Original Research Article

Chemical Composition, Functional and Pasting Properties of Germinated Maize *(Zea mays)- Hildegardia barteri (*Kpaakpa*)*- blanched plantain (Musa paradisiaca) composite flour

Abstract

. The dried *Hildegardia barteri* and maize seeds were cleaned, sorted, soaked, germinated, dried, and separately milled into flour. Matured unripe plantain was washed, peeled, edible portion weighed, sliced, blanched dried, and milled into flour. A mixture design was used to blend the *Hildegardia barteri* flour into seven composite blends with maize and plantain flours respectively (Minitab software version 14.0) and evaluated for chemical, functional, and pasting properties. The results of the proximate composition showed: moisture (8.67 -9.96 %), protein (2.91-18.58 %), fat (2.42 - 29.73%), ash (1.88 - 4.67 %), crude fiber (1.8-2.87 %) and carbohydrate (38.2 - 80.24 %) and energy (354-494 KJ/100 g). Protein, fat, moisture, ash, and crude fiber increased with increasing levels of *Hildegardia barteri* inclusion while carbohydrates decreased significantly ($p \leq 0.05$) with increased levels of *Hildegardia barteri*. Similarly, functional properties- Water Absorption capacity, Bulk Density, Swelling index, and Oil Absorption Capacity of the blends decreased with increased *Hildegardia barteri* flour addition while emulsifying capacity increased. Peak, final, Trough, set back and breakdown viscosities of the composite flours were reduced with the increased addition of *Hildegardia* barteri flour while pasting time and pasting temperature increased. The reverse was the case when maize and plantain flours were increased in the blends. Germinated maize-*Hildegardia barteri*-blanched plantain flour exhibited good nutritional, functional, and pasting characteristics and so could be explored in food formulations like soups, cookies, pastries, biscuits, etc.

Keywords: Chemical Composition, Functional, Pasting properties, *Hildegardia barteri,* composite flour

1. INTRODUCTION

Cereal products such as biscuits and bread have become very popular in Nigeria, particularly among children and adults. These cereal foods have a very high glycemic index which is known to increase blood glucose levels. Wheat-based composite flour is the major flour used in the production of many confectionaries and baked products. It is mainly starch which is lacking in other nutrients, especially micronutrients [1]. Wheat is an exotic cereal crop that is lowly cultivated in many tropical countries of the world including Nigeria. It is always expensive and uneconomical to use. Cereals, roots, and tubers are the major staple foods of people living in the tropics and provide about 75 % of their total calorie intake and 67 % of their total protein intake. Their nutritional value is low because they do not provide micro and macronutrients. Flours produced from only any of these staples have low nutritional value than when they are made into composite flours. Composite flours from legumes and tubers have both high protein and caloric value respectively, thus improving overall nutrition [2]. Legumes play very important roles in the diets of people in the world, especially in countries where their major staple foods are predominantly rich in carbohydrates. They serve as supplements to nutrients provided by cereals, nuts, and vegetables. *Hildegardia barteri* (kpaakpa) is one of the lesser known and less utilized legumes that is consumed in a few rural communities in Ebonyi and Enugu states of Southeastern Nigeria, as a condiment for soup making and for chewing after roasting. The seeds are yet to have any commercial relevance. Ogunsina et al. [3] reported that *Hildergardia barterii* kernel contains 17.5, 37.5, 2.8, and 6.5 % of crude protein, crude fat, ash, and crude fiber, respectively. Owing to the high fat content it could be considered as a functional food. Functional foods have a significant physiological effect on human health as it can be a source of essential nutrients [4]. There has been increased interest in the consumption of functional foods, hence cookies with high nutritional and sensory properties have been produced from non-wheat-based composite flour and this has been well documented [4]. Such cookies which are rich in protein have been reported to be attractive in countries where protein-energy malnutrition is an issue [7]. Despite these efforts, no work has been documented on the study of chemical, functional, and pasting properties of maize-*Hildegardia barteri*-plaintain composite flour. Therefore, this research is aimed at investigating the physicochemical properties of maize-*Hildegardia barteri*-plantain composite flour. The result may provide reference scientific data for the sustainable utilization of composite flour in bakeries and the formulation and production of innovative products.

