Flour is a major ingredient in the majority of ready to eat snack foods, especially in bakery products. Although composite flours can be beneficial, the dough’s rheological and pasting properties play a vital role in the final quality of bakery products. This study was initiated to examine the particle size distribution, rheological and pasting property of composite wheat-anchote flour that is suitable for bakery products. The experiments were carried out by blending anchote to wheat flour with the ratio of 10, 15 and 20% substitution. The pasting properties of Anchote flour included 4025.00, 1075.33, 2949.67, 2171.00 and 1095.67 cP of peak, trough, breakdown, final and set back viscosities respectively and 4.26 min of peak time as well as 70.33 0C pasting temperature. Values of the same attributes for the wheat flour were 2321.00, 299.33, 2021.67, 389.00, 91.67, 5.63 and 77.00 respectively with the relevant units indicated. Regarding the rheological properties, Anchote flour exhibited 66.61% water absorption, 7.40 min development time, 1.16 min stability time, 49.66 Farinograph Unit of mixing tolerance index and 22.66FU of farinogram quality number as compared to the values of 52.63%, 2.16 min, 5.56 min, 72.00 FU and 80.66 FU of the respective properties of wheat flour. All of these properties of composite flours were significantly (p<0.05) affected by Anchote blending ratios.

Keywords: Anchote flour, blending ratio, pasting properties, Particle size and color

INTRODUCTION

Flour is a major ingredient in the majority of ready to eat snack foods, especially in bakery products. Nutritional flour can be made from a variety of pulses, legumes, nuts, root and tubers (Karthikeyan et al., 2017). Wheat gluten protein is mainly responsible for the special viscoelastic properties and strengthens the dough (Shewry et al., 2000; Song and Zheng, 2007). However, the wheat dough is considered nutritionally poor. Wheat flour contains a low level of protein and essential amino acids, such as lysine, tryptophan or methionine (Yadav et al., 2012). In order to fill the nutritional gaps many studies combine the flours with each other. Composite flour is a mixture of various flours usually acquired from different sources, such as roots, tubers, cereals and legumes and may or may not contain also wheat. Composite flours can have nutritional benefits than the individual flours lack (Karthikeyan et al., 2017).

Composite flour is considered advantageous in developing countries as it reduces the importation of wheat flour and encourages the use of locally grown crops as flour (Hugo et al., 2000; Hasmadi et al., 2014).

Local raw materials substitution for wheat flour is increasing due to the growing market for confectioneries (Noor Aziah and Komathi, 2009). Ethiopia is producing only small amount of wheat flour, so the demand for bakery products is met by imports from foreign such as USA, Australian, Europe. Therefore, composite flours provide opportunities to increase the use of domestic agricultural crops in flours for bakery products.

Anchote being among few indigenous vegetable crops in Ethiopia that has been historically given low attention in terms of research as well as production, is not well

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developed and popularized, despite its food and nutrition security and other functional potentials (Habtamu et al., 2013). Anchote is used as both traditional medicine and food source such as healing of broken/fracture bones and displaced joints, and believed that it makes lactating mothers healthier and stronger as it contains high calcium, starch and proteins than other commonly and wide spread root and tuber crops (Endashaw, 2007). Partial Replacement of anchote in wheat flour for producing bakery products such as bread could improve the economic value and nutritional palatability of anchote (Demelash, 2016).

Anchote, being a gluten free tuber crop may behave quite differently from wheat with regard to rheological properties in terms of its pliability, extensibility and rollability. The rheological and pasting properties of dough’s describe how they deform, flow or rupture under applied stress and could be used as a tool in the selection and specification of appropriate raw materials. They have importance in terms of product formulation and optimization, quality control, machining properties of the dough, scale-up of the process and automation (Hamann and Macdonald, 1992). Rapid Visco Analyzer (RVA) is primarily used to analyze the rheological behavior of flour as it relates to food applications. The suitability of composite flour for producing a cake, cookie, bread or snack products can be evaluated using the RVA (Itagi and Singh, 2012).

However, the Granulation characteristics of milled flours affect the rate of hydration and swelling capacity during processing (Hatcher et al., 2009); color determines visual appearance and eye appeal of finished product (MacDougall, 2002). Additionally, rheological and pasting properties of dough are essential for the successful manufacturing of bakery products because they determine its behavior during mechanical handling, thereby affecting the quality of the finished products (Hoseney et al., 1988). Preparing Anchote flour for industrial and household products and then characterizing pasting properties of the flour and rheological properties of the dough during handling under machine is important. There are some studies done earlier that have shown the dough made from composite flours containing Anchote. Thus, the present study focused on the blends of wheat and Anchote flours for examining the particle size distribution, rheological and pasting properties that are suitable for bakery products.

