Functional and Pasting Characteristics of Flour Blend from Wheat, Mushroom (*Pleurotus ostreatus*) and Unripe Plantain (*Musa paradisiaca*) Flour

[1]Folusho O. Ajala, *[1]Grace O. Ogunlakin, [2]Grace O. Babarinde and [1]James A. Adeyanju
[1]Department of Food Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.
[2]Department of Food Science, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.
foluyemzy@gmail.com|{googunlakin|gobabarinde|jaadeyanju}@lautech.edu.ng

ORIGINAL RESEARCH ARTICLE

Abstract- The functionality of blended samples is likely to be affected by incorporating other flour into wheat flour for baked goods, meanwhile this has not been fully researched. Therefore, the purpose of this study was to ascertain the functional and pasting qualities. of flour from wheat, mushroom and unripe plantain so as to maximize its potentials in baking industry. Using response surface methodology (optimal mixture design), different formulations were created from wheat, mushroom, and unripe plantain flour mixes. The ranges of values for bulk density (BD), water absorption capacity (WAC), swelling capacity (SC), solubility index (SI), dispersibility and least gelation concentration of the blends were 0.74-0.80 g/cm^3, 76.15-94.63%, 478.45-574.01%, 8.10-13.72%, 73.30-77.50% and 15.60-20.70%, respectively. The ranges of values for pasting properties: peak, trough, break-down, final-viscosity, setback, peak time and pasting temperature were 842-1727, 473-926, 368- 806, 1190-1875, 716 -989 RUV, 5.46- 5.87 min and 80.90 -91.85 °C, respectively. The flour blend formulation, 80:10:10 (wheat: mushroom: unripe plantain) gave best functional properties in terms of bulk density, water absorption capacity and swelling capacity and comparable well with 100% wheat flour. The result therefore showed that quality flour blend obtained from wheat, mushroom and unripe plantain has improved functionality than the individual wheat flour. This will be a valuable element in the formulation of foods such thick dough, soups, and baked goods.

Keywords- Wheat, Mushroom, Unripe plantain, Flour blends, Functional properties

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1 INTRODUCTION

The utilization of local and underutilized crops to develop composite has gotten a lot of attention in food product development research (Ajani *et al*., 2016; Jafari *et al*., 2018; Gbenga-Fabusiwa *et al*., 2018; Emmanuel *et al*., 2019; Hasmadi *et al*., 2020). This has really helped in lessening total dependence on imported wheat. Composite flour is a blend of flours derived from legumes, tubers, vegetables, cereals, and protein-rich flour, which may or may not contain wheat flour, that was developed to satisfy the functional and nutritional needs of a given food (Noorfarahzilah *et al*., 2014).

Wheat is a grain of the Graminae family. It is more popular than other cereals because of its functionality in baking industry. In many baking procedures, wheat flour is the main ingredient and basic material (Okpala and Egwu, 2015). The amount of wheat produced yearly exceeds the amount of any other grain or food crop that is consumed as flour, primarily in the form of breads (FAO, 2013). Mushroom is also called white vegetables or boneless vegetarian meat. They fall between the best vegetables and animal protein source (Manjunathan and Kaviyarasan, 2011). Mushroom is rich in proteins, fibres, minerals and vitamins and abundant in essential amino acid (Jayachandran *et al*., 2017).

*Corresponding Author

According to Mhanda *et al*. (2015), it is a source of quality protein, has about 44.93% and thus will supplement well a cereal-based diet. Mushroom can be used to battle protein malnutrition in cereal-dependent developing countries because of its quality protein (FAO 1996). The value of mushroom protein is two times as that of potatoes and asparagus, four times as that of carrots and tomatoes (Kakon *et al*., 2012). Mushrooms have been used for centuries as human food, being valued predominantly for their array of textures and flavours.

Plantain (*Musa paradisiaca*) is grown traditionally in West Africa as a source of local staple diets. It can be transformed into more imperishable products like flour which can be kept for future use (Kwofie *et al*., 2020). Plantain is a starchy main food crop in Nigeria that feeds millions of people. Apart from the dietary fibre, plantains contain minerals that are essential such as sodium, potassium and various vitamins. Plantains, when processed to flour or chips, could be possible food options for obese individuals (Mepba *et al*., 2007). It is a prominent dietary staple food in Nigeria, due to its adaptable and quality nutritional characteristics, where it is consumed mainly as snacks (*dodo*) and also processed into chips to make flour for stiff dough.