2. MATERIALS AND METHODS

2.1 Material procurement

Hildegardia barteri seeds were obtained from the independent Layout area of Enugu. Maize and plantain were procured from Ogbete market, Enugu, Nigeria.

2.2 Preparation of *Hildegardia* barteri seed flour

The Hildegardia barteri flour was prepared by sorting, cleaning, soaking for 36 h with 4 h air resting, and then germinating for 96 h. The grains were oven dried for 48 h at a temperature of 50 ^{0}C (Gulfex Scientific DHG 9202, England) and milled into flour using an attrition mill (Panasonic MX-AC 2105). The flour was packaged in plastic containers with lids and stored at 4°C in a refrigerator prior to blending and evaluation.

2.3 Preparation of germinated maize flour

The maize grains were sorted and cleaned and two kilograms (2 kg) weighed and steeped in excess water at 28 ^{0}C ± 2 ^{0}C for 24 h. The steeped grains germinated for 96 h. The germinated grains were oven dried in a hot air oven (Gulfex Scientific DHG 9202, England) at a temperature of 50 ^{0}C for 48 h, milled into flour using an attrition mill (Panasonic MX-AC 2105), and sieved using a 0.45 mm mesh size. The flours obtained were packaged in plastic containers with lids and stored at 4 °C in a refrigerator prior to use.

2.4 Preparation of unripe plantain flour:

The matured unripe plantain was washed in tap water and peeled and two kilograms of edible portion was weighed and sliced into cylindrical pieces of 2 cm thickness with a stainless knife. The sliced samples were blanched in hot water (80 ^{0}C) for 5 min and dried in a hot air oven at 60 °C (Gulfex Scientific DHG 9202, England) for 24-48 hr. The dehydrated plantain samples were milled using an attrition mill (Panasonic MX-AC 2105) and passed through a 0.45 mm mesh size sieve to obtain the flour. The flours were packaged in plastic containers with lids and stored at 4 °C in a refrigerator prior to further use. A mixture design was used to blend the

*Hildegardia barteri (*Kpaakpa) flour into seven composite blends with maize and plantain flours respectively (Minitab software version 14.0) as in Table 1.

Table 1: Formulations of Germinated *Hildegardia barteri*, germinated maize, and blanched plantain flours respectively.

Blend no.	H.barteri (%)	Germinated Maize (%)	Plantain (%)
1	100	0.0	0.0
2	50.0	50.0	0.0
3	0.0	100	0.0
4	33.3	33.3	33.3
5	0.0	0.0	100
6	0.0	50.0	50.0
7	50.0	0.0	50.0
8	16.7	16.7	66.7
9	66.7	16.7	16.7
10	16.7	66.7	16.7

Key: H.barteri= *Hildegardia barteri*

2.5 Determination of physicochemical properties of composite flours

The physicochemical composition of all the pure and composite flour samples was determined using the standard methods as described by AOAC [6]. The crude protein content of each sample was determined using the micro-Kjeldahl method as described by Chang [7]. The total nitrogen was determined and multiplied with a factor of 6.25 to obtain the protein content. The carbohydrate content of each flour sample was calculated by difference [8]. The bulk density was determined by the method of Wang and Kinsella [9] with slight modification. Emulsification capacity was determined using the method described by Kaushal et al. [11]. The method described by Onwuka [11] was used to determine the water and Oil absorption capacity respectively. Rapid Visco-Analyzer (RVA) as described by Newport Scientific [12], Warriewood, Australia was used to analyze the pasting properties of the composite flours upon heating and subsequent cooling. Three grams of flour and 25.0 ml of distilled water were dispensed into the canister containing the sample. A paddle was inserted and shaken through the sample before the canister was inserted into the RVA. The slurry was heated from 50-95 ^{0}C with a holding time of 2 min followed by cooling to 50 ^{0}C. The rate of heating and cooling was at a constant rate of 11.25 ^{0}C per min. The rotation speed was set to 960 rpm for the first 10 sec and to 160 rpm until the end. Peak viscosity, trough viscosity, final viscosity, peak time, and pasting temperature were read from the pasting profile with the aid of thermocline for Windows software connected to a computer Newport Scientific, [12]. The viscosity was expressed in terms of centipoises (10 Centipoise is equivalent to a Rapid Visco Unit (RVU)) [13].

