Effects of the Inclusion of Andrographis paniculata Leaf on the Functional Properties and Pasting Characteristics of Wheat-pearl Millet-Based Flour Blends

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Authors’ contributions

This work was carried out in collaboration between both authors. Authors DTI and MKB designed the study. Author DTI wrote the protocol, wrote first draft of the manuscript, managed the literature searches and performed the statistical analysis. Author MKB supervised and correct the manuscript. Both authors contributed towards the execution of the protocol in the lab. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2020/v18i430226

ABSTRACT

This study evaluated flour blends from Wheat, Pearl millet and Andrographis paniculata leaf for functional properties and pasting characteristics profiling. The functional properties such as solubility, gelling capacity, water absorption capacity (WAC), Oil absorption capacity (OAC), Bulk density, foaming capacity and stability and swelling capacity and the pasting characteristics were studied. The inclusion of A. paniculata leaf flour in the blends revealed a significant general increase in water absorption capacity, oil absorption capacity, swelling capacity, and bulk density. However, a general decrease in the foaming capacity, solubility, and least gelation was observed as the inclusion of A. paniculata leaf flour increased. The pasting properties of WPMF (flour blend

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Keywords: Wheat; pearl millet; Andrographis paniculata leaf; functional properties; pasting characteristics.

1. INTRODUCTION

With increased demand for food products that provide benefit beyond their normal function, development of functional flours from blends of whole grains, underutilized grains and medicinal plant parts like leaf, roots and stems is one cardinal approach in naturally mitigating the effects of chronic diseases ravaging our today's world. But profiling the functional properties and the pasting potentials of developed flour blends is an important index to their functionality, usability, cooking and baking quality. In recent years, there has been an increase of products based on whole grains because they contain a higher content of dietary fibre, micronutrients and bioactive compounds Gong et al., [1].

Wheat is a very popular and unique cereal among other cereals used for making bread, biscuit, and other aerated baked products and can only grow in very few developing countries. Wheat is one of the most popular cash crops grown in Nigeria. Wheat culinary used is basically in flour form. It is typically milled into flour which is then used to make a wide range of foods including bread, crumpets, muffins, noodles, pasta, biscuits, cakes, pastries, cereal bars, sweet and savoury snack foods, crackers, crisp-breads, sauces and confectionery.

Pearl millet grains can be considered a possible alternative for food diversification because they have the fibres, minerals, proteins and antioxidants with similar or even higher levels than those found in traditional grains such as rice, sorghum and maize Serna-Saldívar, [2]; Taylor et al., [3]. The chemical composition of pearl millet (dry basis) is, on average, 72.2% carbohydrate, 11.8% protein, 6.4% lipid, 7.8% dietary fibre and 1.8% minerals. However, variations of these levels are possible due to genotype, climatic conditions, soil nutrient content and type of processing. In addition to the above mentioned, Pear millet is a high-energy cereal that contains carbohydrates, and fat. It is rich in B vitamins, especially niacin, B17, B6 and folic acid, calcium, iron, potassium, magnesium and zinc and manganese Gbenyi et al., [4]; Taylor et al., [3].

Andrographis paniculata which generally known as “King of Bitters” belongs to the Acanthaceae family of the andrographis genus Ederma et al., [5]. This genus is made up of 28 species, with Andrographis paniculata, or the King of Bitters, being the most powerful and one of the few possessing healing properties. Andrographis paniculata (Burm.f.) Nees is a medicinal herb with extremely bitter taste. It has been used for centuries to treat respiratory infections, fever, herpes, sore throat and a variety of other chronic and infectious diseases Gupta et al., [6]. Its major constituents are diterpenoids, flavonoids and polyphenols Chao and Lin, [7]. King of bitter is extensively used in indigenous system of medicines as home remedy for various diseases in India and most African traditional system. It is used to treat hepatitis, gastrointestinal tract and upper respiratory infections, fever, herpes, and a variety of other chronic and infectious diseases Mishra et al., [8]. Overall, the herb is known to be a powerful immune boost. Therefore, the study aims to investigate the influence of the varying proportion of inclusion of A. paniculata leaf on the functional and pasting properties of wheat-pearl millet based flour blends.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Source of food materials

Wheat grain (Triticum aestivum), pearl millet grain (Pennisetum glaucum) were purchased at Apata market, Ibadan, Oyo state, Nigeria); and ‘King of bitter’ leaf (Andrographis paniculata) was cultivated and harvested from David’s Farm at Araromi Ogo Oluwa Area of Davog, Akure. Nigeria).