MATERIAL AND METHODS

Source of Materials

The raw materials used are Anchote (Coccinica abysssicina (L)) and “Hawi” wheat (Triticum astivum L) variety. Anchote (Coccinica abysssicina (L)) was purchased from the Nekemte farm gate market. Wheat (Triticum astivum L) variety (Hawi) was purchased from Kulumsa Agricultural Research Center. All chemical used were analytical grade.

Preparation of Anchote Flour

Anchote (Coccinica abyssicina (L)) flour was prepared according to Habtamu et al. (2013) method after drying using oven dryer (Memmert, model 765, Germany). The selected tubers were peeled using a sharp stainless steel knife and slice using a slicer to obtain a sliced thickness of 6 mm, but other dimensions in terms of length and width were not kept constant for all the samples. The sliced product was washed in water and placed on a sieve to remove excess water. It was then dried in a cabinet oven dryer operated at 50°C with a constant circulating air velocity for 24 hrs. After drying, the material was pulverized separately using a laboratory hammer mill (Nima, model NM3500, Japan) and sieved through a 350µm size screen to obtain flour with uniform particle sizes. The flour samples were separately packaged in polyethylene bags until used for analysis and stored at room temperature.

Preparation of Wheat Flour

‘Hawi’ wheat variety was cleaned; stones, dirty and other extraneous materials were removed. Whole wheat flour was obtained by using grain milling (Model 3510-011p Collins, USA). The wheat grain powder was sieved through a 350µm sieve size to obtain fine homogenized flour. The flour was sealed in a polyethylene bag and stored at room temperature (Peter et al., 2017) until further use.

Composite Flour

The composite flours of wheat flour (Hawi variety) and Anchote flour were prepared as follows; B₁ is blending ratio (10% Anchote flour and 90% wheat flour), B₂ is blending ratio 2 (15% Anchote flour and 85% wheat flour), B₃ is blending ratio 3 (20% Anchote flour and 80% wheat flour), W is Control (100% wheat flour) and A is control (100% Anchote flour) were employed for evaluation of particle size distribution, rheological and pasting properties of Wheat, Anchote and their Composite Flour.

Particle size distribution

The particle size distribution of flour samples obtained from the blends of wheat and Anchote flour was carried out using a sieve analysis technique as described by Lesego (2014). Different sieves with varying aperture sizes (53, 106, 150, 180, 250, 300µm) were arranged on top of each other with the one having the biggest aperture on the topmost level and then arranged in decreasing order. The sieves were fastened into a rigid position using a fastening screw after a standard quantity of the flour sample (50g) already placed inside the topmost sieve. The sieve was shaken for 10 min after which the quantity of flour retained on each sieve was collected and weighed, and calculated as:

\[
\text{%Recovered} = \frac{W_{\text{recovered}}}{W_{\text{total}}} \times 100
\]

Where: \( W_{\text{sieve}} \) is the weight of the aggregate in the sieve \( W_{\text{total}} \) is the weight of the total aggregate.
**Color measurement**

The color values of the flours were measured in three different zones of the crust using a digital spectrophotometer Mini Scan EZ (Model: CR-10 Minolta, Japan), which was provided with the software. A chromometer was calibrated with the standard black and white color. The results reported are averages of three measurements in each sample using CIELAB $L^*$, $a^*$ and $b^*$ values. $L^*$ value is the lightness variable from 100 for perfect white to zero for black, while $a^*$ and $b^*$ values are the chromaticity values, +redness/-greenness and +yellowness/blueness, respectively (Palatnik et al., 2015).

\[
\text{Chroma} (C^*) = \sqrt{a^{*2} + b^{*2}} \tag{2}
\]

\[
\text{Hue} (h^*) = \tan^{-1}\frac{b^*}{a^*} \tag{3}
\]

**Pasting Properties of Wheat, Anchote and Composite Flours**

The pasting profile was determined using Rapid Visco Analyser (Model no 4500 Perten instruments Australian). The sample about (3.5g, 14% moisture basis) was mixed with a 25mL distilled water to make a flour suspension in the sample holding cup to determine the viscosity using a rapid visco analyzer. A 13 minutes heating and cooling cycle was used in which the sample was held at 50 °C for 1 minute, heated from 50 to 95 °C in 3.5 minutes, held at 95 °C for 3 minutes and then cooled to 50 °C in 3.5 minutes, held for 2 minutes at 50 °C. All pasting properties; peak viscosity (PV), Trough viscosity (TV), break down viscosity (BDV), final viscosity (FV), set back viscosity (SBV) and pasting temperature (PT) was determined using the software Thermo Cline for windows version 3 (Deka and Sit, 2016; Mahasuk et al., 2010).