For composite flours to be applied in the production of food product, a foreknowledge of their performance is required as inappropriate knowledge of these functionalities may result in products with varying consumer acceptability (Iwe *et al*., 2017). For efficient utilization and acceptance of wheat, mushroom and unripe plantain composites flour, studies on its desirable functional properties are important as their application to produce baked goods is primarily governed by these

properties. If the composite flour is suitably defined in terms of pasting and functional behaviour, substituting wheat flour with unripe plantain and mushroom flours for product development could be successful.

Several studies have been conducted in investigating the pasting and functional characteristics of composite flours made by substituting wheat flour with locally available crops or completely made from local crops (Mepba *et al.*, 2007; Julianti *et al.*, 2017; Meka *et al.*, 2019; Peter-Ikechukwu *et al.*, 2020; Asouzu *et al.*, 2020) but no work has been done using mushroom and plantain flours. As a result, this study was conducted in order to promote the use of composite flour derived made from indigenous crops such as mushroom and unripe plantain because of their nutritional quality and availability. This study, therefore aimed at providing information on the functional and pasting characteristics of flour blend developed from wheat, mushroom and unripe plantain with the intention of establishing the full industrial potential of these composite flours for utilization in bakery and pastry food products.

2 MATERIALS AND METHODS
2.1 MATERIALS
Fresh mushrooms were sourced and purchased from balance diet cold store, Ibadan while unripe plantain, wheat flour (Honeywell brand), margarine, baking powder, table salt, granulated sugar, and eggs were purchased at a market in Ibadan.

2.2 MUSHROOM FLOUR PREPARATION
The mushrooms were washed and with a knife chopped into small pieces, then blanched in boiling water at 80 °C for 3 min and the water was emptied out. They were spread out in trays, which were dried (55 °C, 9 h) in a cabinet drier, and then cooled to ambient temperature. The dried mushroom was ground after cooling, sieved (200 μm) and packaged in an air-tight container until ready for use (Singh and Thakur, 2016).

2.3 PLANTAIN FLOUR PREPARATION
Plantain flour was prepared using Falade and Olugbuyi (2010) method with slight modifications. Matured plantain fruits were peeled with kitchen knives (stainless-steel), and the pulp was cut into 1.5 mm thick uniform slices, which were blanched (80 °C, 5 min) in order to avoid browning and the water was then emptied from them. The samples were dried at 55 °C for 24 h in a cabinet dryer (Olaoye *et al.*, 2006). The dried samples were hammer-milled, sieved (200 μm), and stored in an air-tight container for subsequent processing.

2.4 EXPERIMENTAL DESIGN AND FLOUR FORMULATION
The design of the experiment was done with response surface methodology (RSM- Design expert 6.0. Stat Ease Inc Minneapolis, USA) using optimal mixture design. The following were the independent variables in the design: wheat flour (80-100%), mushroom flour (0-20%) and plantain flour (0-20%) while the functional and pasting

features were the dependent variables. The experimental design generated 10 runs (Table 1)

Table 1. Flour blend formulations from the optimal mixture model of RSM

Run	Wheat flour (%)	Mushroom flour (%)	Plantain flour (%)
1	86. 67	6.67	6.67
2	80.00	0.00	20.00
3	83.33	13.33	3.33
4	90.00	10.00	0.00
5	90.00	0.00	10.00
6	93.33	3.33	3.33
7	83.33	3.33	13.33
8	80.00	10.00	10.00
9	80.00	20.00	0.00
10	100.00	0.00	0.00

2.5 FUNCTIONAL PROPERTIES OF FLOUR BLENDS
The bulk density was calculated using the approach of Asoegwu *et al.* (2006). The flour mixture was placed in a 25 cm³ graduated cylinder, gently tapped 10 times on the flat bench top to pack it and new sample volume was recorded. The mass of the flour was divided by the bulk volume to get the bulk density value.

The water absorption capacity (WAC) of flour mixes was evaluated using the method of Onwuka (2005). Each sample (1 g) was measured into a tube and well mixed with 10 cm³ of water using a warring whirl mixer for 30 min. The mixture was left for 30 min at ambient temperature which then centrifuged at 5000 rpm for 30 min. The volume of supernatant was noted, then decanted into crucible and dried in oven at 105 ⁰C until the supernatant was dried off, which was cooled by being placed in a desiccator. The residue in the tube was weighed as well as the crucible dried with the supernatant and WAC was computed by dividing the weight of centrifugated tube minus the weight of the tube with the weight of the sample.

