***Evaluation of Nutritional and Pasting Properties of Composite Flour from Blends of Pearl Millet and Wheat Flours incorporated with Valorized Pineapple Pomace Flour***

.

ABSTRACT

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| **Aims:** Nutritional qualities and pasting properties of flour from blends of pearl millet flour and wheat flour incorporated with valorized pineapple pulp flour were assessed.**Study design:** Four composite flour samples were prepared at different levels of pearl millet flour, wheat flour together with pineapple pomaces incorporations resulting in 100% blends of a completely randomized design.**Place and Duration of Study:** Study was conducted at the Processing Unit of the department of Food Science and Technology, Federal University of Technology, Akure, Nigeria, between 2022 and 2024.**Methodology:** The samples were analysed for their proximate composition (moisture, ash, crude fiber, crude protein, crude fat and carbohydrate contents), pasting characteristics, and bioactive activities (total phenol, total flavonoid and Fe2+ chelation).**Results:** The results showed that the composite flour were shelf stable with moisture content around 10%. In addition, the ash and crude contents fibre improved with decreasing wheat flour contents but with increasing pearl millet and pineapple pomace contents. The results revealed that wheat flour is the primary source of protein as sample MFP with 50 % Pearl millet flour, 50 % Wheat flour and 0 % Pineapple pomace had the highest protein content (8.23%). Pearl millet also contributed significantly to the protein content. Pearl millet and pineapple pomace considerable increased the bioactive activities (total phenol, total flavonoids and Fe2+ chelation activity). Pearl millet also resulted in better pasting activities.**Conclusion:** It is therefore possible to produce composite flour consisting of better proximate composition, pasting properties and antioxidants properties with lower wheat flour contents but with pearl millet and pineapple pomace contents. |

*Keywords: bioactive activity, composite flour, pasting properties, pearl millet, pineapple pomace, proximate composition,*

1. INTRODUCTION

Bread is a basic staple food that is widely eaten all over the world, serving as the main source of energy and nutrients (Prassad et al., 2024). However, bread that is primarily prepared from wheat flour has some drawbacks such as complete nutrients, cost of production and people with celiac diseases. Composite flour formulation has been developed to address the drawbacks (Awolu, 2017; Bamigbola et al., 2016; Kamel *et al*., 2018).

“Worldwide, consumption of ready-to-eat convenient and inexpensive gluten-free snacks and baked food products from cereals, tubers and legumes is increasing” (Awolu et al., 2016b) “This was aimed at diversification of the consumption of wheat-based food products due to incidences of celiac disease and economic challenges” (Awolu et al., 2015; 2016b)

“Trends on the use of non-wheat flours for bread production has led to researches on improving the rheological characteristics of such non-wheat flours” (Oloniyo et al., 2021)

“Pearl millet (Pennisetum glaucum) is a species of millet widely grown in Nigeria; Nigeria being the world’s third largest producer after India and Niger” (FAO, 1995). “Millets generally have been discovered to be rich in dietary fibre, minerals, phytochemicals (especially phenolic compounds) and vitamins which make them to be health promoting” (Saleh et al.,2013). “Millets have been incorporated into wheat in the production of bread, biscuits, and ready-to-eat snacks” (Awolu, 2017; Saha et al.,2011).

“Pomaces are solid waste by-products of fruits and are rich in dietary fiber. They can be obtained from fruits after they have been processed to make juice, pulps, jams and jellies” (Awolu et al., 2016b; Nagarajaiah and Prakash, 2016). “They are globally recommended for their health benefits” (Wang et al., 2002; Charoenthaikij et al., 2010). “Pomace fibre possesses unique functional properties that can modify the texture, taste, and shelf life of food products.

Pomaces offer a rich source of bioactive ingredients with excellent technological and nutritional properties” (Awolu and Osigwe, 2019; Awolu et al., 2020). “Their affordability and versatility make them ideal components or additives in food products, and they are also cost-effective” (Homayouni et al., 2013). “However, pineapple (Ananas comosus) pomace is mainly produced as canned fruit and consumed fresh” (Tran, 2006). The increasing production of processed pineapple and citrus juice produces massive waste and by-products.