**Rheological Properties of Wheat, Anchote and Composite flours dough**

Dough strength was measured by Farinograph (Model Brabender GmbH and co.kg, B27504) according to AACC (2000) method No.54–21 of constant dough weight method at 30 ± 0.2°C using a 300 g mixing bowl, operating at 63 rpm. Each flour sample in the range of 284.5–300 g on a 14% moisture basis was weighed and placed into the corresponding Farinograph mixing bowl. Water from a burette was added to the flour and mixed to form dough. As the dough mixed, the farinograph consistence (BU) versus time (min.) was recorded for 20 min. Farinograph values: Water Absorption Capacity (WAC%), dough development time (DT min.), dough stability time (ST min.), mixing tolerance index (MTI FU), and farinographic number (FQN FU) were evaluated by AACC Method using the Farinograph software (Brabander® Farinograph version: 2.3.6, 1996–2005, Microsoft corporation).

**Statistical analysis**

The data obtained from triplicate experiments and their means were analyzed by ANOVA using SAS 9.1 software package (SAS Institute Inc., Cary, NC), and the Fisher’s least significant difference (LSD) performed to separate varieties with significantly different ($p < 0.05$) means. Statistical significance was set at a level of 95% confidence. Results were reported as means ± standard error.
RESULTS AND DISCUSSIONS

Particle size distribution

The result of particle size showed that the Anchote flour had larger proportion (65%) of large particle size (≥150µm) category and decreased at lower sieve sizes, while the opposite was observed for wheat flour (Table 1). This implies that wheat flour was comprised of more (64.67%) smaller particles (≤106 µm) than Anchote flour (Table 1). This was probably because Anchote roots contain more fiber, which to some extent might be hard to mill fine and hence, result in larger particles of Anchote. It is well established that the degree of flour fineness in a milling operation depends on the type and efficiency of the applied machine (Oladunmoye et al., 2010). The small grain size and tempering of wheat before milling improves milling efficiency and resulted in finer particles of wheat flour.

There were a significance (p<0.05) differences in proportions of the different particle sizes which include 300, 250, 180, 150, 106, 53 and< 53µm for composite wheat- Anchote flours of various blending ratios (Table 1).

Increasing the proportion of Anchote in the composite flours resulted in increase of the proportion of the larger particles ≥ 150 µm. For example, particles of 300 µm increased to 5.8, 5.86 and 6.25% for Anchote blends of 10, 15 and 20%, respectively. Similar trends of increments of larger particles happened to the different size categories above to 150 µm. The opposite was observed in cases of particle size categories below 150 µm. Most of the changes were not significant (P>0.05).

This study agreed with the finding reported by Lesego (2014) that described the pattern for particle size distribution with different sieve sizes was shifted from smaller size to the larger sieve size category as the level of supplementation morama bean increased in wheat-morama bean composite flour. According to, UNECA (1985), particle size of about 130 µm is suitable for wheat flour intended for baking bread, biscuits and other pastry products. Crabtree and James (1982) indicated that particle size of about 180 µm and fiber-free is ideal composite flour for bread making. From the current finding, wheat flour and composite flours particle size distribution were within the range expected for cookies baking.

Color of wheat, Anchote and their composite flours

Color is an important quality factor directly related to the acceptability of food products, and is an important physical property to report (Amir G. et al., 2002). The color components of wheat, Anchote and their composite flours are shown in Table 2.

Table 1. Particle size distribution of wheat, Anchote and composite flours (%).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>300µm</th>
<th>250µm</th>
<th>180µm</th>
<th>150µm</th>
<th>106µm</th>
<th>53µm</th>
<th>&lt; 53µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>5.75 ± 0.14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.89 ± 0.09&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.38 ± 0.37&lt;sup&gt;c&lt;/sup&gt;</td>
<td>16.31 ± 0.86&lt;sup&gt;c&lt;/sup&gt;</td>
<td>21.96 ± 1.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>31.22 ± 2.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.49 ± 0.33&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>A</td>
<td>7.69 ± 0.53&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.55 ± 1.15&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17.94 ± 2.51&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29.85 ± 0.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.18 ± 1.11&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.98 ± 0.69&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.81 ± 0.42&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>B1</td>
<td>5.80 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.49 ± 0.27&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.07 ± 1.65&lt;sup&gt;b&lt;/sup&gt;</td>
<td>18.04 ± 1.48&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21.36 ± 1.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>31.10 ± 0.44&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.14 ± 0.73&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>B2</td>
<td>5.86 ± 0.18&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>7.33 ± 0.57&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.54 ± 1.20&lt;sup&gt;b&lt;/sup&gt;</td>
<td>20.73 ± 0.50&lt;sup&gt;b&lt;/sup&gt;</td>
<td>17.86 ± 0.80&lt;sup&gt;b&lt;/sup&gt;</td>
<td>28.37 ± 1.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.31 ± 1.23&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>B3</td>
<td>6.25 ± 0.16&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.34 ± 0.16&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.43 ± 0.61&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22.02 ± 1.94&lt;sup&gt;b&lt;/sup&gt;</td>
<td>16.21 ± 0.34&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>25.78 ± 0.15&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.97 ± 0.59&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD</td>
<td>4.34</td>
<td>8.13</td>
<td>10.05</td>
<td>5.57</td>
<td>5.08</td>
<td>4.22</td>
<td>8.66</td>
</tr>
<tr>
<td>CV</td>
<td>0.49</td>
<td>1.08</td>
<td>3.03</td>
<td>2.16</td>
<td>1.71</td>
<td>2.00</td>
<td>1.33</td>
</tr>
</tbody>
</table>