2.1.2 Food materials authentication

The 'King of bitter' leaf (Andrographis paniculata) was identified and authenticated at the Forest
Research Institute (FRIN), Jericho, Ibadan, Nigeria with the herbarium number of 111951; while both wheat and pearl millet grains were also authenticated at the Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, Nigeria.

2.2 Methods

2.2.1 Wheat flour processing

Wheat flour was processed into flour using the method of Amani, [9] with slight modifications. The wheat grains collected were cleaned to remove the stones, dust, woods and any other foreign materials from the grains. The clean and healthy wheat grain was finely grind in an electric grinder and passed through a 60 mesh size sieve. The powdered sample was stored in air tight container until further use for experiments.

2.2.2 Pearl millet flour processing

Pearl Millet flour was processed using the method of Vaijapurkar et al., [10] with slight modifications. The pearl millet grains were cleaned to removed dirt, sand and other extraneous material by winnowing. The cleaned grains were briefly washed and oven-dried until constant moisture content was obtained. It was later milled in an attrition mill, sieved and the pearl millet flour obtained stored in sealed polythene bags at room temperature for analysis.

2.2.3 Andrographis paniculata flour processing

A. paniculata leaf was processed into flour through the following process. The freshly harvested ‘King of Bitter’ leaves were washed to remove dirt and soaked in 1% saline solution (NaCl) for 5 minutes to get rid of microbes. The leaves were drain of excess water and dried under shade to avoid loss of nutrients. The dried sample was milled into flour using Philips laboratory blender (HR2811 model) and stored in an air tight polythene bags for further analysis. Fig. 1 shows the flowchart for the Preparation of the flour blends (Wheat, Pearl Millet and Andrographis paniculata leaf).

2.2.4 Formulation of the flour blends

The wheat and Pearl millet was used as a base material at equal proportion for the preparation of flour mix with varying proportion of Andrographis paniculata leaf flour. The composite flour was formulated with reference to 50% Wheat: 50% Pearl millet standard blend ratio for biscuit production, a method described by Amani [9] and Vaijapurkar et al. (2015) with slight modifications (Table 1).

2.3 Determination of Water Absorption Capacity (WAC) of the Flour Samples

Ten (10) milliliters of distilled water was added to 1 g of the flour sample in a beaker. The suspension was stirred using magnetic stirrer for 3 min. The suspension obtained was thereafter centrifuged at 3500 rpm for 30 min, and the supernatant was measured into a 10 ml graduated cylinder. The water absorbed by the flour was calculated as the difference between the initial volume of the sample and the volume of the supernatant. The WAC was determined according to the equation below (Adebowale et al., [11]).

\[
WAC = \frac{\text{initial volume–final volume of distilled water}}{\text{weight of sample used}} \times 100 \quad (1)
\]

2.4 Determination of Oil Absorption Capacity (OAC) of the Flour Samples

Ten (10) milliliters of vegetable oil was added to 1 g of the flour sample in a beaker. The suspension was stirred using magnetic stirrer for 3 min. The suspension obtained was thereafter centrifuged at 3500 rpm for 30 minutes, and the supernatant was measured into a 10 ml graduated cylinder. The oil absorbed by the flour was calculated as the difference between the initial volume of the sample and the volume of the supernatant. The OAC was determined according to the equation below (Adebowale et al., [11]).

\[
OAC = \frac{\text{initial volume of the oil–final volume of oil}}{\text{weight of the sample}} \times 100 \quad (2)
\]