“Plants comprising of beneficial phytochemicals may supplement the needs of the human body by acting as natural antioxidants” (Panche et al., 2015). “Functional diets rich in plant-based foods have

been suggested as a safer strategy for managing several diseases caused by oxidative stress due to the presence of high bioactive compounds in the plants” (Awolu and Oladeji, 2021; Ogundele et al., 2016). “Interestingly, several food wastes are rich in bioactive compounds and so are being employed in the preparation of functional foods” (Awolu et al., 2019; Sharma et al. 2017).

This study aimed at producing pearl millet-based flour for potential use in baked food production. The pearl millet was composited with wheat flour and pineapple pomace flour. The inclusion of pineapple pomace was to improve the nutritional and rheological properties of the pearl millet-based composite flour.

2. material and methods

**2.1 Materials**

Wheat flour, pearl millet (*Pennisetum glaucum L*), and pineapple were purchased from Oja-Oba, Akure, Ondo State, Nigeria. Pearl millet and pineapple were authenticated at the Department of Food Science and Technology, Federal University of Technology, Akure, Ondo State, Nigeria. The reagents used for the analyses were of analytical grade.

## **2.2 Preparation of pearl millet flour**

## The method of Jideani (2005), modified by Awolu (2007) was used. Pearl millet seeds (1Kg) was sorted and thoroughly washed using warm (65 °C) water. It was later oven-dried (thermostated oven, Model MC-1959K, China) at 50 °C for 24h, milled using locally fabricated attrition mill and passed through 200 μm sieve in order to obtain fine pearl millet flour, stored in a sealed plastic container at room temperature for further processing.

## **2.3 Pineapple Pomace Preparation**

Pineapple (*Annanas comosus*) pomaces were prepared in the Food Processing Laboratory, Department of Food Science and Technology, Federal University of Technology, Akure, Ondo State, Nigeria. The pineapple was washed, peeled, and oven-dried (Model 320, Gallenkamp, England) at 80 °C for 12 h and milled (Asiko Attrition Mill, Lagos, Nigeria; Serial No A11). The pineapple pomace powder was sieved using 500 µm aperture sieve and packed in an air-tight container until it was used (Awolu et al., 2019; Arijit et al., 2020).

**2.4 Blends formulation**

The blending ratios of the raw materials (pearl millet flour, wheat flour and pineapple pomace flour) for the composite flour blends are presented in Table 1.

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**Table 1. Formulation of Composite Flour Blends**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sample** | **Pearl Millet Flour** | **Wheat Flour** | **Pineapple Pomace Flour** |
| PFP | 75% | 25% | 0% |
| PMF | 75% | 15% | 10% |
| MFP | 50% | 50% | 0% |
| PWP | 50% | 45% | 5% |

**2.5 Determination of Proximate Composition**

The proximate composition, including moisture, ash, protein, fat and fiber contents of the flour samples, were determined using Official Methods of Analysis of AOAC International (AOAC, 2005). The carbohydrate content was determined by subtracting the moisture, ash, protein, and fat percentage from hundreds

**2.6 Evaluation of Pasting Properties**

The pasting characteristics were determined by using Micro- Visco- Amylograph (model 803201 by Brabender, Germany) according to the standard AACC (2000) methods. About 15 g of the sample was mixed with 100 mL of water. The sample was placed inside the amylograph and allowed to run for about 27 min.

**2.7 Determination of Antioxidant Properties**

Sample extracts were prepared using acidified methanol (1% HCl in methanol). It was extracted using 50 mL of solvents with 0.5 g of the sample. The sample was stirred for 4 h on a shaker, centrifuged at 3500 rpm for 10 min (25 ◦C) in a 40 mL plastic centrifuge tube, and the supernatants were decanted into a clean, dried container. Thus, the decanted supernatants were used to determine antioxidant properties.