Values are means ± SD and values in the same column with different superscript letters are significantly different from each other (P< 0.05). Where, W = Control (wheat flour 100%), A = 100% Anchote flour, B1= 90 % wheat flour and 10% Anchote flour, B2= 85 % wheat flour and 15% Anchote flour, B3= 80 % wheat flour and 20% Anchote flour.

Table 2. Color value of wheat, Anchote and composite flours.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>L&lt;sup&gt;*&lt;/sup&gt;</th>
<th>a&lt;sup&gt;*&lt;/sup&gt;</th>
<th>b&lt;sup&gt;*&lt;/sup&gt;</th>
<th>Hue(°)</th>
<th>Chroma</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>92.80 ± 1.76&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.21 ± 0.51&lt;sup&gt;d&lt;/sup&gt;</td>
<td>7.72 ± 0.84&lt;sup&gt;d&lt;/sup&gt;</td>
<td>73.89 ± 4.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.05 ± 0.80&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>A</td>
<td>82.24 ± 2.26&lt;sup&gt;d&lt;/sup&gt;</td>
<td>6.63 ± 0.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17.76 ± 0.90&lt;sup&gt;a&lt;/sup&gt;</td>
<td>69.55 ± 0.44&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.96 ± 0.93&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>B1</td>
<td>90.83 ± 1.09&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2.88 ± 0.15&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8.40 ± 1.28&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>70.90 ± 2.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.88 ± 1.25&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>B2</td>
<td>89.30 ± 0.30&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>3.47 ± 0.32&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.71 ± 1.32&lt;sup&gt;b&lt;/sup&gt;</td>
<td>70.17 ± 2.46&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.31 ± 1.28&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>B3</td>
<td>88.08 ± 0.47&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.85 ± 0.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.65 ±0.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>70.12 ± 1.64&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.33 ±0.35&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD</td>
<td>2.54</td>
<td>0.58</td>
<td>1.84</td>
<td>4.52</td>
<td>1.79</td>
</tr>
<tr>
<td>CV%</td>
<td>1.57</td>
<td>8.49</td>
<td>9.32</td>
<td>3.50</td>
<td>8.57</td>
</tr>
</tbody>
</table>

Values are means ± SD and values in the same column with different superscript letters are significantly different from each other (P< 0.05). Where, W = Control (wheat flour 100%), A = Anchote (100%), B1= 90 % wheat flour and 10% Anchote flour, B2= 85 % wheat flour and 15% Anchote flour, B3= 80 % wheat flour and 20% Anchote flour.
There was significance ($p<0.05$) differences in color values of the control sample and composite flours as shown in (Table 2). The mean $L^*$ values were 82.24 and 92.80 for Anchote and wheat flour, respectively. These were significantly ($p<0.05$) different from each other. The $L^*$ value decreased as Anchote flour substitution increased in wheat-Anchote composite flours. The values were 90.83, 89.30 and 88.08 for Anchote blends of 10, 15 and 20%, respectively. The same trend was reported by previous work of Shazia et al. (2012) who showed that the $L^*$ value for composite flours decreased as sweet potato flour supplementation increased in wheat-sweet potato blended flours. This study was in contrary with the finding reported by Eriksson et al. (2014) who showed that the $L^*$ value of composite flours increased with increase cassava flour substitution in wheat-cassava composite flours due to the higher (91.85 -95.43) $L^*$ value of cassava flour than wheat flour with $L^*$ value of 89.7. The lightness ($L^*$) is an indication of the brightness. Flours that were pale are those with $L^*$ values >42 and the dark flours was for $L^*$ values <42. Therefore, all-composite flours had $L^*$ values more than 88.08 which indicates the flours were pale in color.

There were also significant ($p<0.05$) differences in $a^*$ and $b^*$ value among flours as shown in (Table 2). The $a^*$ mean value was 2.21 and 6.63 for wheat and Anchote flour, respectively, whereas the $b^*$ values were 7.72 and 17.76, respectively. It can be seen that wheat flour had smaller values of $a^*$ and $b^*$ component whereas, the Anchote flour had larger values. The composite flours exhibited increment in values of the two-color components ($a^*$ and $b^*$) with Anchote records of 2.88, 3.47 and 3.85 for component of $a^*$for the Anchote blends of 10, 15 and 20% respectively, and records of 8.40, 9.71 and 10.65, respectively, for component $b^*$. These indicated that redness and yellowness color component increased in the composite flours with the addition of more Anchote in the blends. Similar, results were reported by Singh et al., (2008) who stated that the $a^*$ and $b^*$ values increase with sweet potato flour substitutions, while studying effect of incorporating sweet potato flour in wheat flour on quality characteristics of cookies.