2.6 Statistical Analysis

Analysis of all the samples was done in triplicate and data generated was analyzed statistically using Statistical Package for Social Sciences (SPSS) Version 17.0 for Windows, SPSS Inc. Illinois, USA). Mean separation was carried out using the Least Significant difference (LSD). Statistical significance was accepted at a 0.05 level of probability ($p \leq 0.05$).

3. RESULTS AND DISCUSSION

3.1 Proximate composition

The proximate composition of *Hildegardia barteri* -maize-plantain composite flour blends is presented in Table 2. The mean moisture value ranged from 8.67 to 11.62 %) with the control sample having the lowest moisture while sample $H_{66.7}M_{16.7}$ $P_{16.7}$ had the highest. It was observed that moisture content increased with the increased blending of the three food commodities. Most of the samples varied significantly from each other and were below 14 % recommended for long periods of storage, indicating good storageability of the flours [14, 15].

The low moisture level could be due to the high water absorption capacity of the flour samples and will enhance the shelf life and overall acceptability of the food product. The protein content ranged from 2.91 to 18.58 % with 100 % *Hildegardia barteri* flour recording the highest mean value while 100 % unripe plantain flour had the least score. It was observed that an increased level of substitution with *Hildegardia barter* (kpaakpa) flour resulted in increased protein content. This may be due to the high protein content of *Hildegardia barteri* (kpaakpa) seed flour and is in line with the report of Anyadioha et al, [16] which revealed enhanced protein in germinated *Hildegardia barteri.* The high protein content of the flour will be of significance in curbing the problem of protein-energy malnutrition occasioned by the high cost of animal protein especially in the developing world. The fat content of most of the samples was significantly different ($p<0.05$) from each other and ranged from 2.42 to 29.73 %. Sample $H_{50}M_{0.0}P_{50.0}$ had the highest value while sample $H_{0.0}M_{50.0}P_{50.0}$ had the lowest. It was observed that high *Hildegardia barteri* (kpaakpa) flour inclusion resulted in increased fat content of the flour. This was due to the fact that *Hildegardia barteri* (kpaakpa) seed flour is a rich source of fat. Flour with high-fat content could be desirable in formulating bakery products like cookies, breads, and cakes, hence fat increases energy density and provides essential fatty acids needed by the body for mental development. The ash content ranged from 1.88 to 4.67 % with most of the samples showing no significant variation with the control. The ash content decreased with increased levels of maize flour as observed in Table 2. The observed high ash content of the composite flours could be attributed to the high mineral contents of *Hildegardia barteri* (kpaakpa) and plantain. Fortification with great protein legume flours could provide a good possibility to improve the dietary quality of necessary protein consumed by many people. The crude fiber content of the composite flour ranged from 2.87 % for a pure blend of *Hildegardia barteri* flour to 1.8 % for blend $H_{16.7}M_{16.7}P_{66.7}$ indicating significant variation. The result however showed that H.barteri is a good source of fiber. Crude fiber content (1.8 % to

2.87 %) and carbohydrate content (38.2- 80.24 %) and energy content (354-494 KJ/100 g) were recorded. Carbohydrates have an inverse correlation with crude fiber. The result showed that the composite flours are excellent sources of carbohydrates and energy.