***Total phenol content (TPC):*** Phenolic content of samples was determined by the Folin–Cicolteau reagent according to Bastos et al. (2006). The concentration was calculated using gallic acid as standard. Phenolic content was measured at 760 nm and was expressed as mg gallic acid/100 g sample.

***Determination of total flavonoids:*** Total flavonoid content of the samples was determined using the aluminum chloride (AlCl3) colorimetric method described by Bastos et al. (2006) with minor modifications. Briefly, 1 mL of the extract (1 mg/ mL in methanol) or a standard quercetin solution (20, 40, 60, 80, and 100 mg/l) was mixed with 1 mL of 2% AlCl3 in methanol. After 40 min of

staying at room temperature (23 ± 2 ◦C), the absorbance against blank was measured at 430 nm

 using a Spectrophotometer

***Determination of iron chelating activity*:** The iron chelating activity was determined according to the method of Haro-Vicente et al. (2006). Extract (1 mL) was added to 100 μl of 1 mM FeSO4⋅7H2O. The reaction mixture was left at room temperature for 2 min. After which 0.5 mL of 1, 10-phenanthroline (0.5 mM) was added, and the mixture was incubated for 10 min at room temperature. The absorbance was read at 510 nm.

**Statistical Analysis**

SPSS v. 21 (IBM SPSS Statistics, US) was used to statistically examine the results. The mean and standard deviation of the samples were determined and One-Way Analysis of Variance (ANOVA) was done for comparison. However, the statistically significant difference of all samples analyzed were performed (p≤0.05).

3. results and discussion

**3.1 Proximate composition of the flour samples**

The moisture contents of the samples ranged from 8.55% to 11.79%. There were no significant (p> 0.05) differences in the moisture contents of samples PFP, MFP and PWP. Since the moisture content of sample MFP was around 10%, and was not significantly different from those of samples PFP and PWP, it can be inferred that the moisture contents of the samples indicated shelf stable samples since moisture contents of 10% and below have been reported to be shelf stable (Akhtar et al. 2008; Elleuch et al. 2011).

The values of the moisture contents also indicate that the flour samples would sufficiently support biochemical activities at dried shelf stable state.

The presence of wheat flour in the composite flour enhances the protein contents more than the other raw materials. Protein plays vital roles in the nutritional composition of foods. In addition, Protein is an important component that enhances the rheological properties of composite flours (*Bakare et al*., 2016). It has also been reported that decreasing wheat contents in composite flour leads to decreased protein and gluten contents (Bakare et al., 2016)

The ash contents were considerable, and serves as index for mineral contents in the samples. Increase in ash content has been reported with reduction in wheat content of a composite flour (Bakare et al., 2016; Olatunji and Akinrele, 1978) Flour samples with rich minerals composition are advantageous in preparation of weaning food formulations.

Crude fiber is needed for gut health and has an effect of reducing blood sugar levels. Among the characteristics, it is stipulated that the addition of Sample PMF increases the fiber content in the bread (8.00%), which can positively affect the functional features of the product’s properties, including texture and satiety.Recommended globally for its health benefits pomace fiber possesses unique functional properties  modifying the texture, taste, and shelf life of food products, such as water-holding capacity, gel-forming ability, fat mimetic properties, thickening characteristics, and anti-staling benefits (Charoenthaikij *et a*l., 2016: Sabanis *et al*., 2009).

The percentage of fat is found to be highest in sample PWP, which can improve the calorie value as well as the taste of the final bread product. Carbohydrate contents are considerably high as required for flour products for production of baked food products. High carbohydrate contents contribute to high calorific contents of the foods.

