except for 100% SF, which obtained the highest (5222). The blending gave the flours a longer paste peak times, and hence the starch granules swelled gradually and had better resistance to mechanical damage.

### Rheological properties of composite dough blends

The results obtained from farinograph characteristics for dough made from a composite flours are presented in Table 4. Doughs consistence for composite flours (303-786 FU) showed a significant (p<0.05) difference and it decreased comparing to the 100% flours, but it was close (±100 FU) to the desired consistence, mostly 500 FU for wheat, which exhibited 482 FU. The decrease in consistence of the flours may be due to the availability of bound water that occurs as a result of the absence of gluten proteins in the flours and the action of enzymes (protease and α-amylase) on the dough components (Vizitiu et al., 2012).

| Sample Codes | C (FU) | WA (%) | DDT (min) | S (min) | DS (FU) | DS (FU), ICC | FQN |
|--------------|--------|--------|-----------|---------|---------|-------------|-----|
| 100% SF      | 119    | 50.5   | 1.0       | 0.8     | 71      | 42          | 17  |
| 100% FMF     | 327    | 55.7   | 2.5       | 1.8     | 68      | 174         | 25  |
| 100% WF      | 482    | 55.6   | 2.3       | 0.9     | 88      | 109         | 27  |
| C-01         | 946    | 67.2   | 1.2       | 0.2     | 389     | 33          | 13  |
| C-02         | 612    | 58.8   | 1.8       | 1.7     | 183     | 192         | 20  |
| C-03         | 674    | 60.4   | 2.2       | 1.3     | 155     | 177         | 22  |
| C-04         | 303    | 55.1   | 1.9       | 1.3     | 177     | 187         | 20  |
| C-05         | 381    | 57     | 1.5       | 1.2     | 153     | 151         | 16  |
| C-06         | 579    | 62     | 3.4       | 2.1     | 181     | 188         | 26  |
| C-07         | 617    | 62.8   | 2.2       | 0.6     | 266     | 277         | 22  |
| C-08         | 786    | 67.2   | 2.5       | 0.6     | 324     | 306         | 27  |
| C-09         | 491    | 59.8   | 2.4       | 0.9     | 200     | 193         | 23  |
| C-10         | 952    | 71.3   | 1.7       | 1.4     | 379     | 383         | 21  |

100%SF: 100% Sorghum Flour, 100%FMF: 100% Finger Millet Flour, 100%WF: 100% Wheat Flour and samples coded with C-01 up to C-10 are composite flours obtained from D-optimal result for composite flour formulation and preparation of biscuit samples accordingly as presented in table 1. C = Consistency, WA = Water Absorption, DDT = Development Time, S = Dough Stability, DS = Degree of Softening, FQN = Farinographic Quality Number.

Table 4. Rheological property (Farinographic characteristic) of composite flour blends

While 100% SF flour absorbed the lowest amount of water (50.5%). Dough development time (DDT) reflects the time between the first addition of water and the time when the dough seems to have optimum elastic and viscous properties for the retention of gas (Vizitiu et al., 2012). In this case, sorghum flour exhibited the minimum (1.0 min) time and sample C-06 had the maximum (3.4 min). Compositing the flours had shown a significant (p<0.05) difference and an increase in DDT which has a positive effect on doughs quality. Doughs stability for the composite flours was ranged between the lowest (0.2 min) for raw amaranth flour and the highest (1.8 min) for 100% finger millet flour. Finger millet flour showed the better stability for mixing which resulted in an increase of stability for the composite flours containing a higher amount of it (Miralbes, 2004). Minimum stability was obtained for the most of the composite flours that differ significantly from the control wheat flour. But there was an improvement in dough stability as the amount of finger millet flour in the composite flours increased, which is similar with the findings of Vijayakumar and Mohankumar (2009).

Degree of softening (DS) parameter had ranged between 33 and 383 FU for raw amaranth flour and sample C-10, respectively. The values for DS showed a significant (p<0.05) difference among the composite flour blends. Raw amaranth flour and sample C-08 exhibited the lowest (13) and the highest (27) FQN, respectively, resulting in a significant (p<0.05) difference among the composite flour blends. The study showed that amaranth flour is a weak flour and not able to stay long without breaking, while sorghum and finger millet flour had a better quality in terms of FQN.
The functional property evaluations of the composite flours were presented in Table 5. There was a significant (p<0.05) difference among them with a range of 0.57-0.87 g/mL, 1.78-2.68 g/g, 0.98-1.78 g/g, 3.60-5.75 mL/mL, 4.52 up to 8.03 g/g and 0.02-0.29 g/g for bulk density (BD), water absorption capacity (WAC), oil absorption capacity (OAC), swelling index (SI), swelling power (g/g) and water solubility index (WSI), respectively.

The BD ranged between 0.57 and 0.87 g/mL and the control wheat flour exhibited the lowest value along with some of the composite flours with C-01 having the highest BD value. There was no significant (p>0.05) difference among the composite flour blends and the higher BD of the composite flours demonstrated grater compactness and possible mixed effect caused by the interaction of the molecules of the composite flours. The higher BD observed for C-01 (0.87 g/mL) implies that a solid, thick and compact packaging material may be required for this product as bulk density can influence the selection of packaging materials which relates to the sample particle size (Adeleke and Odedeji, 2010).