The Hue angle (°) has been described as the color perceived by the naked eye, and is measured in degrees. The values were 69.55 for Anchote and 73.89 for wheat flours with significant ($p<0.05$) difference between them. The hue angle values place the flours in the yellow region of the CIEL*a*b* color space. These color indices were not significantly ($p>0.05$) different among the flours. The Hue angles greater than 90° denote a yellowish color, whereas those lower than 90°, as observed in all control and composite flours, suggest a slightly yellow to orange color.

Chroma was the chromaticity coordinates, which is perpendicular distance from the lightness. The values are 8.05 for wheat flour and 18.96 for Anchote flour with significant ($p<0.05$) difference between them as shown in Table 3. The values for composite flours increased with increase the blending ratio of Anchote flour with significant ($p<0.05$) difference between them. Even though, related results were reported by Singh et al., (2008), sweet potato flour has a chroma values 23.21 and hue angle 58.44 and wheat flour has chroma value 58.44 and hue angle 73.50.

**Pasting Properties of Wheat, Anchote and Composite Flours**

Pasting profile of flour is one of the most important properties influencing the quality and aesthetic consideration of food that affects the texture, digestibility and end use of starch-based food commodities (Ajanaku et al., 2012). The pasting properties are important as it is used in predicting the pasting behavior of the flour samples. The pasting properties (such as peak, trough, setback, breakdown, final viscosities, peak time and pasting temperature) of the wheat, Anchote flour and their composite flours are presented (Table 3). The result obtained by RVA expressed as cP (1 RVU = 12 centipoises).

The RVA results indicated that the composite flours had distinct pasting properties as compared to the control sample (wheat flour) as well as the Anchote flour as presented in (Table 3). Peak viscosity is indicative of the strength of pastes, which are formed from gelatinization during processing in food applications(Adebowale, Sanni, & Onitilo, 2008) and is measured as the highest value of viscosity attained by the paste during the heating cycle (50-95 °C). The peak viscosity of the wheat flour was 2321.00 cP whereas, that of Anchote was 4025.00 cP with significant ($p<0.05$) difference between them. The peak viscosity of the composite flours was significantly ($p<0.05$) lower than that of Anchote but greater than of wheat flour. These findings confirmed earlier reports that cereal starches have a lower peak viscosity compared to tubers and root starches (Biliaderis, 2009). Though, increasing the proportion of Anchote from 10, 15 and 20% resulted in increase in peak viscosity to 2501.33, 2585.67 and 2685.67cP, respectively. The study was in line with the finding reported by Adeleke and Odedeji (2010) that showed the peak viscosity of composite flours (131.42-271.08RVU) increased with the increase incorporation level of sweet-potato flour in wheat-sweet potato blend flours.

Two factors interact to determine the peak viscosity of a cooked starch paste: the extent of granule swelling (swelling capacity) and solubility. Higher swelling capacity and water absorption capacity is indicative of higher peak viscosity while higher solubility as a result of starch degradation results in reduced paste viscosity (Shittu et al., 2001). High peak viscosity is an indication of high starch content (Osungbaro, 1990) and this could explain why Anchote-wheat composite flours sample had higher peak viscosity compared to whole wheat flour. The high peak viscosity values of the composite blends may be suitable for products requiring high gel strength and elasticity as reported by Adebowale et al. (2008).
Trough viscosity is sometimes called shear thinning, hot paste viscosity. It is the minimum viscosity value in the constant temperature phase of the RVA pasting profile and it measures the ability of the paste to withstand breakdown during cooling (Ayo-Omogie and Ogunsakin, 2013). The values were 299.33 and 1075.33 cP for wheat and Anchote, respectively, as shown in Table 3. The trough viscosity of Anchote flour was significantly (p<0.05) higher 1075.33 cP than 299.33 cP of wheat flour. The values were significantly (p<0.05) increased with increase in the substitution level of Anchote flour in wheat-anchote composite flours. Blending wheat with Anchote flour at a ratio of 10, 15 and 20% raised the trough viscosity to 321.33, 471.33 and 484.67 cP, respectively. These values are greater than that of wheat and less than that of Anchote flour. A similar trend was reported by Ehimen et al. (2017), who showed that the trough viscosity of the composite flours increased as the substitution level of sweet potato flour increased in the unripe banana-pigeon pea - sweet potato composite flours, with trough viscosity ranging from 17.71 to 263.96 RUV.