Table 2: Proximate Composition (%) of Flour Blends

Sample code	Protein	Ash	Fibre	Moisture	Fat	CHO	Energy (KJ/100 g)
$\mathbf{H_{100}M_{0.00}P_{0.00}}$	18.58 ± 1.32^{a}	2.82 $\pm 0.06^{c}$	2.87 $\pm 0.11^{a}$	9.77 $\pm 0.57^{b}$	29.73 $\pm 052^{a}$	38.2 ± 0.94^{d}	494 ± 0.7^{a}
$\mathbf{H_{50}M_{50.0}P_{0.00}}$	14.28 $\pm 0.59^{b}$	2.81 $\pm 0.11^{c}$	2.33 $\pm 0.12^{b}$	9.95 ± 0.25^{b}	15.06 ± 0.24^{b}	55.18 $\pm 1.4^{c}$	409.74 ± 0.6^{b}
$\mathbf{H_{0\cdot 00}M_{100.0}P_{0.00}}$	10.03 $\pm 0.16^{c}$	1.88 ±0.02e	2.25 ± 0.05^{c}	9.13 ± 0.1^{c}	4.42 ± 0.56^{e}	72.27 ± 0.81^{b}	369.38 ± 0.6^{c}
$\mathbf{H_{33.3}\ M_{33.3}P_{33.3}}$	10.40 $\pm 0.01^{c}$	2.34 $\pm 0.01^{d}$	2.74 $\pm 0.08^{a}$	9.84 ± 0.14^{b}	4.88 $\pm 0.01^{e}$	69.78 $\pm 0.1^{b}$	364.71 ± 0.2^{c}
$\mathbf{H_{0.0}M_{0.0}P_{100.0}}$	2.91 ± $.09^{e}$	3.22 $\pm 0.05^{b}$	2.65 $\pm 0.01^{b}$	8.70 $\pm 0.17^{c}$	2.42 ± 0.03^{f}	80.24 ± 0.5^{a}	354.39 ± 0.9^{c}
$\mathbf{H_{0.0}M_{50.0}P_{50.0}}$	5.34 ± 0.17^{d}	3.05± 0.01^{b}	2.45 $\pm 0.02^{b}$	9.94 $\pm 0.02^{b}$	4.42 ± 0.29^{e}	74.95 ± 52^{b}	360.94 ± 1.0^{c}
$\mathbf{H_{50.0}M_{0.0}P_{50.0}}$	12.48 ± 0.01^{c}	4.67 ± 0.13^{a}	2.46 $\pm 0.19^{b}$	9.78 ± 0.29^{b}	16.78 ± 0.29^{b}	57.36 ± 52^{c}	418.33 ± 1.3^{a}
$\mathbf{H_{16.7}M_{16.7}\ P_{66\cdot 7}}$	6.39 ± 0.99^{d}	2.00 ± 0.02^{e}	1.80 $\pm 0.01^{c}$	11.62 $\pm 0.00^{a}$	6.83 ± 1.01^{d}	71.14 ± 26^{b}	363.66 ± 1.2^{c}
$\mathbf{H_{66.7}M_{16\cdot 7}\ P_{16\cdot 7}}$	14.48 $\pm 0.91^{b}$	2.85 $\pm 0.04^{c}$	2.88 $\pm 0.05^{a}$	10.24 ± 0.19^{b}	6.86 $\pm 0.00^{d}$	62.61 ± 27^{c}	369.69 ± 0.9^{c}
$\mathbf{H_{16.7}M_{66.7}\ P_{16\cdot 7}}$	10.27 ± 0.18^{c}	2.89 $\pm 0.09^{c}$	2.87 $\pm 0.01^{a}$	9.50 $\pm 0,01^{b}$	9.81 ± 0.03^{c}	64.65 ± 29^{c}	388.23 ± 1.7^{b}
$\mathbf{W_{100\cdot 00}}$	10.72 ± 0.02^{c}	2.73 $\pm 0.20^{c}$	1.39 ± 0.04^{d}	8.67 ± 0.03^{c}	1.38 ± 0.01^{f}	76.11 ± 0.14^{a}	355.8 ± 84^{c}