The WAC varied between 1.78 and 2.68 g water/g flour. The control wheat flour (100% WF) had the lowest (1.78 g water/g flour) and sample C-05 had the higher (2.68 g/g) WAC than the rest of the composite flour blends showing no significant (p<0.05) difference. The variations of the composite flours in particle size distribution may have influenced the WAC for the composite flours. According to Abu et al. (2006) the physical entrapment of oil within the flour starch structures significantly influences the oil absorption in flours starch as it is not able to possess nonpolar sites as compared to those flour components found in proteins. The composite flour had better with sample C-08 exhibited the lowest (0.98 g oil/g flour) and C-07 the highest (1.78 g oil/g flour). According to Taiwo et al. (2017), the effect of OAC can be seen at the storage ability of a flour sample which is very important to take into consideration when developing a new food product as it can have an influence on the shelf life stability of the products. Thus, the biscuit samples prepared from the composite flours could have a relatively lower shelf life as compared to the control.

There were significant (p<0.05) differences in SP among the composite flours and the control wheat flour. The swelling power of composite flour blends ranged from 4.52 up to 8.03 g/g. C-01 had the highest SP, while C-02 had the lowest value. The increased amount of amaranthus flour had increased the swelling power in composite flours. As Carcea and Acquistucci (1997) indicated, the water absorption of the starch granules in the flour could be influenced by SP/SI capacity of the flours. The wet gluten content (WGC) determination resulted nil for 100% grain flours and composite flour blends, while the control exhibited (31.48%) and this result is comparably the same with the result of Thorat and Ramachandran (2016). This proves that the grains used in this study are gluten free.

### Functional properties of composite flours

| Samples                  | Parameters          | Parameters          | Parameters          | BD (g/mL) | WAC (g/g) | OAC (g/g) | SI (mL/mL) | SP (g/g) | WSI (g/g) | WGC (%) |
|--------------------------|---------------------|---------------------|---------------------|-----------|-----------|-----------|------------|----------|-----------|---------|
| 100% SF                  |                      |                      |                      | 0.61 ±0.8 | 2.27 ±0.8 | 1.40 ±0.2 | 5.63 ±0.1 | 5.89 ±0.8 | 0.06 ±0.7 | Nil      |
| 100% FMF                 |                      |                      |                      | 0.59 ±0.6 | 2.32 ±0.2 | 1.32 ±0.2 | 5.75 ±0.4 | 4.77 ±0.5 | 0.20 ±0.7 | Nil      |
| 100% WF                  |                      |                      |                      | 0.57 ±0.9 | 1.78 ±0.4 | 1.09 ±0.2 | 4.75 ±0.6 | 7.05 ±0.6 | 0.14 ±0.2 | 31.5 ±0.14 |
| C-01                     |                      |                      |                      | 0.87 ±0.7 | 2.38 ±0.2 | 1.39 ±0.2 | 4.40 ±0.6 | 8.03 ±0.5 | 0.18 ±0.8 | Nil      |
| C-02                     |                      |                      |                      | 0.57 ±0.9 | 2.32 ±0.2 | 1.21 ±0.2 | 5.59 ±0.1 | 4.51 ±0.6 | 0.23 ±0.1 | -        |
| C-03                     |                      |                      |                      | 0.58 ±0.7 | 2.33 ±0.9 | 1.28 ±0.2 | 4.80 ±0.7 | 6.48 ±0.4 | 0.18 ±0.6 | -        |
| C-04                     |                      |                      |                      | 0.58 ±0.8 | 2.45 ±0.7 | 1.31 ±0.2 | 4.27 ±0.2 | 4.56 ±0.7 | 0.20 ±0.8 | -        |
| C-05                     |                      |                      |                      | 0.57 ±0.2 | 2.68 ±0.4 | 1.21 ±0.2 | 3.92 ±0.4 | 5.72 ±0.9 | 0.22 ±0.2 | -        |
| C-06                     |                      |                      |                      | 0.57 ±0.5 | 2.47 ±0.3 | 1.30 ±0.2 | 3.60 ±0.3 | 5.27 ±0.7 | 0.23 ±0.1 | -        |
| C-07                     |                      |                      |                      | 0.57 ±0.1 | 2.56 ±0.2 | 1.78 ±0.2 | 3.96 ±0.4 | 7.37 ±0.6 | 0.17 ±0.3 | -        |
| C-08                     |                      |                      |                      | 0.57 ±0.1 | 2.48 ±0.7 | 0.98 ±0.2 | 3.79 ±0.6 | 6.44 ±0.9 | 0.29 ±0.9 | -        |
| C-09                     |                      |                      |                      | 0.64 ±0.6 | 2.45 ±0.9 | 1.32 ±0.2 | 4.08 ±0.5 | 4.72 ±0.9 | 0.17 ±0.5 | -        |
| C-10                     |                      |                      |                      | 0.58 ±0.9 | 2.48 ±0.1 | 1.02 ±0.2 | 3.91 ±0.4 | 5.39 ±0.3 | 0.11 ±0.3 | -        |

*100% SF: 100% Sorghum Flour, 100% FMF: 100% Finger Millet Flour, 100% WF: 100% Wheat Flour. Samples coded with C-01 up to C-10: are composite flours obtained from D-optimal result for composite flour formulation and preparation of biscuit samples accordingly as presented in table 1. All data are means of three replicates ± SD. Means with the same superscripts in a column do not differ significantly (p < 0.05) among the composite flours.