**Table 2. Proximate composition of composite flour samples**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Sample | Moisture (%) | Protein (%) | Ash (%) | Fibre (%) | Fat (%) | CHO (%) |
| PFP | 11.59±0.28a | 7.12±0.10a | 2.80±0.10c | 6.70±0.02b | 2.04±0.10c | 69.83±0.50a |
| PMF | 8.55±0.63b | 5.60±0.80b | 4.90±0.12b | 8.00±0.10a | 4.03±0.10b | 68.96±1.32a |
| MFP | 10.87±0.30a | 8.23±0.62a | 5.31±0.12a | 5.70±0.01c | 4.85±0.12a | 65.10±0.34b |
| PWP | 11.74±0.30a | 7.2±0.10a | 1.90±0.05d | 5.70±0.01c | 5.10±0.13a | 68.41±0.11a |

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

***KEYS:***

PFP (75 % Pearl millet flour, 25 % Wheat flour and 0 % Pineapple pomace),

PMF (75 % Pearl millet flour, 15 % Wheat flour and 10 % Pineapple pomace),

MFP (50 % Pearl millet flour, 50 % Wheat flour and 0 % Pineapple pomace),

PWP (50 % Pearl millet flour, 45 % Wheat flour and 5% Pineapple pomace).

**3.2. Pasting Properties of Composite Flour samples**

The pasting characteristics of the flour blends are presented in Table 2. Sample PFP had the best viscosity characteristics judging from the peak viscosity, trough viscosity, final viscosity and pasting temperature. The peak viscosity represents the pastes strength from gelatinization; it is the maximum viscosity attained during cooking (Adebowale et al., 2011).

The holding strength is the minimum viscosity after the peak, and a measure of the ability of granules to remain undisrupted during holding at high temperature (92oC) and high mechanical shear stress (Adegunwa et al., 2012). Holding period has been reported to be accompanied by breakdown in viscosity also known as the trough, hot paste viscosity, shear thinning, or paste stability. A lower breakdown viscosity is required, as it signifies a higher stability (Adegunwa et al., 2012).

The pasting temperature represents the temperature at which the viscosities first increase by at least two RVU over 20 s periods (Adegunwa et al., 2012). It is an indication of the temperature required to cook the starch (Adegunwa et al., 2012), or the minimum temperature at which starch granules in the flour swell (Awolu, 2017).

Setback viscosity corresponds to retrogradation (a realignment of the crystalline structure of starch during cooling) and leads to syneresis and staling.

Unfortunately, sample PFP had the highest breakdown and set back viscosities. Sample PFP had 75% pearl millet in the blends without pineapple pomace. It can be inferred therefore that pearl millet promotes the pasting properties of samples which means it is a potential source of raw materials for the development of non-wheat flour blends. One of the factors affecting the development of non-wheat composite flour is the challenges of low viscoelastic properties. However, in this study, pearl millet flour displayed a very good pasting characteristics.

Sample MFP with 50% pearl millet flour and 505 wheat flour performed next to sample PFP in terms of its pasting characteristics. However, samples PMF and PWP showed that addition of pineapple pomace had negative effects on the pasting characteristics of the samples.

**Table 3. Pasting properties of Composite Flour samples**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Sample | Peak Viscosity | Trough Viscosity | Breakdown Viscosity | Final Viscosity | Setback Viscosity | Pasting Temperature | Pasting Time |
| PFP | 4419.00±0.01a | 2371.00±0.01a | 2048.00±0.02a | 4697.00±0.03a | 2326.00±0.01a | 77.35±0.02d | 5.60±0.01c |
| PMF | 2068.00±0.02c | 1318.00±0.01c | 750.00±0.03d | 2397.00±0.01c | 1079.00±0.02c | 78.25±0.01b | 5.20±0.02d |
| MFP | 3035.00±0.01b | 1862.00±0.03b | 1173.00±0.01b | 3303.00±0.01b | 1441.00±0.01b | 77.45±0.02c | 6.00±0.03a |
| PWP | 1940.00±0.01d | 1152.00±0.02d | 788.00±0.01c | 2136.00±0.02d | 984.00±0.01d | 79.05±0.01a | 5.93±0.01b |

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

***KEYS:***

PFP (75 % Pearl millet flour, 25 % Wheat flour and 0 % Pineapple pomace),

PMF (75 % Pearl millet flour, 15 % Wheat flour and 10 % Pineapple pomace),

MFP (50 % Pearl millet flour, 50 % Wheat flour and 0 % Pineapple pomace),

PWP (50 % Pearl millet flour, 45 % Wheat flour and 5% Pineapple pomace).