According to Falade et al. (2014), breakdown viscosity is associated with the tendency of the cooked starch to disintegrate. Breakdown viscosity is the viscosity of the paste after being heated at holding temperature of 95 °C. Wheat flour alone had the lowest 2021.67 cP breakdown value, whilst Anchote flour had the highest 2949.67 cP breakdown viscosity with significance (p<0.05) difference between them. The higher breakdown in viscosity implies the lower the ability of the samples to withstand heating and shear stress during cooking (Adebawale and Lawal, 2004). Also, the higher values of breakdown are associated with higher peak viscosities, which in turn are related to the degree of swelling of starch granules during heating (Ragaee and Abdel, 2006).

The breakdown viscosity of the composite flours was significantly (p<0.05) higher than that of the wheat flour, but, lower than that of Anchote flour as shown in Table 3. No significant (p>0.05) differences were observed among the values of the three composite flours. This study was corroborated by report of Adeleke and Odedeji (2010), who stated that the breakdown viscosity of the composite flours was raised as the inclusion level of sweet potato flour increased in wheat- sweet potato flours range from 41.00-110.0 RUV.

Final viscosity is commonly used to define the quality of the particular starch-based flour, since it indicates the ability of the flour to form a viscous paste after cooking and cooling. It also gives a measure of the resistance of paste to shear force during stirring (Adebawale et al., 2008). The final viscosities of wheat and Anchote flour were significantly (p<0.05) different from each other with values of 389.00 and 2171.00 cP respectively, as shown in (Table 3). As more and more Anchote flour was supplemented into wheat flours the final viscosity was significantly (p<0.05) increased, indicating high resistance of paste to shear force during stirring. The highest value 656.33 cP was absorbed for samples with 20% Anchote, whereas the lowest value 423.00 cP for sample with 10% Anchote. This may attributed to high carbohydrate content in anchote flours (Demelash, 2016). A similar trend was reported by Adeleke and Odedeji (2010), who showed that the final viscosity of composite flour increased with increase the incorporation level of sweet-potato flour in wheat-sweet potato flours blends.

The difference between final viscosity and trough viscosity give rise to a pasting property known as setback viscosity. It is the phase of the pasting curve after cooling the starches to 50 °C. This stage involves re-association, retrogradation or re-ordering of starch molecules (Abd et al., 2000). There was significant (p< 0.05) difference between wheat and Anchote flours with values of 91.67 and 1095.67 cP, respectively, as shown in (Table 3). As more and more incorporation of Anchote flour in wheat flour the setback viscosity of composite flours were significantly (p< 0.05) increased. Blending wheat with Anchote flour at a ratio of 10, 15 and 20% raised the setback viscosity to 101.67, 166.00 and 171.67 cP respectively. These values are greater than that of wheat and less than that of Anchote flour. This study agreed with the finding of Odedeji and Adeleke (2010) who showed, that the setback viscosity increased as sweet potato flour supplementation was increased in wheat – sweet potato composite flour. Higher setback value is synonymous to
reduced dough digestibility (Shittu et al., 2001) while low setback value is an indication that the starch has a low tendency to retrograde or undergo syneresis during freeze thaw cycles (Fasasi, 2009).

Peak time is the time in minutes at which the peak viscosity occurred in the pasting profile. The peak time values for Anchote and wheat flour were 4.26 and 5.63 min, respectively, with significant \((P < 0.05)\) difference from each other as shown in Table 4.5. As more and more incorporation of Anchote flour in wheat flour the peak time of composite flours were significantly \((P < 0.05)\) decreased. The values were 5.43, 5.20 and 5.16 min as the substitution ratio of Anchote flour increased to 10, 15 and 20%, respectively. While blending Anchote flour with wheat flours the peak time were decreased, it indicates less cooking or processing time. Comparable results were reported with range from (5.57 - 6.20 min) for wheat-high quality cassava blend flours reported by Oluwakemi et al. (2017). Also, similar were reported by Olapade. A. and Adeyemo, A, (2014) stated that the peak time for wheat flour was higher values 6.27 min than that of cassava flour of 3.9 min.

The pasting temperature is the temperature at which irreversible swelling of the starch granules occur, leading to the formulation of a viscous paste in an aqueous solution. It is a measure of the minimum temperature required to cook a given starchy food sample (Sandhu et al., 2005). It gives an indication of the minimum temperature and energy costs involved. The pasting temperature for Anchote flour was 70.33 °C and for wheat 77.00 °C both of which are significantly \((p<0.05)\) different from each other. A comparable result was reported by Julianti, E. et al., (2017), the pasting temperature for wheat, sweet potato and maize starch were 77.8, 67.78 and 74.1°C, respectively. As more and more incorporation of Anchote flour in wheat flour the pasting temperature of composite flours were significantly \((p<0.05)\) decreased. The pasting temperature of the composite flours were 76.33, 74.66 and 73.66 °C for those containing 10, 15 and 20% Anchote flour, respectively, with statistical \((p<0.05)\) difference between the highest and the lowest values.