2.5 Determination of Bulk Density of the Flour Samples

Bulk density was estimated by method described by Onwuka, [12]. Ten (10) gram flour samples was gently filled into 10 ml graduated cylinders. The bottom of each cylinder was tapped gently on a laboratory bench several times until diminution of the sample level ceases after filling to the 10 ml mark. Bulk density was then calculated as weight per unit volume of sample (g/ml).
Bulk density = \frac{\text{weight of sample}}{\text{volume of sample}} \quad (3)

### 2.6 Determination of Least Gelation Concentration (LGC) of the Flour Samples

Series of sample suspensions of increasing concentrations such as 2, 4, 6, 8, 12, 14, 16, 18 and 20% (w/v) were prepared in distilled water (10 mL). All the suspensions were heated gently for 1 h in a boiling water bath followed by cooling at 4°C for 2 h. The suspensions were inverted and the LGC was taken as the concentration at which the inverted suspension did not fall or slip (Coffman and Garcia, [13]).

### 2.7 Determination of Foaming Capacity of the Flour Samples

Foaming capacity was studied as described by (Coffman and Garcia [13]) with slight modifications. One gram of each flour blend was whipped with 60 mL of distilled water for 5 min in a Kenwood blender (Model A907 Dve) at high speed and poured in a 250 mL graduated cylinder. The volume of foam before and after whipping was expressed as foam capacity. The percentage volume increase was calculated

\[
\text{Foaming capacity} = \frac{\text{Volume before whipping} - \text{Volume after whipping}}{\text{Volume of sample}} \times 100 \quad (4)
\]

### 2.8 Determination of Swelling Capacity of the Flour Samples

This was determined as the ratio of the swollen volume to the ordinary volume of a unit weight of the flour. The method of Okaka and Potter [14] with some modifications was used for determining the swelling capacity. The sample filled up to 10 mL mark in a 100 mL graduated cylinder was added with water to adjust total volume to 50 ml. The top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. The suspension was inverted again after 2 min and allowed to stand for further 30 min. The volume occupied by the sample was taken after 30 min.

\[
\text{Swelling index} = \frac{\text{Final volume occupied by sample after swelling}}{\text{Initial volume occupied by sample before swelling}} \quad (5)
\]

### 2.9 Determination of Pasting Properties of the Flour Samples

Pasting properties of flours was determined using a Rapid Visco Analyzer (Model RVA4500). Three grams of the flour samples were weighed into a dried empty canister; 25 mL of distilled water was dispensed into the canister containing the sample. The mixture was thoroughly stirred and the canister was fitted into the RVA as per manufacturer’s instructions. The slurry was heated from 50 to 95°C with a holding time of 2 min followed by cooling to 50°C with 2 min holding time. The rate of heating and cooling was at a constant rate of 11.25°C min⁻¹. The pasting profile was determined with the aid of Thermocline for Windows Software connected to a computer Kaur and Singh, [15].

### 2.10 Determination of pH of the Flour Samples

The pH of the samples was determined by weighing about 5 g of the sample into a beaker, mixed with 20 mL of distilled water. The resulting suspension was stirred for 5 min and left to settle for 10 min. The pH of the water phase was measured using a calibrated pH meter Benesi, [16]

### 2.11 Statistical Analysis

Data were subjected to analysis of variance using SPSS (IBM version. 20.0, SPSS Inc., Quarry Bay, Hong Kong) and presented as means (±SEM). Comparisons between different groups were done using Analysis of Variance (ANOVA) and Duncan’s Multiple Range Test (DMRT). Values of p < 0.05 were considered as statistically significant as described by Yalta and Talha (2008).