Islam *et al.* (2012) method was adopted to determine the swelling index of the formulated flour. Twenty-five grams of the sample was filled in a 200 cm³ of graduated cylinder. One hundred and fifty millilitres (150 cm³) of cold water were poured into it, allowed to rest for 2 h and the level of swelling was observed. Adebowale *et al.* (2005) method was used to determine the least gelation concentration (LGC) of each sample. Sample suspension of 2 to 20% (w/v) was poured into 5 cm³ distilled water. The tubes that contained the suspensions were heated for one hour inside the boiling water (100 °C) and rapidly cooled in ice (4 °C) for 24 h. LGC was determined to be the concentration when the sample from inverted tube did not slip or fall down.

2.6 PASTING PROPERTIES OF FLOUR BLENDS
Rapid Visco Analyser (RVA) as described by Oyarekua (2009) was adopted to evaluate pasting properties of the samples. Three grams (3 g) of the sample was weighed

into canister and dissolved with 25 cm^3 distilled water. This was heated uniformly from 25 to 95 °C and held for 15 min. It was then cooled at 50 °C and the variables: peak, trough, breakdown, final viscosity and setback, peak time and pasting temperature were measured.

2.7 STATISTICAL ANALYSIS
The experiment of this study followed a Completely Randomized Design (CRD) and the significant differences were assessed using analysis of variance (one-way). The Duncan's New Multiple Range Test was used to separate the means of the results obtained with 5% level of significance, using the Statistical Package for Social Sciences (SPSS) version 16.

3 RESULT AND DISCUSSION
3.1 FUNCTIONAL PROPERTIES OF FLOUR BLEND
The results for functional characteristics of flour blends (wheat, mushroom and unripe plantain flours) are shown in Table 2. The bulk density had the range of 0.74-0.80 g/cm^3, with flour blend 80:20:0 (wheat: mushroom: unripe plantain flour) having the least value while flour blend 90:0:10 (wheat: mushroom: unripe plantain) and 80:10:10 (wheat: mushroom: unripe plantain), the highest value. The absence of plantain flour may be responsible for the lower value observed in sample 80:20:0. In this investigation, the bulk density results of the formulations were found to differ (p<0.05) significantly from each other. The values in this finding were found greater than the values in previous study of Omoniyi et al. (2016) with the range 0.59-0.68 %, for flour mixes of sweet-potato and soybean.

The range of values obtained for the water absorption capacity was 76.15-94.63% for all flours blends. The values obtained are significantly (p<0.05) differ from each other. The absorption capacity was observed lowest in flour blend 90:0:10 (wheat: mushroom: unripe plantain) and highest in blend 80:20:0 (wheat: mushroom: unripe plantain). However, it was discovered that increasing the amount of mushroom and unripe plantain flour in the flour blend enhanced the WAC of the mixture. The values obtained were slightly lower than those of Bamigbola et al. (2016) for wheat, plantain and tiger-nut flour blends.

The swelling capacity of wheat, mushroom, and unripe plantain flour mixes ranged from 478.45 to 574.01%, with sample 93.33:3.33:3.33 (wheat: mushroom: unripe plantain) showing the lowest value and sample 80:10:10 (wheat: mushroom: unripe plantain) with the highest swelling capacity value. It was observed that the mushroom flour contributed to increase in the swelling capacity but the substitution of both mushroom and plantain flour in equal proportion gave a higher value of swelling capacity. The swelling capacity of flours is said to be dependent on some factors which includes formulation and processing methods (Chandra and Samsher, 2013).

The results of solubility content ranged from 8.10 to 13.72% with flour blend 80:20:0 (wheat: mushroom: unripe plantain) having the least value and blend 83.33:3.33:13.33 (wheat: mushroom: unripe plantain) having the highest value. Water solubility index results were significantly (p<0.05) different from each composite flour blend. Solubility which is an indication of degree of dispersion of granules after cooking (Bankole et al., 2013) and as well as denaturation, which is a measure of protein functionality, increased as mushroom flour was substituted and declined as plantain flour was substituted.