**3.3 Antioxidant Properties of the yoghurt samples**

Reduction of wheat flour and increase of pineapple pomace in the pearl millet-based samples significantly (p≤ 0.05) increased the phenolic contents (Fig. 1). Samples PMF and PWP with reduced wheat flour incorporation but increased pineapple pomace incorporation showed better phenolic contents, and hence antioxidants activities.

Total phenolic contents are important plant constituents with redox properties responsible for antioxidant activities (Aryal, 2019). Free radicals and other reactive oxygen species contribute to the development of many diseases (Shahidi and Naczk 2004). Phenolics are capable of scavenging free radicals, chelate metal catalysts, activating antioxidant enzymes, reducing α-tocopherol radicals, and inhibiting oxidases (Amic et al., 2003).

Phenolic compounds scavenge free radicals by donating hydrogen atoms to free radicals; hence, may protect cell constituents against oxidative damage and limit the risk of various degenerative diseases associated with oxidative stress (Anderson and Wolf 1995).

Flavonoids are polyphenolic molecules synthesized by plants. They are powerful antioxidants with

anti-inflammatory and immune system benefits (Melgar et al., 2018) causing modulation and prevention of oxidation produced by free radicals within the body cells. Samples with pineapple pomaces (PMF and PWP) showed (Fig. 2) great flavonoids activities far and above those without pineapple poamces (PFP and MFP)

It has been reported that Fe2+ reducing power is associated with the antioxidant activity and this relationship has been established with numerous bioactive compound isolated from natural plants (Siddhurajua, 2006). Pearl millet definitely showed good Fe2+ chelating activities. There are considerable Fe2+ chelating activities from the pineapple pomace too (Fig. 3). Over all, all the samples showed good antioxidants potentials.

Fig1: Antioxidant (phenol) analysis (mg GAE/g)

***KEYS:***

PFP (75 % Pearl millet flour, 25 % Wheat flour and 0 % Pineapple pomace),

PMF (75 % Pearl millet flour, 15 % Wheat flour and 10 % Pineapple pomace),

MFP (50 % Pearl millet flour, 50 % Wheat flour and 0 % Pineapple pomace),

PWP (50 % Pearl millet flour, 45 % Wheat flour and 5% Pineapple pomace).

Fig. 2: Flavonoid contents of samples

***KEYS:***

PFP (75 % Pearl millet flour, 25 % Wheat flour and 0 % Pineapple pomace),

PMF (75 % Pearl millet flour, 15 % Wheat flour and 10 % Pineapple pomace),

MFP (50 % Pearl millet flour, 50 % Wheat flour and 0 % Pineapple pomace),

PWP (50 % Pearl millet flour, 45 % Wheat flour and 5% Pineapple pomace).

Fig. 3: Fe2+ Chelation activities of samples

***KEYS:***

PFP (75 % Pearl millet flour, 25 % Wheat flour and 0 % Pineapple pomace),

PMF (75 % Pearl millet flour, 15 % Wheat flour and 10 % Pineapple pomace),

MFP (50 % Pearl millet flour, 50 % Wheat flour and 0 % Pineapple pomace),

PWP (50 % Pearl millet flour, 45 % Wheat flour and 5% Pineapple pomace).

4. Conclusion

This study gives a boost to composite flour development with potentials of using lowr whaet flour contents and using pearl millet flour. Further incorporation with pineapple pomace sufficiently improved the bioactive activities and cfrude fibre contents. Pearl millets also increased the pasting properties as well as ash contents, protein contents and crude fibre contents. Therefore, pearl millet flour, wheat flour and pineapple pomace could serve as potential raw materials for production of composite flour with improved nutritional (antioxidants and proximate) properties and viscoelastic characteristics.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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