### 3. RESULTS AND DISCUSSION

#### 3.1 Functional Properties of Flours from Wheat, Pearl Millet, and Andrographis paniculata Leaf and their Blends

The results of the functional properties of Flours from Wheat, Pearl Millet, and Andrographis paniculata Leaf and their Blends are presented in Table 2. The bulk density of 100% wheat flour (WF) was 0.69 g/ml, which is slightly lower than the bulk density of 0.71 g/cm³ for wheat flour earlier reported by Akubor et al. [17]. The bulk
density for 100% pearl millet flour (PM) and 100% A. paniculata leaf flour (APL) were 0.67 g/ml and 0.47 g/ml respectively. A gradual increase was observed in the bulk density value of the flour blends with values ranging from 0.56 – 0.72 g/ml. WPMAPLF 2 had the highest bulk density and were significantly different (p<0.05) from other flour blends. This implies that the bulk density of WPMAPLF2 offers packaging advantage to the flour because greater quantity of the flour can be packed within a constant volume than other flour blends Fagbemi, [18]; Bolade and Buraimoh, [19]; Fagbemi, [18] and Yemesrach et al., [20]. Bulk density is one of very important functional properties parameter used to determine heaviness of a sample. Due to its direct correlation impact on package materials, bulk density is usually being considered in making choices on packaging requirement and material handling Karuna, et al.,[21]. The Low bulk density of the blends may be considered advantageous when determining transportation cost and space requirement; as less space will be required for packaging of such flour. The water absorption capacity (WAC) of the 100% wheat flour, 100% pearl millet flour and 100% A. paniculata leaf flour were 104.50%, 126.40% and 76.70% respectively (Table 2). The values ranged from 98.33%– 109.34% in the blends (Table 2). It was however observed that WAC of the flour blends increased with increase in A.paniculata leaf flour inclusion. According to Kinsella [22] the ability of food materials to absorb water is linked to its protein content.

Water absorption capacity is important in food where water will be imbibed without dissolution of protein, thus increasing their viscosity and body thickening Seena and Sridhar, [23]. It was observed that addition of A. paniculata leaf flour to wheat-pearl millet based flour confers high water binding capacity which, in turn improves the reconstitution and textural abilities obtainable from flour blends and thus, high WAC of flours is essential in food formulations where absorption of water is desirable. Hence, the highest WAC recorded for sample WPMAPL5 is a reflection of the higher protein content which was absorbs and binds with more water Shakpo et al.,[24].The WAC of the flour blends increase as the level of inclusion of A. paniculata leaf increased. This implies that addition of A. paniculata leaf improves the reconstitution ability of the flour blends, except for the sharp decrease observed for the WPMAPLF5 with WAC value of 67.33%.

Fig. 1. Flowchart for the preparation of the flour blends (Wheat, Pearl millet and Andrographis paniculata leaf)

[Source: Amani (2009) and Vaijapurkar et al. (2014); with slight modifications]
The oil absorption capacity (OAC) of the flour blends were in such food products (Kinsella, [22]; Retainer, thereby increasing the mouth feel of appreciated in foods where oil acts as a phenomenon is best observed in PMF, while APLF had the least value (Table 2). The least OAC value of 79.80% was observed for WPMAPLF4, while the highest OAC value of 116.60 was observed for WPMAPLF2. The OAC result of the flour blends, especially, the increased value observed for WPMAPLF2 implies that the flour blends has an increased functionality in retaining flavor and improvement on the mouth feel.

Solubility is an index of protein functionality such as denaturation and its potential applications Oluwalana et al., [31]. The solubility of the flours from wheat, pearl millet and Andrographis paniculata leaf and their blends were (3.03, 2.50 and 3.65)% and (10.42, 4.41, 8.70, 3.87, 4.20, and 4.61)% respectively as presented in the Table 2.

The swelling index (SI) of the raw materials and the flour blends varied significantly (P < 0.05). The swelling index values obtained for the raw materials for the flour blend ranged from 283.30 to 410.40%, While swelling index for the flour blends ranged from 346.60 to 447.70% (Table 2). The least SI value of 283.30% was observed in APLF, while the highest SI value of 410.40% was observed for WPMAPLF1, WPMAPLF2 and WPMAPLF 3 (87.82, 116.60, and 103.68) respectively. The least OAC value of 79.80% was observed for WPMAPLF4, while the highest OAC value of 116.60 was observed for WPMAPLF2. The OAC result of the flour blends, especially, the increased value observed for WPMAPLF2 implies that the flour blends has an increased functionality in retaining flavor and improvement on the mouth feel.