### Proximate and mineral composition of composite flour blends and biscuit samples

#### Proximate composition

As Table 6 shows, the proximate composition of biscuit samples produced from the composite flours varied significantly (p<0.05) with a range of 2.22-10.43%, 6.65-10.85%, 1.89-3.4%, 28.62-37.75%, 1.40-1.73% and 46.90-57.23% for moisture, protein, crude fibre, crude...
fat, ash and carbohydrate, respectively. There was no significant (p<0.05) difference in the moisture content of the prepared biscuit samples. The moisture content of the biscuit samples were significantly lower comparing to the required moisture content for such products (<10%), which can result in a better shelf life and reduced effect on the quality attributes of the product. The protein content varies significantly (p<0.05) among the biscuit samples with sample C-01 having the highest (13.75%), while the control sample had the lowest (7.01%). All the formulated biscuit samples had higher protein content than the control, which is close and conformed to the minimum FAO/WHO recommended value of 10%. The protein content of the samples had shown an increase as the proportional amount of amaranth (18.90%) and sorghum (11.73%) flour increased, which is comparably the same with the result of Belton and Taylor (2002) and Sousa et al. (2014). The fiber contents of the biscuit samples were significantly (p<0.05) different, but the values were well within the recommended range (5 g/100 g) of FAO/WHO. The carbohydrate content of biscuit samples increased with the addition of finger millet flour. This may be due to higher carbohydrate content in finger millet than in amaranthus and sorghum flour, which conforms with the results of Sousa et al. (2014) and Suma et al. (2014).

Mineral analysis

Ready to eat foods, like biscuits, have a potential to fulfill the recommended dietary allowance (RDA) (600-1200 mg/100g) for minerals with a significantly lower consumption comparing to other kind of foods. This is found to be the most important for those who suffer from malnutrition and mineral deficiency. Most of biscuit samples prepared from the composite flour blends had significantly (p<0.05) higher iron content than the control (16.88 mg/100 g). The iron content ranged between 14.21 to 23.21 mg/100 g for the prepared biscuit samples as presented in Table 7. However, there was a significant (p<0.05) difference in the zinc content of biscuit samples and it ranged from 2.44 to 3.60 mg/100 g, where sample C-08 obtained the highest value. Phosphorus resulted in a significant (p<0.05) difference between the composite and control wheat flour. It ranged from 252.76 to 277.39 mg/100 g for biscuit samples prepared from the composite flours and the increased amount of finger millet in the composite flours resulted better in phosphorous content. Biscuit samples prepared from the composite flour had a significant (p<0.05) difference as compared to the control in terms of calcium content. Sample C-03 exhibited the highest 27.54 mg/100 g and the sample C-09 (15.65 g/100 g) had the lowest mineral value for calcium. The results showed that biscuit samples prepared from composite flours have shown better results in terms of mineral content and conform with the findings of Belton and Taylor (2002).

Table 6. Proximate analysis of raw flour blends and baked biscuit samples (dry basis)

| Sample          | Chemical Composition |
|-----------------|----------------------|
|                 | Moisture Content (%) | Crude Protein (%) | Crude Fiber (%) | Crude Fat (%) | Ash (%) | CHO (%) | Energy Value (Kcal/100gm) |
| 100%AP          | 9.38 ± 0.21          | 18.90 ± 0.02      | 2.22 ± 0.03     | 6.87 ± 0.15   | 1.66 ± 0.04 | 60.97 ± 0.92 | 381.87 ± 0.48 |
| 100%SF          | 9.58 ± 0.75          | 11.73 ± 0.04      | 2.48 ± 0.1      | 3.00 ± 0.31   | 1.64 ± 0.12 | 71.57 ± 1.03 | 360.20 ± 0.97 |
| 100%FMF         | 10.01 ± 0.25         | 8.23 ± 0.01       | 2.23 ± 0.02     | 2.37 ± 0.03   | 1.72 ± 0.01 | 75.44 ± 0.67 | 354.25 ± 1.04 |
| 100%WF          | 10.43 ± 0.31         | 10.75 ± 0.01      | 1.80 ± 0.02     | 3.54 ± 0.21   | 0.62 ± 0.02 | 72.86 ± 0.59 | 366.30 ± 1.25 |
| C-00            | 2.79 ± 0.13c         | 7.01 ± 0.16c      | 1.31 ± 0.15c    | 31.50 ± 0.30d | 1.77 ± 0.02 | 55.62 ± 0.95 | 534.02 ± 0.87 |
| C-01            | 2.60 ± 0.14          | 13.75 ± 0.12c     | 1.91 ± 0.21c    | 28.75 ± 0.45c | 1.59 ± 0.10c | 51.40 ± 1.32d | 519.35 ± 0.56d |
| C-02            | 3.41 ± 0.14d         | 10.83 ± 0.03c     | 2.18 ± 0.04b    | 28.62 ± 0.35d | 1.63 ± 0.06c | 53.33 ± 0.47cd | 514.22 ± 0.99d |
| C-03            | 3.21 ± 0.15c         | 11.05 ± 0.14c     | 1.69 ± 0.08cd   | 31.75 ± 0.41c | 1.40 ± 0.01d | 50.90 ± 0.86d | 533.55 ± 0.93c |
| C-04            | 2.42 ± 0.05c         | 9.65 ± 0.03f      | 1.57 ± 0.12cd   | 31.25 ± 0.10le | 1.73 ± 0.11ab | 53.38 ± 1.09cd | 533.37 ± 0.05f |
| C-05            | 2.22 ± 0.03c         | 10.05 ± 0.02d     | 1.89 ± 0.70d    | 30.75 ± 0.10le | 1.69 ± 0.02a | 53.40 ± 1.23cd | 530.55 ± 1.05c |
| C-06            | 2.81 ± 0.01c         | 10.77 ± 0.01bc    | 1.78 ± 0.15cd   | 29.62 ± 0.23de | 1.57 ± 0.08c | 53.45 ± 0.68d | 523.46 ± 0.08c |
| C-07            | 3.22 ± 0.01d         | 9.80 ± 0.12b      | 2.04 ± 0.01c    | 30.75 ± 0.08de | 1.73 ± 0.04ab | 52.46 ± 0.87cd | 525.79 ± 0.97c |
| C-08            | 2.81 ± 0.04c         | 9.40 ± 0.16c      | 1.38 ± 0.07de   | 29.75 ± 0.25de | 1.63 ± 0.07ab | 55.03 ± 0.12cd | 525.47 ± 0.67c |
| C-09            | 2.62 ± 0.12c         | 10.85 ± 0.04bc    | 1.46 ± 0.04cd   | 30.25 ± 0.17de | 1.71 ± 0.1ab  | 53.11 ± 1.04cd | 528.09 ± 0.85c |
| C-10            | 3.21 ± 0.01d         | 9.81 ± 0.06bc     | 1.95 ± 0.13de   | 30.75 ± 0.03de | 1.72 ± 0.01ab | 52.56 ± 0.85cd | 526.23 ± 0.49c |