### Rheological Properties of Wheat, Anchote and Composite flours dough

#### Water absorption capacity (WAC)

Water absorption capacity is the amount of water absorbed by the flour to form dough of standard consistency. It is used to estimate the time of baking. Typical absorption levels for flour used in bakery industry, which values ranged from 60-65% was high absorption capacity (Mariana et al., 2016). The water absorption of wheat, Anchote and composite flours are presented in (Table 4). The values were 52.63% for wheat flour dough and 66.61% for Anchote flour dough with significant \((p<0.05)\) different between them. The higher value of WAC of Anchote was because of the high starch and fiber content. The water absorption capacity of composite flours indicated that increases in the blending ratio of Anchote flour resulted in increased water absorption capacity of the composite flours dough. Composite flours of 10, 15 and 20% Anchote flour substituted dough had WAC of 53.10, 55.70 and 58.61%, respectively, with significance \((p<0.05)\) difference between the lowest and highest value. Several studies also reported that the dough made from composite flours of tuber crops absorbed more water than that made from wheat flour alone (Morita et al., 2002).

### Table 4. Rheological properties of dough of wheat, Anchote and composite flours.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Water Absorption (%)</th>
<th>Development Time (min)</th>
<th>Stability Time (min)</th>
<th>MTI(FU)</th>
<th>FON (FU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>52.63 ± 3.23&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.16 ± 0.05&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.56 ± 0.83&lt;sup&gt;a&lt;/sup&gt;</td>
<td>72.00 ± 2.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>80.66 ± 4.04&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>A</td>
<td>66.61 ± 1.17&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.40 ± 0.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.16 ± 0.057&lt;sup&gt;d&lt;/sup&gt;</td>
<td>49.66 ± 1.52&lt;sup&gt;c&lt;/sup&gt;</td>
<td>22.66 ± 2.51&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>B1</td>
<td>53.10 ± 0.55&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>2.43 ± 0.11c</td>
<td>4.46 ± 0.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>69.66 ± 0.57&lt;sup&gt;a&lt;/sup&gt;</td>
<td>73.66 ± 7.51&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>B2</td>
<td>55.70 ± 1.38&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>2.56 ± 0.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.43 ± 0.10&lt;sup&gt;c&lt;/sup&gt;</td>
<td>66.33 ± 1.52&lt;sup&gt;b&lt;/sup&gt;</td>
<td>71.00 ± 4.58&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>B3</td>
<td>58.61 ± 0.23&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>3.93 ± 0.20&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.10 ± 0.11&lt;sup&gt;c&lt;/sup&gt;</td>
<td>64.16 ± 2.51&lt;sup&gt;b&lt;/sup&gt;</td>
<td>69.00 ± 4.52&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD</td>
<td>3.05</td>
<td>1.03</td>
<td>0.69</td>
<td>2.64</td>
<td>10.32</td>
</tr>
<tr>
<td>CV</td>
<td>2.92</td>
<td>5.94</td>
<td>10.41</td>
<td>2.26</td>
<td>9.24</td>
</tr>
</tbody>
</table>

Values are means ± SD and values in the same column with different superscript letters are significantly different from each other \((p<0.05)\). Where, W = Control dough (wheat flour 100%), A = 100% Anchote flour dough, B1 = 90% wheat flour and 10% Anchote flour composite dough, B2 = 85% wheat flour and 15% Anchote flour composite dough, B3 = 80% wheat flour and 20% Anchote flour composite dough.

#### Dough development time (DDT)

Time of development (formation) of the dough is the time required for the formation of gluten, i.e. until the consistency of 500 BU. Development time is the time from the first addition of water to the time the dough reaches the point of greatest torque. During this phase of mixing, the water hydrates the flour components and the dough is developed. The DDT (Dough development time) of wheat, Anchote and composite flours are presented in Table 4. The mean values for DDT was 2.16 and 7.40 min for wheat and Anchote flours, respectively. These values were significantly \((p<0.05)\) different from each other. The results are closely relevant to the findings reported by Amir et al. (2015), who showed that the maize, sorghum and wheat composite flours had DDT ranged from 1.5 to 5.83min.
The DDT values increased as Anchote flour substitution increased in composite flours dough. The values were 2.43, 2.56 and 3.93 min for composite flours containing Anchote flour of 10, 15 and 20%, respectively, with significance ($p<0.05$) difference between the highest and the lowest values. But, substitution of Anchote flour up to 15% did not bring significant ($p>0.05$) effect on DDT of sample. Generally, increasing substitution of Anchote flour in the composite flours dough would result in the longest DDT. This increment of DDT might be due to low gluten protein contents of the blended flours and relatively high amount fiber content of Anchote flour. This study was in line with the finding reported by Abera et al. (2017), who showed that the dough development time became longest as more and more taro flour was incorporated in wheat-taro composite flours dough for bread making. Dough development time increases with the increase in the proteolytical degradation of protein and with a decrease in the size of starch granule and the increase in the content of damaged starch due to the increase in specific surface area which absorbs water (Thiele et al., 2002).