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Table 2. Functional properties of flours from wheat, pearl millet, and *Andrographis paniculata* leaf and their blends

<table>
<thead>
<tr>
<th>Sample</th>
<th>Foaming capacity (%)</th>
<th>Water absorption capacity (%)</th>
<th>Oil absorption capacity (%)</th>
<th>Solubility (%)</th>
<th>Swelling capacity (%)</th>
<th>Least gelation (%)</th>
<th>Bulk Density (g/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF</td>
<td>34.62 ± 0.01</td>
<td>104.50 ± 0.06</td>
<td>89.90 ± 0.06</td>
<td>3.03 ± 0.04</td>
<td>410.40 ± 0.00</td>
<td>2.00 ± 0.00</td>
<td>0.61 ± 0.01</td>
</tr>
<tr>
<td>PMF</td>
<td>29.63 ± 0.01</td>
<td>126.40 ± 0.06</td>
<td>81.73 ± 0.09</td>
<td>2.50 ± 0.06</td>
<td>349.50 ± 0.00</td>
<td>2.00 ± 0.00</td>
<td>0.67 ± 0.01</td>
</tr>
<tr>
<td>APL</td>
<td>26.92 ± 0.01</td>
<td>76.70 ± 0.01</td>
<td>163.43 ± 0.32</td>
<td>36.50 ± 0.06</td>
<td>283.30 ± 0.06</td>
<td>6.00 ± 0.00</td>
<td>0.47 ± 0.01</td>
</tr>
<tr>
<td>WPMF</td>
<td>23.08 ± 0.08</td>
<td>99.13 ± 0.01</td>
<td>86.50 ± 0.12</td>
<td>10.42 ± 0.04</td>
<td>375.58 ± 0.04</td>
<td>2.00 ± 0.00</td>
<td>0.58 ± 0.05</td>
</tr>
<tr>
<td>WPMAPLF1</td>
<td>34.62 ± 0.01</td>
<td>98.33 ± 0.01</td>
<td>87.82 ± 0.04</td>
<td>4.41 ± 0.02</td>
<td>346.60 ± 0.09</td>
<td>2.00 ± 0.00</td>
<td>0.56 ± 0.00</td>
</tr>
<tr>
<td>WPMAPLF2</td>
<td>18.52 ± 0.01</td>
<td>104.88 ± 0.02</td>
<td>116.60 ± 0.12</td>
<td>8.70 ± 0.00</td>
<td>447.70 ± 0.00</td>
<td>2.00 ± 0.00</td>
<td>0.72 ± 0.14</td>
</tr>
<tr>
<td>WPMAPLF3</td>
<td>18.48 ± 0.04</td>
<td>106.47 ± 0.26</td>
<td>103.68 ± 0.24</td>
<td>3.87 ± 0.27</td>
<td>365.90 ± 0.03</td>
<td>2.00 ± 0.00</td>
<td>0.65 ± 0.03</td>
</tr>
<tr>
<td>WPMAPLF4</td>
<td>19.24 ± 0.01</td>
<td>102.07 ± 0.52</td>
<td>79.80 ± 0.00</td>
<td>4.20 ± 0.00</td>
<td>404.73 ± 0.06</td>
<td>4.00 ± 0.00</td>
<td>0.58 ± 0.01</td>
</tr>
<tr>
<td>WPMAPLF5</td>
<td>15.39 ± 0.01</td>
<td>67.33 ± 0.03</td>
<td>84.73 ± 0.04</td>
<td>4.61 ± 0.01</td>
<td>420.85 ± 0.05</td>
<td>2.00 ± 0.00</td>
<td>0.64 ± 0.01</td>
</tr>
</tbody>
</table>

Results are mean values of triplicate determination ± standard deviation. Mean value within the same column having the same letter are not significantly different at P<0.05.