*100%AF: 100% Amaranth Flour, 100% SF: 100% Sorghum Flour, 100% FMF: 100% Finger Millet Flour, 100% WF: 100% Wheat Flour and C-00: biscuit prepared from 100% wheat flour as a control. Samples coded with C-01 up to C-10. Represents the biscuit samples prepared from composite flour blends which were developed by using D-optimal Design as presented in Table 1. a-c All data are means of three replicates ± SD. Means with the same superscripts in a column do not differ significantly (p<0.05).
The physical characteristics of biscuit samples prepared from composite flour, as well as a control (100% wheat flour), are presented in Table 8. The diameter (D), thickness (T) and weight (W) of biscuit samples were ranged from 51.48 to 62.00 mm, 8.43 to 11.95 mm and 11.12 to 11.87 g, respectively. In terms of D, there was a significant (p<0.05) difference among the biscuit samples, while there were no significant (p≥0.05) differences in biscuit weight.

The result showed that, as the level of sorghum flour increases, the decrease in biscuit T was more remarkable and the increase in finger millet reduced the W and T of biscuit samples. According to Ragaee and Abdel-Aal (2006), T is affected by the quantity and quality of protein in the flour, whereas weight is basically determined by the quantity of dough baked and the amount of moisture and carbon dioxide diffused out of the biscuit during baking. It was observed that the biscuit samples prepared from the composite flour had relatively higher weight, which may be due to low retention of carbon dioxide gas in the blended dough, hence providing dense biscuit texture (Haridas and Malini, 1991).

The spread factor (SF), which is the ratio of D and T, has been generally adopted as a more reliable measure of biscuit size (Shittu et al., 2007) and it ranged from 5.01 to 6.28. Comparing to the control sample, the most of the biscuit samples formulated from the composite flour exhibited a lower water activity (aw) (Table 8). It could be associated with the higher WAC of wheat flours (Table 5). According to Labuza et al. (1972), reducing aw below 0.7 prevents microbial spoilage and to successfully preserve a food product, water activity would have to be lowered to a range where the rate of deteriorative reactions is minimized. The maximum force (hardness) required to break the biscuit sample was recorded along with the thickness, where this maximum force applied is presented in Table 8. The texture analysis showed a higher firmness as it was required a relatively higher force in biscuit made from composite flours when compared with biscuit made from a control with a confidence level (p<0.05).

The colour of the biscuit samples was related to the colour of the corresponding grain materials composited to prepare the samples. Sample C-08 had higher b* due to the colour derived from the amaranth flour and no differences were observed in lightness (L*). Thus, sample C-05 had the lowest lightness (L=45.51 ± 0.12), which could be due to the increased amount of sorghum flour and decreased value of finger millet flour proportions. The hue green (a*) varied from 10.07 for C-01 to 13.55 for C-00. Lightness of ingredients plays an important role in bakery products due to consumer preferences.

Sensory qualities attributes of baked biscuit samples

The mean sensory scores of biscuit samples prepared from a composite flour blends at different level of sorghum flour proportions. The hue green (a*) varied from 10.07 for C-01 to 13.55 for C-00. Lightness of ingredients plays an important role in bakery products due to consumer preferences.

### Table 7. Physical Properties of Biscuit Samples

| Samples | Diameter (D) | Thickness (T) | Weight (W) |
|---------|--------------|---------------|------------|
| 100%WF  | 260.55 ± 0.90 | 276.11 ± 0.92 | 260.84 ± 1.03 |
| 100%AF  | 277.39 ± 0.54 | 283.03 ± 1.04 | 277.63 ± 1.36 |
| 100%SF  | 276.11 ± 0.92 | 283.03 ± 1.04 | 277.63 ± 1.36 |

**Physical properties of biscuit samples**

The physical characteristics of biscuit samples prepared from composite flour, as well as a control (100% wheat flour), are presented in Table 8. The diameter (D), thickness (T) and weight (W) of biscuit samples were ranged from 51.48 to 62.00 mm, 8.43 to 11.95 mm and 11.12 to 11.87 g, respectively. In terms of D, there was a significant (p<0.05) difference among the biscuit samples, while there were no significant (p≥0.05) differences in biscuit weight.