The dispersibility, which indicates the reconstitution ability of the samples in water according to Otegbayo et al. (2013), ranged from 73.30 to 77.50%. Flour blend with 80:0:20 (wheat: mushroom: unripe plantain) had the lowest dispersibility value while the blend with 83.33:3.33:13.33 (wheat: mushroom: unripe plantain) the highest of dispersibility. The mean value for least gelation concentration, which is the capability of flour blend to form gel ranged between 15.60 and 20.70% with 100% wheat having the lowest and 80:20:0 (wheat: mushroom: unripe plantain). This characteristic provides a structural matrix for storing water and other water-soluble components such as sugars, flavours etc (Ata and El-Shenawi, 2013). The lower the minimum gelation concentration, the more effectively a protein component can gel according to Akintayo et al. (1999) and the capability of the flour blend to swell will also be enhanced as Kaushal et al. (2012) reported.

3.2 PASTING PROPERTIES OF COMPOSITE FLOUR
The pasting properties of wheat, mushroom, and unripe plantain composite flours results were shown in Table 3. The range of value of peak viscosity of the flour formulations was 842-1727 RVU with the lowest value found in flour blend 80:20:0 (wheat: mushroom: unripe plantain) and highest value in 80:0:20 (wheat: mushroom: unripe plantain) flour blends. In this investigation, there were significant (p<0.05) differences in the results. Peak viscosity is the capacity of starch to expand freely before it starts breaking down physically (Sanni et al., 2004). The peak viscosity reduction might be as result of a decrease in carbohydrate content and a change in protein concentration, both of which might affect this viscosity measure.

Trough is the viscosity at which the sample cools down to its lowest point after the initial peak The trough values that ranged between 473 and 926 RVU are the viscosity of the flour blend pastes in terms of its capacity to withstand disintegration during cooling. Flour blend 80:20:0 (wheat: mushroom: unripe plantain) had the least value while blend 90:0:10 (wheat: mushroom: unripe plantain), the highest. This study showed that decreasing mushroom flour substitution lowered trough viscosity while increasing plantain flour substitution raised trough viscosity. Trough and breakdown are paste features that reflect the ability of a food material to remain undamaged when exposed to prolonged periods of high temperatures, as well as its ability to tolerate breakdown during cooking (Adegunwa et al., 2014).

The mean values of breakdown viscosity in this finding had the range of 368-806 RVU. The flour sample 80:20:0 (wheat: mushroom: unripe plantain) had the least value while flour blend 80:0:20 (wheat: mushroom: unripe plantain), the highest breakdown viscosity value. The lower breakdown values observed in this finding could be due to the higher protein content of the flour blend, which occurs from incorporation of mushroom flour. Final viscosity results ranged from 1190 to 1875 RVU with flour blend 80:20:0 (wheat: mushroom: unripe plantain) having the minimum value and blend 83.33:3.33:13.33 (wheat: mushroom: unripe plantain) with the highest value. The value of final viscosity of the flour samples fell as the amount of mushroom flour substituted increased.

Table 2. The results of functional properties of the flour blends

WF (%)	MF (%)	UPF (%)	Bulk Density (g/cm³)	WAC (%)	Swelling Capacity (%)	Solubility (%)	Dispersibility (%)	LGC (%)
86.67	6.67	6.67	0.76^d	78.10^g	521.69^e	8.01^i	77.25^a	17.30^d
80	0	20	0.77^c	81.55^e	496.00^h	9.90^f	73.30^f	16.35^{gf}
83.33	13.33	3.33	0.77^c	88.35^b	523.00^d	13.72^a	75.00^d	19.20^b
90	10	0	0.78^b	83.02^c	494.09^i	13.72^a	75.10^c	17.65^c
90	0	10	0.80^a	76.68^h	503.83^g	9.74^g	74.50^e	16.15^g
93.33	3.333	3.333	0.77^c	78.15^g	478.45^j	9.04^h	75.70^b	16.85^e
83.33	3.33	13.33	0.79^a	78.28^f	533.33^c	9.97^e	77.50^a	16.50^f
80	10	10	0.80^a	83.31^c	574.01^a	11.81^b	75.50^c	18.92^b
80	20	0	0.74^e	94.63^a	544.72^b	10.77^d	74.50^e	20.70^a
100	0	0	0.78^b	81.74^d	514.94^f	10.81^c	76.25^b	15.60^h

In the same column, mean values with different superscripts differ significantly at $p<0.05$.
WF: Wheat Flour, MF: Mushroom Flour, UPF: Unripe Plantain Flour, WAC: Water Absorption Capacity