**Dough Stability time (DST)**

Dough stability is the time in which the farinograph curve is maintained on a line of normal consistency. Stability time is the point between arrival time and departure time and generally indicates the strength of flour (how much gluten flour has and how strong it is) (Hallen et al., 2004). The stability time of the Anchote flour was 1.10 min, whereas that of wheat flour was 5.56 min with significant ($p<0.05$) difference between them (Table 4). The stability time of the composite flours were significantly ($p<0.05$) lower than that of wheat but greater than of Anchote flour. Increasing the proportion of Anchote from 10, 15 and 20% resulted in decreased stability time to 4.46, 3.43 and 3.1 min, respectively. These results were comparable with ranges from 3.30 – 8.70 min for wheat-taro blend flours reported by Abera et al. (2017). Also, the results obtained were in agreement with the findings of Amir et al. (2015), who showed a similar decreasing pattern in stability time with increase sorghum and maize flour replacement in maize, sorghum -wheat composite flours.

**Mixing tolerance index (MTI)**

Mixing tolerance index is used by bakers to determine the amount that dough will soften over a period of mixing. The degree of softening of the dough is represented by the difference between the consistency of 500 BU and the consistency reached by the curve after 12 minutes from achieving standard consistency. There were significant ($p<0.05$) differences in Mixing tolerance index among treatment flours as shown in Table 4. The mean values were 49.66 FU for Anchote and 66.72 FU for wheat flour with significant ($p<0.05$) difference between them as shown in Table 4. The MTI of composite flours were significantly ($p<0.05$) decreased as the Anchote flour incorporation increased in the composite flours. The values reduced to 69.66, 66.33 and 64.76 FU as the substitution ratio increased from 10, 15 and 20%, respectively. This might be due to the absence of gluten protein contents of Anchote flour which contributes to the elasticity of dough. A similar result was reported by earlier work Abera et al. (2017), a decreasing pattern of MTI was observed as the substitution level of taro flour increased in wheat-taro composite flour.

**Farinograph quality number**

Farinograph quality number is an index for measuring the quality of the flour and is measured on the farinogram, on horizontally (in minutes) from the vertical axis of the consistency of the dough to the point where the centerline of the curve meets the horizontal line lowered by 30 FU towards the peak of consistency, multiplied by 10. The mean values of FQN were 22.66 and 80.66FU for Anchote and wheat flour, respectively, as shown in Table 4. These values were significantly ($p<0.05$) different from each other. The FQN of the composite flours dough were significantly ($p<0.05$) higher than Anchote flour and lower than that of wheat flour. No significance ($p>0.05$) difference was observed among the three composite flours dough sample. The study was in similar with findings reported by Shimeles and Martha (2012), who showed that the Brabender farinogram FQN decreased with an increase in a percentage of amaranth flour substitution in wheat flour.

**CONCLUSIONS**

Anchote flour had larger particle sizes than those of the wheat flour, and when increasing the substitution level of Anchote flour in composite flours it shifts the flour particle size distribution from the smaller size to larger size particles flour. The pasting properties showed Anchote had larger peak viscosity which indicates that Anchote and the composite flours had the ability to use for a product requiring high gelling strength elasticity. In addition, the shorter peak time values of Anchote flour is important to reduce processing time and for saving energy during processing. The rheological characteristic of wheat flour and Anchote and its dough were noticed to have significant ($p<0.05$) difference from each other. In the composite flour dough water absorption and dough development time increased but, stability time and mixing tolerance index decreased with increasing in Anchote flour blending ratio. However, substitution up to 15% Anchote flour in whole wheat flour could not significantly ($p>0.05$) affect the rheological behaviors of the composite dough. Generally, rheological properties information could be used for designing industrial processing of the flours for various products.

**CONFLICT OF INTEREST**

The author declare that they do not have any conflict of interest.
REFERENCES


APPENDIX FIGURES.

Figure 1. Wheat flour pasting curve.

Figure 2. Anchote flour pasting curve

Figure 3. Wheat 90% and 10% Anchote composite flours pasting curve.
Figure 4. Wheat 85% and 15% Anchote composite flours pasting curve.

Figure 5. Wheat 80% and 20% Anchote composite flours pasting curve.

Figure 6. Whole wheat flour farinogramm.

Figure 7. Anchote flour farinogramm.
Particle Size Distribution, Rheological and Pasting Properties of Wheat, Anchote and their Composite Flour

Figure 8. Wheat 90% and 10% Anchote composite flours farinogramm.

Figure 9. Wheat 85% and 15% Anchote composite flours farinogramm.

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