The result showed that, as the level of sorghum flour increases, the decrease in biscuit T was more remarkable and the increase in finger millet reduced the W and T of biscuit samples. According to Ragaee and Abdel-Aal (2006), T is affected by the quantity and quality of protein in the flour, whereas weight is basically determined by the quantity of dough baked and the amount of moisture and carbon dioxide diffused out of the biscuit during baking. It was observed that the biscuit samples prepared from the composite flour had relatively higher weight, which may be due to low retention of carbon dioxide gas in the blended dough, hence providing dense biscuit texture (Haridas and Malini, 1991).

The spread factor (SF), which is the ratio of D and T, has been generally adopted as a more reliable measure of biscuit size (Shittu et al., 2007) and it ranged from 5.01 to 6.28. Comparing to the control sample, the most of the biscuit samples formulated from the composite flour exhibited a lower water activity (aw) (Table 8). It could be associated with the higher WAC of wheat flours (Table 5). According to Labuza et al. (1972), reducing aw below 0.7 prevents microbial spoilage and to successfully preserve a food product, water activity would have to be lowered to a range where the rate of deteriorative reactions is minimized. The maximum force (hardness) required to break the biscuit sample was recorded along with the thickness, where this maximum force applied is presented in Table 8. The texture analysis showed a higher firmness as it was required a relatively higher force in biscuit made from composite flours when compared with biscuit made from a control with a confidence level (p<0.05).

The colour of the biscuit samples was related to the colour of the corresponding grain materials composited to prepare the samples. Sample C-08 had higher b* due to the colour derived from the amaranth flour and no differences were observed in lightness (L*). Thus, sample C-05 had the lowest lightness (L=45.51 ± 0.12), which could be due to the increased amount of sorghum flour and decreased value of finger millet flour proportions. The hue green (a*) varied from 10.07 for C-04 to 13.55 for C-01. Lightness of ingredients plays an important role in bakery products due to consumer preferences.

Sensory qualities attributes of baked biscuit samples

The mean sensory scores of biscuit samples prepared from a composite flour blends at different level of sorghum flour proportions. The hue green (a*) varied from 10.07 for C-01 to 13.55 for C-00. Lightness of ingredients plays an important role in bakery products due to consumer preferences.

### Table 7. Mineral analysis of raw flour blends and baked biscuit samples (dry basis)

| Samples | Mineral Composition (mg/100 g) |
|---------|------------------------------|
| Fe      | Zn                           | P                   | Ca                  |
| 100%AF  | 13.96 ± 0.98                 | 2.67 ± 0.23         | 273.80 ± 0.52       | 25.53 ± 0.74 |
| 100%SF  | 24.19 ± 0.42                 | 2.73 ± 0.28         | 303.03 ± 0.32       | 24.16 ± 1.04 |
| 100%FMF | 22.97 ± 0.38                 | 3.05 ± 0.85         | 281.01 ± 0.47       | 24.93 ± 1.25 |
| 100%WF  | 10.96 ± 0.15                 | 3.74 ± 1.02         | 34.56 ± 0.65        | 57.19 ± 0.63 |
| C-00    | 16.88 ± 1.04                 | 2.92 ± 1.09         | 26.87 ± 0.74        | 22.71 ± 0.54 |
| C-01    | 18.14 ± 2.14                 | 2.86 ± 0.94         | 252.76 ± 0.68       | 18.84 ± 0.41 |
| C-02    | 17.62 ± 0.90                 | 2.44 ± 1.21         | 269.77 ± 0.64       | 12.75 ± 0.30 |
| C-03    | 16.41 ± 1.05                 | 2.82 ± 1.41         | 255.65 ± 0.91       | 27.54 ± 1.25 |
| C-04    | 20.05 ± 0.68                 | 2.69 ± 0.56         | 261.70 ± 1.02       | 20.20 ± 1.42 |
| C-05    | 19.15 ± 0.26                 | 2.71 ± 0.32         | 277.39 ± 0.54       | 25.02 ± 0.57 |
| C-06    | 17.29 ± 0.87                 | 2.75 ± 0.47         | 276.63 ± 0.97       | 25.20 ± 1.36 |
| C-07    | 23.21 ± 1.42                 | 2.49 ± 0.36         | 260.84 ± 1.03       | 22.32 ± 0.74 |
| C-08    | 15.79 ± 1.03                 | 2.68 ± 0.85         | 276.11 ± 0.92       | 26.46 ± 0.95 |
| C-09    | 14.21 ± 0.45                 | 2.60 ± 0.96         | 260.55 ± 0.90       | 15.65 ± 1.45 |
| C-10    | 14.86 ± 0.91                 | 2.70 ± 1.03         | 274.52 ± 0.46       | 16.5 ± 0.85  |

*100%AF: 100% Amaranth Flour, 100%SF: 100% Sorghum Flour, 100%FMF: 100% Finger Millet Flour, 100%WF: 100% Wheat Flour and C-00: biscuit prepared from 100% wheat flour as a control. Samples coded with C-01 up to C-10. Represents the biscuit samples prepared from composite flour blends which were developed by using D-optimal Design as presented in Table 1.