Where:
- WF - Wheat flour (100%); PMF - Pearl millet (100%); APL - *Andrographis paniculata* leaf (100%); WPMF - Blend of Wheat- Pearl millet at Ratio (50:50)%; WPMAPLF1 - Blend of Wheat- Pearl millet- *Andrographis paniculata* leaf flour at Ratio (49:49:2)%; WPMAPLF2 – Blend of Wheat- Pearl millet- *Andrographis paniculata* leaf flour at Ratio (48:48:4)%; WPMAPLF3 – Blend of Wheat- Pearl millet- *Andrographis paniculata* leaf flour at Ratio (47:47:6)%; WPMAPLF4 – Blend of Wheat- Pearl millet- *Andrographis paniculata* leaf flour at Ratio (46:46:8)%; WPMAPLF5 – Blend of Wheat- Pearl millet- *Andrographis paniculata* leaf flour at Ratio (45:45:10)%
Table 3. Pasting characteristics of flours from wheat, pearl millet, and *Andrographis paniculata* leaf and their blends

<table>
<thead>
<tr>
<th>Sample</th>
<th>Peak Viscosity (RVU)</th>
<th>Trough (RVU)</th>
<th>Breakdown (RVU)</th>
<th>Final Viscosity (RVU)</th>
<th>Setback (RVU)</th>
<th>Peak Time (min)</th>
<th>Pasting Temp(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WF</td>
<td>512.00 ± 0.04</td>
<td>273.00 ± 0.00</td>
<td>239.00 ± 0.01</td>
<td>697.00 ± 0.29</td>
<td>424.00 ± 0.00</td>
<td>5.20 ± 0.00</td>
<td>89.70 ± 0.00</td>
</tr>
<tr>
<td>PMF</td>
<td>858.00 ± 0.01</td>
<td>500.00 ± 0.00</td>
<td>358.00 ± 0.00</td>
<td>1392.00 ± 0.23</td>
<td>892.00 ± 0.00</td>
<td>5.20 ± 0.00</td>
<td>82.35 ± 0.00</td>
</tr>
<tr>
<td>APLF</td>
<td>20.00 ± 0.58</td>
<td>11.00 ± 0.88</td>
<td>9.00 ± 0.58</td>
<td>13.00 ± 0.58</td>
<td>2.00 ± 0.57</td>
<td>5.20 ± 0.00</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>WPMF</td>
<td>658.00 ± 0.57</td>
<td>286.00 ± 1.15</td>
<td>372.00 ± 0.58</td>
<td>923.00 ± 0.57</td>
<td>637.00 ± 0.58</td>
<td>5.07 ± 0.01</td>
<td>84.80 ± 0.06</td>
</tr>
<tr>
<td>WPMAPLF1</td>
<td>563.00 ± 0.57</td>
<td>221.00 ± 0.58</td>
<td>342.00 ± 1.15</td>
<td>702.00 ± 1.15</td>
<td>481.00 ± 0.57</td>
<td>5.07 ± 0.02</td>
<td>84.75 ± 0.03</td>
</tr>
<tr>
<td>WPMAPLF2</td>
<td>497.00 ± 1.15</td>
<td>186.00 ± 0.57</td>
<td>311.00 ± 0.57</td>
<td>586.00 ± 1.15</td>
<td>400.00 ± 5.77</td>
<td>4.93 ± 0.10</td>
<td>84.10 ± 0.83</td>
</tr>
<tr>
<td>WPMAPLF3</td>
<td>466.00 ± 1.14</td>
<td>170.00 ± 2.89</td>
<td>296.00 ± 1.15</td>
<td>525.00 ± 1.15</td>
<td>355.00 ± 0.58</td>
<td>4.80 ± 0.12</td>
<td>83.15 ± 0.56</td>
</tr>
<tr>
<td>WPMAPLF5</td>
<td>483.00 ± 1.73</td>
<td>171.00 ± 0.58</td>
<td>312.00 ± 1.15</td>
<td>521.00 ± 0.58</td>
<td>350.00 ± 2.89</td>
<td>4.80 ± 0.09</td>
<td>83.85 ± 0.06</td>
</tr>
</tbody>
</table>