Means ± standard deviation of triplicate determinations. Means with different superscripts along the same column are significantly different ($p \leq 0.05$). **key:** M.C= Moisture Content; CHO = Carbohydrate; H =Hildegardia barteri flour; M= Malted Maize flour; P= Blanched Plantain flour. **Key:**$H_{100}M_{0.00}p_{0.00}$ = (100: 0:0: ratios of *H. barteri*- Malted Maize-Blanched Plantain)**,** $H_{50}M_{50.0}P_{0.00}$ = (50: 50:0: ratios of *H. barteri*- Malted Maize-Blanched Plantain)**,** $H_{0\cdot 00}M_{100.0}P_{0.00}$ =(0: 100:0: ratios of *H. barteri*- Malted Maize-Blanched Plantain**,** $H_{33.3}$ $M_{33.3}P_{33.3}$ =(33.3: 33.3:33.3 ratios of *H. barteri*- Malted Maize-Blanched Plantain**,** $H_{0.0}M_{0.0}P_{100.0}$ =(0: 0:100: ratios of *H. barteri*- Malted Maize-Blanched Plantain)**,** $H_{0.0}M_{50.0}P_{50.0}$ = (0: 50:50: ratios of *H. barteri*- Malted Maize-Blanched Plantain)**,** $H_{50.0}M_{0.0}P_{50.0}$ = (50: 0:50: ratios of *H. barteri*- Malted Maize-Blanched Plantain)**,** $H_{16.7}M_{16.7}$ $P_{66\cdot 7}$ = (16,7: 16.7:66.7: ratios of *H. barteri*- Malted Maize-Blanched Plantain)**,** $H_{66.7}M_{16\cdot 7}$ $P_{16\cdot 7}$ = (66,7: 16.7:16.7: ratios of *H. barteri*- Malted Maize-Blanched Plantain)**,** $H_{16.7}M_{66.7}$ $P_{16\cdot 7}$ = (16,7: 66.7:16.7: ratios of *H. barteri*- Malted Maize-Blanched Plantain)**,** W_{100} = 100 % wheat flour (Control sample)