**All data are means of three replicates ± SD. Means with the same superscripts in a column do not differ significantly (p<0.05).**
are presented in Table 9. The statistical analysis of the data showed that the biscuit samples prepared from the composite flour blends were significantly (p<0.05) different from the control with the exception of sample C-09 which had comparably good sensory score with the control in appearance, colour, crispness, texture and overall acceptability with a sensory score of 7.05, 6.95, 6.90, 6.90 and 6.65, respectively, and sample C-05 in terms of flavour with a sensory score of 6.20. However, there were no significant (p>0.05) differences with respect to biscuit texture, appearance and crispness among the composite biscuit samples. It is evident from the results that the control had the highest overall acceptability in sensory score followed by biscuit prepared from C-09 composite flour blends, while sample C-06 ranked the least in most of the sensory attributes, which is comparatively in agreement with the results of Karki et al. (2016). The low rating recorded may be due to the low level of sorghum and finger millet flour which resulted in poor colour and it might have affected the overall sensory attribute of the biscuit. This shows that using gluten free cereals alone to prepare biscuits will have very low acceptability as compared to wheat. The low sensory score for texture, flavour and acceptability for the composite flour blend biscuits may possibly be improved by addition of non-gluten proteins, such as egg and milk protein or soybean protein, or hydrocolloids and natural emulsifying agents that could mimic the viscoelastic properties of gluten (Alvarez-Jubete et al., 2010; Lazaridou and Biliaderis, 2009; Renzette et al., 2008).

Table 9. Sensory quality attributes evaluation of biscuit samples biscuit samples

| Sample | Appearance | Color | Crispness | Taste | Flavor | Texture | Overall Accept. |
|--------|------------|-------|-----------|-------|--------|---------|----------------|
| C-00   | 5.78 ± 1.45ab | 8.00 ± 1.60ab | 7.75 ± 1.11ab | 7.20 ± 2.04ab | 7.40 ± 1.50ab | 7.90 ± 1.48ab | 7.80 ± 1.67ab |
| C-01   | 6.90 ± 1.37ab | 6.80 ± 1.67ab | 6.70 ± 1.78ab | 6.40 ± 1.16ab | 5.60 ± 1.81ab | 5.95 ± 1.54ab | 6.45 ± 1.46ab |
| C-02   | 6.40 ± 1.71ab | 6.40 ± 1.50ab | 6.70 ± 1.41ab | 6.20 ± 1.64ab | 6.00 ± 1.58ab | 6.30 ± 1.80ab | 6.20 ± 1.31ab |
| C-03   | 5.80 ± 1.85ab | 5.30 ± 1.83ab | 5.60 ± 1.36ab | 5.85 ± 2.10ab | 5.20 ± 1.85ab | 6.10 ± 1.68ab | 5.85 ± 1.30ab |
| C-04   | 5.90 ± 1.71ab | 5.75 ± 1.65ab | 6.95 ± 1.31ab | 6.10 ± 1.37ab | 5.95 ± 1.35ab | 5.95 ± 1.50ab | 6.20 ± 1.28ab |
| C-05   | 6.50 ± 1.71ab | 6.15 ± 1.03ab | 6.85 ± 1.13ab | 6.65 ± 1.49ab | 6.20 ± 1.36ab | 6.35 ± 1.46ab | 6.30 ± 0.97ab |
| C-06   | 5.50 ± 1.14ab | 5.25 ± 1.48ab | 6.20 ± 1.60ab | 5.70 ± 1.89ab | 5.20 ± 1.54ab | 5.90 ± 0.96ab | 5.65 ± 1.53ab |
| C-07   | 5.80 ± 1.27ab | 5.70 ± 1.86ab | 6.60 ± 1.87ab | 5.35 ± 1.75ab | 5.10 ± 1.77ab | 5.90 ± 1.07ab | 5.41 ± 2.08ab |
| C-08   | 6.25 ± 1.74ab | 6.25 ± 1.71ab | 6.85 ± 1.26ab | 6.10 ± 1.41ab | 5.90 ± 1.58ab | 5.80 ± 1.57ab | 6.15 ± 1.26ab |
| C-09   | 7.05 ± 1.31ab | 6.95 ± 1.05ab | 6.90 ± 1.29ab | 6.50 ± 1.23ab | 6.15 ± 1.53ab | 6.90 ± 1.33ab | 6.65 ± 1.26ab |
| C-10   | 5.80 ± 1.73ab | 5.90 ± 1.33c | 6.60 ± 1.39c | 5.55 ± 1.23c | 5.55 ± 1.53c | 6.00 ± 1.52c | 5.70 ± 1.26c |

*All data are means of three replicates ± SD. Means with the same superscripts in a column do not differ significantly (p>0.05).
which can possibly be improved by using natural emulsifying and non-gluten proteins. The indicative optimal proportion of composite flours was amaranth flour 50%, sorghum 40%, and 10% finger millet flour. At this proportion the biscuits had a comparably better sensory quality attributes. Thus, these flours can be used in gluten-free biscuit formulations as replacement for wheat flour as they increase the nutritional value.

Funding: This research received no external funding.

Acknowledgments: Authors would like to acknowledge Melkasa and Adet agricultural research centres for providing sorghum and finger millet samples.

References

AACC (2000): Approved methods of the American Association of Cereal Chemist. American Association of cereal Chemists Press, 10th Edn.(St. Paul), MN.

Abdelghafor, R.F., Mustafa, A.I., Ibrahim, A.M.H., Krishnan, P.G. (2011): Quality of Bread from Composite Flour of Sorghum and Hard White Winter Wheat. Adv. J. Food Sci. Technol. 3 (1), 9-15.