Results are mean values of triplicate determination ± standard deviation. Mean value within the same column having the same letter are not significantly different at P<0.05.

where:
- WF-Wheat flour (100%);
- PMF-Pearl millet (100%);
- APLF- Andrographis paniculata leaf (100%);
- WPMF- Blend of Wheat- Pearl millet at Ratio (50:50)%;
- WPMAPLF1– Blend of Wheat- Pearl millet-Andrographis paniculata leaf flour at Ratio (49:49:2)%;
- WPMAPLF2 – Blend of Wheat- Pearl millet- Andrographis paniculata leaf flour at Ratio (48:48:4)%;
- WPMAPLF3- Blend of Wheat- Pearl millet- Andrographis paniculata leaf flour at Ratio (47:47:6)%;
- WPMAPLF4– Blend of Wheat- Pearl millet- Andrographis paniculata leaf flour at Ratio (46:46:8)%;
- WPMAPLF5 – Blend of Wheat- Pearl millet - Andrographis paniculata leaf flour at Ratio (45:45:10)%
3.2 Pasting Characteristics of Flours from Wheat, Pearl Millet, and Andrographis paniculata Leaf and their Blends

The pasting properties of Wheat flour, Pearl millet flour and Andrographis paniculata leaf flour and their blends are presented in Table 3. Pasting properties are important in determining the cooking and baking qualities of flour (PBIP, 2005). The pasting properties of gruels made from flours also have direct relationship with the starch content of such flour (Fagbemi, [36]). In Table 3, the peak viscosity of the flour blends ranged from 20 to 6%. The highest value was recorded with APLF and WPMAPLF blends with 4% and 6% respectively. Thus, the gelation power was relatively stable for all the flour blends. These values are still lesser than that reported for great northern bean flour (10%), cowpea (16%) by Sathe and Salunkhe [35].

Least gelation power (%), an index of gelling tendency (ability to form gel) of sample is very important in food preparations. Gelation power for the flour blends ranged from 2 to 6%. The highest value was recorded with APLF and WPMAPLF blends with 4% and 6% respectively. Thus, the gelation power was relatively stable for all the flour blends. These values are still lesser than that reported for great northern bean flour (10%), cowpea (16%) by Sathe and Salunkhe [35].

The break down viscosity is regarded as a measure of the degree of disintegration of starch granules to pasting stability during heating. The value for the raw materials ranged from 9 RVU to 358 RVU (Table 3). APLF had the least value, while PMF had the highest value. The breakdown viscosity of the flour blends ranged from 296 to 372 RVU (Table 3). The breakdown viscosity of the flour blends is significantly different (p < 0.05) compared to the control and was seen to reduce as the level of inclusion of the leaf increases. Higher breakdown values are associated with higher peak viscosities which in turn are related to the degree of swelling of starch granules during heating. 

Breakdown viscosity was highest in the control flour sample and least in WPMAPLF4 (Table 3). Final viscosity of the raw materials flours ranged from 13 to 1392 RVU (Table 3). APLF had the least value of 13 RVU, while PMF had the highest value of 1392 RVU (Table 3). The final viscosity of the flour blends ranged from 521 to 923 RVU (Table 3). WMPF, which is the control sample had the highest value of 923 RVU, followed closely by WPMAPLF1 and WPMAPLF2 with 702 RVU and 586 RVU respectively. WPMAPLF5 had the least final viscosity of 521 RVU as the value was observed to decrease as the level of incorporation of A. paniculata leaf flour in the blend increased. Final viscosity which is used to define the quality of particular starch-based flour, since it indicates the ability of the flour to form a viscous paste after cooking and cooling Adebowale et al., [40]. Final viscosity also gives a measure of the resistance of paste to shear force during stirring Adebowale et al., [41]. The difference between the final viscosity and the trough gives rise to the setback viscosity which correlates with the ability of starches to gel into semi solid paste and it is the phase of pasting curve after cooking. This stage involves re-association of retrogradation, of starch molecules, hence, reduction in dough digestibility for higher setback viscosity and lower tendency of retrogradation for lower setback viscosity (Sandhu et al., [37]).