Table 3. The result of pasting properties of the flour blends

WF (%)	MF (%)	UPF (%)	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Set Back (RVU)	Peak Time (min)	Pasting temp. (°C)
86.67	6.67	6.67	1480.00^e	810.00^e	564.00^f	1789.00^d	978.00^b	5.80^c	89.60^d
80	0	20	1727.00^a	920.00^b	806.00^a	1740.00^f	879.00^g	5.79^d	80.90^j
83.33	13.33	3.33	1090.00^i	623.00^h	466.00^h	1495.00^i	871.00^f	5.60^f	90.45^b
90	10	0	1406.00^f	729.00^g	666.00^d	1711.00^g	981.00^b	5.46^h	89.60^d
90	0	10	1629.00^b	929.00^a	699.00^c	1857.00^b	927.00^e	5.86^b	82.25^i
93.33	3.33	3.33	1514.00^d	791.00^f	722.00^b	1760.00^e	968.00^c	5.59^i	88.00^f
83.33	3.33	13.33	1539.00^c	885.00^c	653.00^e	1875.00^a	989.00^a	5.86^b	84.70^h
80	10	10	1214.00^h	728.00^g	485.00^g	1687.00^h	958.00^d	5.87^a	91.85^a
80	20	0	842.00^j	473.00^i	368.00^i	1789.00^d	978.00^b	5.80^c	89.60^d
100	0	0	1539.00^c	823.00^d	656.00^e	1813.00^c	989.00^a	5.72^e	87.25^g

In the same column, mean values with different superscripts differ significantly at $p<0.05$.
WF: Wheat Flour, MF: Mushroom Flour, UPF: Unripe Plantain Flour

This quality measures the ability of the flour for gel/viscous formation after heating and cooling, as well as its resistance to shear stress when stirring (Adebowale *et al*., 2005). Though, the addition of both mushroom and unripe plantain flours favours the final viscosity of the flour blend but the mushroom flour in small quantity.

The results of setback of the flour mixes ranged between 716 and 989 RVU with flour blend of 80:20:0 (wheat: mushroom: unripe plantain) having the least value while blend of 100:0:0 and 83.33:3.33:13.33 (wheat: mushroom: unripe plantain), the highest value. The flour blend of 100:0:0 and 83.33:3.33:13.33 (wheat: mushroom: unripe plantain) were not differed significantly from each other. As the mushroom flour substitution levels increased, the setback values decreased, showing that the higher the percentage of substitution, the greater the retrogradation that occur during cooling and the longer flour-based foods will last.

The peak time is a measurement of how long it takes to cook according to Adebowale *et al*. (2005). It is the time the peak viscosity occurred and it ranged between 5.46 and 5.87 min in this study. Flour blend of 90:10:0 (wheat: mushroom: unripe plantain) had the least value of 5.46 min, whereas the highest value was observed in the flour blend of 80:10:10 (wheat: mushroom: unripe plantain). The results showed significant ($p<0.05$) differences of the peak time. The increased value of protein of the flour samples resulted in a longer peak time, since Kiin-Kabari and Banigo (2015) discovered that peak time increases as the amount of protein concentrate in the sample increases.

The temperatures of pasting for the flour blends ranged between 80.90 and 91.85 °C with flour sample 80:0:20 (wheat: mushroom: unripe plantain) having the least value and sample 80:10:10 (wheat: mushroom: unripe plantain), the maximum value. Pasting temperature is one of the parameters that indicates the optimum temperature for cooking flour and the associated energy cost as reported by Otegbayo *et al*. (2006). The increased protein content in the flour samples was revealed to be the cause of the higher pasting temperature.

4 CONCLUSION

The adoption of response surface methodology (optimal mixture design) assisted in obtaining the best flour combination in terms of quality features. A functional wheat-based composite flour was developed, containing wheat, mushroom, and unripe plantain flour, and it demonstrated good conformity to flour properties. The flour mix composition of 80:10:10 (wheat: mushroom: unripe plantain) provided the optimum functional qualities in terms of BD, WAC and SC. The results of the pasting qualities test demonstrated that replacing wheat flour with mushroom and unripe plantain improved the composite flour's pasting properties The inclusion of mushroom and unripe plantain flour in wheat-based confectionaries will increase the home and industrial consumption of these crops in developing countries. It is therefore recommended that flour blends of wheat,

mushroom and unripe plantain in ratio 80:10:10, be used to produce of baked products. Further study is thereby recommended on the microstructural analysis of the new product.

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