Abu, J., Badifu, G., Akpapunan, M. (2006): Effect of crude palm-oil inclusion on some physico-chemical properties of gari, a fermented cassava food product. J. Food Sci. Technol. 24, 73-79.

Adebwayne, Y. A., Adeyemi, I. A., Oshodi, A. A. (2005): Functional and physicochemical properties of flours of six Mucuna species. Afr. J. Biotechnol. 4 (12), 1461-1468.

Adeleke, R.O., Odejede, J.O. (2010): Functional Properties of Wheat and Sweet Potato Flour Blends. Pak. J. Nutr. 9 (6), 535-538.

Adeyemi, S.A.O, Ogazi, P.O. (1985): The place of plantain in composite flour,Commerce industry. Lagos State, Nigeria. World Health Organization (WHO), Rep. Ser. 1973. No 522 Committee WHO Geneva.

Alvarez-Jubete, L., Auty, M., Arendt, E. K., Gallagher, E. (2010): Baking properties and microstructure of pseudocereal flours in gluten-free bread formulations. Eur. Food Res. Technol. 230, 435-445. http://dx.doi.org/10.1007/s00217-009-1184-z

Amoo, A.R.N., Dufie, W.F., Ibok, O. (2014): Physicochemical and pasting properties of starch extracted from four yam varieties. Food Sci. Nutr. 2 (6), 262-269. https://doi.org/10.11648/j.fjnts.20140206.14

Anonymous. (2016): Crop Variety Register. Addis Ababa, Ethiopia: Ministry of Agriculture and Natural Resources.

AOAC (2000): Official Methods of Food Analysis, Association of Official Analytical Chemists. Washington, DC, USA, 15th ed.

Awolu, O.O., Oluwaferanmi, P.M., Fafowora, O.I., Oseyemi, G.F. (2015): Optimization of the extrusion process for the production of ready-toeat snack from rice, cassava and kersting’s groundnut composite flours. LWT - Food Sci. Technol. 64, 18-24. http://dx.doi.org/10.1016/j.lwt.2015.05.025

Belton, P.S., Taylor, J.R.N. (2002): Pseudocereals and less Common Cereals; Grain Properties and Utilization Potential (Belton, P.S., Taylor, J.R.N. (eds.), New York, USA: Springer-Verlag Berlin Heidelberg, pp. 282.

Bourekoua, H., Benatallah, L., Zidoune, M.N., Rosell, C.M. (2016): Developing gluten free bakery improvers by hydrothermal treatment of rice and corn flours. LWT - Food Sci. Technol. 73, 342-350. http://dx.doi.org/10.1016/j.lwt.2016.06.032

Carcea, M., Acquistucci, R. (1997): Isolation and physicochemical characterization of fonio (Digitaria exilis Stapf) starch. Starch/Stärke 49, 131–135. http://dx.doi.org/10.1002/star.19970490403

Cornejo, F., Novillo, G., Villarecs, E., Rosell, C.M. (2019): Evaluation of the physicochemical and nutritional changes in two amaranth species (Amaranthus quitensis and Amaranthus caudatus) after germination. Food Res. 1 (22), 1-7. https://doi.org/10.1016/j.foodres.2019.01.022

Dautant, F.J., Simancas, K., Sandoval, A.J., Müller, A.J. (2007): Effect of temperature, moisture and lipid content on the rheological properties of rice flour. J. Food Eng. 78, 1159-1166. https://doi.org/10.1016/j.jfoodeng.2005.12.028

Desai, A.D., Kulkarni, S.S., Sahoo, A.K., Ranveer, R.C., Dandge, P.B. (2010): Effect of Supplementation of Malted Ragi Flour on the Nutritional and Sensorial Quality Characteristics of Cake. Adv. J. Food Sci. Technol. 2 (1), 67-71.

Ezeocha, C.V., Okafor, J.C. (2016): Evaluation of the Chemical, Functional and Pasting Properties of Starch from Trifoliate Yam (Dioscorea dumetorum) Landraces. Eur. J. Adv. Res. Biol. Life Sci. 4 (2), 53-63.

Gallagher, E. (2008): Formulation and nutritional aspects of gluten-free cereal products and infant foods. In: Gluten-Free Cereal Products and Beverages, Arendt, E.K., Bello, F.D. (eds.), Elsevier Inc., pp. 321-346.

Haridas, P.R., Malini, H.R. (1991): Effect of incorporating wheat bran on the rheological characteristics and bread making quality of flour. Int. Food Res. J. 28 (2), 92-97.

ICC (2000): Association of International Cereal Science and Technology, Vienna, Austria.