Setback viscosity of the raw materials ranged from 2 to 892 RVU (Table 3). PMF had the highest setback viscosity, while APLF had the least value. The setback viscosity of the flour blends ranged from 350 to 637 RVU (Table 3). Peak time which is the measure of cooking time ranged from 4.80 to 5.20 min for the raw
materials (Table 3), while peak time for the flour blends ranged from 4.80 to 5.07 min (Table 3).

The pasting temperature is essentially the temperature at the onset of rise in flour viscosity during heating Bolade et al.,[19]. The value for the raw material flours ranged from 0.00 to 89.70°C (Table 3), while that of the flour blends ranged from 83.15 to 84.80°C. The control flour (WPMF) had the highest pasting temperature of 84.80°C, while WPMAPLF4 had the least pasting temperature of 83.15°C. A higher pasting temperature indicates higher water binding capacity, higher gelatinization tendency and lower swelling property of starch-based flour due to high degree of association between starch granules Adebowale et al., [41].

4. CONCLUSION

Based on the observed functional and pasting characteristics observed from the flour blends, the inclusion of Andrographis paniculata leaf flour into wheat-pearl millet based flour as a supplementary ingredient in the food formulations is a step in the right direction as its revealed appreciable reducing and increasing potential effect on both functional and pasting properties of all the flour understudied. The inclusion of A. paniculata leaf flour in the blends revealed a significant general increase in water absorption capacity, oil absorption capacity, swelling capacity, and bulk density. However, a general decrease in the foaming capacity, solubility, and least gelation was observed as the inclusion of A. paniculata leaf flour increased.

The pasting properties of WPMF (flour blend without the inclusion of A. paniculata leaf flour) exhibited the following values: peak viscosity (658 RVU), breakdown (372 RVU), final viscosity (923 RVU), setback (637 RVU), peak time (5.07 min), and pasting temperature (84.8°C). The inclusion of A. paniculata leaf flour in the blends led to a significant general decrease in all the pasting factors. The inclusion of A. paniculata had a significant effect on the functional and pasting properties of wheat-pearl millet based flour.

However, more studies are required to elucidate the nutritional potentials, and health implication of the inclusion of A. paniculata leaf into food matrix and in the production of confectionery products like biscuit, cake, bread, among others. Besides, the findings may be useful to food industries producing functional foods for potential development of functional confectionery products.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES


Available: http://dx.doi.org/10.1023/A:1008153404357


APPENDIX

Pasting property of wheat, pearl millet, and *Andrographis paniculata* leaf and their blends.

**APPENDIX A. Pasting Properties of Wheat Flour**
APPENDIX B. Pasting Properties of Pearl Millet Flour

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APPENDIX C. Pasting Properties of *Andrographis paniculata* Flour

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APPENDIX D. Pasting Properties of Wheat Flour and Pearl Millet Flour (50:50) %

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APPENDIX E. Pasting Properties of Wheat-Pearl Millet- Andrographis paniculata Leaf Flour (49:49:2) %

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APPENDIX E. Pasting Properties of Wheat-Pearl Millet- Andrographis paniculata Leaf Flour (49:49:2) %
APPENDIX F. Pasting Properties of Wheat-Pearl Millet- *Andrographis paniculata* Leaf Flour (48:48:2) %

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APPENDIX G. Pasting Properties of Wheat-Pearl Millet- *Andrographis paniculata* Leaf Flour (47:47:4) %

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APPENDIX H. Pasting Properties of Wheat-Pearl Millet- Andrographis paniculata Leaf Flour (46:46:6) %

APPENDIX I. Pasting Properties of Wheat-Pearl Millet- Andrographis paniculata Leaf Flour (45:45:10) %

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