Kabuo, N.O., Alagbaoso, O.S., Omeire, G.C., Peter-Ikechukwu, A.I., Akajiaku, L.O., Obasi, A.C. (2018): Production and Evaluation of Biscuits from Cocoyam (Xanthosoma Sagittifolium Cv

67
Okoriko). Wheat Composite Flour. J. Food Nutr. Res. 2 (2), 53–61.
Karki, R., Mishra, A., Ojha, P., Subedi, U. (2016): Comparative Study on the Sensory Quality of Prepared Biscuit and Cake from Amaranthus and Sorghum. J. Food Sci. Technol. Nepal 9, 79–84.
Labuz, P., Jones, K.A., Sinsky, A.J., Gomez, R., Wilson, S., Miller, B. (1972): Effects of drying conditions on cell viability and functional properties of single cell protein. J. Food Sci. 37, 103–107. https://doi.org/10.1111/j.1365-2621.1972.tb03396.x
Lazaridou, A., Biliaderis, C.G. (2009): Gluten-Free Doughs: Rheological Properties, Testing Procedures, Methods and Potential Problems. In: Gluten-Free Food Science and Technology, Gallagher, E. (ed.), West Sussex, United Kingdom: Wiley-Blackwell Publishing Ltd., pp. 52–82.
Lee, Ju Hun, Cho, Ah-Ra, Hong, J.Y., Park, Dong-June, Lim, Seung-Taik. (2012): Physical properties of wheat flour composites dry-coated with microparticulated soybean hulls and rice flour and their use for low-fat doughnut preparation. J. Cereal Sci. 56, 636-643. http://dx.doi.org/10.1016/j.jcres.2012.08.011
Manley, D. (2000): Technology of Biscuits, Crackers and Cookies, Cambridge, England: CRC Press LLC, pp. 396-426.
Miralbes, C. (2004): Quality control in the milling industry using near infrared transmittance spectroscopy. Food Chem. 88, 621-628. http://dx.doi.org/10.1016/j.foodchem.2004.05.004
Morris, C. F., King, G. E., Rubenthaler, G. L. (1997): Contribution of Wheat Flour Fractions to Peak Hot Paste Viscosity. Cereal Chem. 74 (2), 147–153.
Muyonga, J.H., Nabakabya, D., Nakimumugwe, D.N., Masinde, D. (2008): Efforts to promote Amaranth production and consumption in Uganda to fight Malnutrition. In: Using Food Science and Technology to Improve Nutrition and Promote National Development, Robertson, G.L., Lupien, J. R. (eds.), International Union of Food Science & Technology, pp. 2-10.
Omobolanle, O., Oluwatoyin, A., Michael, I., Adefunke, B., Olamiji, A. (2017): Evaluation of Potentials of some selected seeds' flours as partial Substitute for Wheat in Cookies production. Intl. J. Sci. Eng. Res. 8 (3), 739–752.
Ragae, Sanaa, Abdel-Aal, El-Sayed M. (2006): Pasting properties of starch and protein in selected cereals and quality of their food products. Food Chem. 95, 9-18. http://dx.doi.org/10.1016/j.foodchem.2004.12.012
Renzetti, S., Belloa, F.Dal, Arendt, E.K. (2008): Microstructure, fundamental rheology and baking characteristics of batters and breads from different gluten-free flours treated with a microbial transglutaminase. J. Cereal Sci. 48, 33–45. http://dx.doi.org/10.1016/j.ccs.2007.07.011
Schoenenlehrer, R., Linsberger, G., Kaczyk, L., Berghofer, E. (2006): Production of short dough biscuits from the pseudocereals amaranth, quinoa and buckwheat with common bean. Ernährung ER 30, 101–107.
Shittu, T.A., Raji, A.O., Sanni, L.O. (2007): Bread from composite cassava-wheat flour: I. Effect of baking time and temperature on some physical properties of bread loaf. Food Res. 40, 280-290. http://dx.doi.org/10.1016/j.foodres.2006.10.012
Sousa, C., Moreno, M.L., Comino, I. (2014): Alternative Grains as Potential Raw Material for Gluten-Free Food Development in The Diet of Celiac and Gluten Sensitive Patients. Austin J. Nutr. Food Sci. 2 (3), 1-9.
Sulieman, A.A., Zhu, K., Peng, W., Hassan, H.A., Obadi, M., Siddeeg, A., Zhou, H. (2019): Rheological and quality characteristics of composite gluten-free dough and biscuits supplemented with fermented and unfermented Agaricus bisporus polysaccharide flour. Food Chem. 271, 193-203. https://doi.org/10.1016/j.foodchem.2018.07.189
Suma, F., Urooj, A., Asha, MR., Rajiv, J. (2014): Sensory, Physical and Nutritional Qualities of Cookies Prepared from Pearl Millet (Pennisetum Typhoideum). J. Food Process. Technol. 5 (10), 1-6. https://doi.org/10.4172/2157-7110.1000377
Taiwo, E.O., Sekinat, A.A., Adegbola, D.O., Kemiola, A.A., Joke, S.A. (2017): Chemical composition and sensory qualities of wheat-sorghum date cookies. Food Technol. Biotechnol. Nutr. 12 (1-2), 71-76.
Thorat, S.S., Ramachandran, P. (2016): Effect of Finger Millet Flour on Rheological Properties of Wheat Dough for the Preparation of Bread. Int. J. Food Sci. Nutr. 5 (4), 74–81.
Tsehaye, Y., Berg, T., Tsegaye, B., Tanto, T. (2006): Farmers’ management of finger millet (Eleusine coracana L.) diversity in Tigray, Ethiopia and implications for on-farm conservation. Biodivers. Conserv. 15, 4289–4308. https://doi.org/10.1007/s10531-005-3581-3
Vijayakumar, P.T., Mohankumar, J.B. (2009): Formulation and characterization of Millet flour blend incorporated composite flour. Int. J. Agric. Sci. 1 (2), 46-54.
Vizitiu, Daniel, Ognean, Mihai, Danciu, Ioan. (2012): Rheological Evaluation of Some Laboratory Mills. Bulletin of the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 69 (2), 440-446. https://doi.org/10.15835/BUASVMCN-AGR%3A8796