3.2 Functional Properties

The Functional Properties of Composite Flour are presented in Table 3 below. The result indicates that as the addition of *Hildegardia barteri* flour increased, the bulk density reduced. On the other hand, the increased addition of maize and plantain flour resulted in higher bulk density (volumetric density). This could be attributed to variations in starch content of the foods. The higher the starch content the more likely the increase in bulk density. The bulk densities of all composites flours investigated were not significantly different from each other ($p \geq 0.05$).The bulk density gives an indication of the porosity of the food product which imparts the design of the package and can be used to determine the relative volume and type of the packaging materials required [17]. The swelling index followed the same trend with a volumetric density as the increased *Hildegardia barteri* inclusion into the flour showed reduced swelling. The swelling indices of the flour samples differed significantly ($p \leq 0.05$) from each other. The variation could be related to associative binding within the starch granules while the strength and character of the micellar network may be related to the amylose content which confers high swelling power [18, 19]. Flours with good swelling capacities are primarily used for thickening soups, sauces gravies, etc. Water absorption capacity is the ability of a product to associate with water under a water-limiting condition. The water binding capacity ranged from 90 % in samples $H_{50}M_{50}P_{0.0}$ and $H_{100}M_{0.0}P_{0.0}$ to 153 % in the control (W_{100}). The water absorption capacity of samples $H_{50}M_{50}P_{0.00}$ and $H_{100}M_{0.0}P_{0.0}$ did not result in any significant increase in water uptake. This might be due to less availability of polar amino acids, reduced amylose leaching, and solubility which resulted in loss of starch crystalline structure. The samples with three components $H_{33.3}M_{33.3}P_{33.3}$, $H_{16.7}M_{16.7}P_{66.7}$, $H_{66.7}M_{16.7}P_{16.7}$, $H_{16.7}M_{66.7}P_{16.7}$, had reasonable values of water binding capacity and varied significantly from each other. The observed variation in different flours may be due to different protein concentrations, their degree of interaction with water, and conformational characteristics [20]. It could also be due to the high water absorption capacity of maize and plantain flours respectively which probably improved the structural matrix for holding water, sugars, and other components [21]. The oil absorption capacity of the processed flours ranged from 66.67 % to 110.07 % in all the flours with sample $H_{100}M_{0.0}P_{0.0}$ having the lowest value and sample comprising 100 % plantain flour recording the highest value. There were no significant differences ($p \leq 0.05$) in OAC among samples with increased addition of maize and plantain flours ($H_{16.7}M_{16.7}P_{66.7}$, $H_{16.7}M_{66.7}P_{16.7}$, $H_{0.0}M_{50}P_{50}$) as compared with the control (100% wheat) but differed significantly ($p \leq 0.05$) from sample $H_{100}M_{0.0}P_{0.0}$.,$H_{66.7}M_{16.7}P_{16.7}$ and $H_{66.7}M_{16.7}P_{16.7}$. It is evident from the result that the increased inclusion of maize and plantain flour resulted in increased oil absorption. The possible reason for the increase in the OAC of composite flours after the incorporation of maize and plantain flour is the variations in the presence of a non-polar side chain, which might bind the hydrocarbon side chain. Composite flours with high oil and protein content might have adverse negative effects on oil absorption. This is due to the hydrophilic and hydrophobic constituents of proteins. Non-polar amino acid side chains can form hydrophobic interactions with hydrocarbon chains of lipids [22]. This is in compliance with a report by Kaushal et al. [10]. This result showed that the composite flours could be used in various food formulations where flavor enhancement, improvement of palatability, and extension of shelf life are priorities as in bakery and baby foods where fat absorption is desired [22]. Like the oil absorption capacity, the higher the *Hildegardia barteri* flour inclusion the higher the emulsion capacity of the flour. The emulsion capacity of different flours ranged from 31.82-68.33 % for samples $H_{0.0}M_{0.0}P_{100.0}$ and $H_{100}M_{0.00}P_{0.00}$ respectively. The high value of emulsion capacity recorded in some of the composite flours could be attributed to the high protein content (interaction between proteins and carbohydrates) in legumes flour [17]. This may impact to the emulsion and the formation of cohesive films by the absorption of rigid globular protein molecules that are more resistant to mechanical deformation leading to exposure of hydrophobic and hydrophilic amino acid residues. Soluble proteins enhance the emulsifying capacity of foods [2]. All composite flours showed the relatively good capacity of emulsion activity.

Table 3: Functional Properties of Composite Flour

	WAC (%)	SI (%)	B D g/cm^{3}	O A C (%)	E C (%)
$H_{100}M_{0.00}P_{0.00}$	90.00 ± 0.00^{d}	142 ± 2.51^{c}	0.61 ± 0.02c	66.67 ± 0.14^{c}	68.33 ± 057^{a}
$H_{50}M_{50}P_{0.00}$	90.00 ± 0.00^{d}	149 ± 7.92^{c}	0.63 ± 0.01^{c}	91.67 ± 0.14^{b}	65.67 ± 0.57^{a}
$H_{0\cdot00}M_{100}$:$P_{0.00}$	104.00 ± 1.40^{c}	133 ± 7.76^{c}	0.67 ± 0.01^{b}	93.33 ± 0.57^{b}	46.67 ± 1.52^{c}
$H_{33.3}$ $M_{33.3}P_{33.3}$	100.00 ± 0.50^{c}	155 ± 8.14^{b}	0.71 ± 0.01^{ab}	100 ± 0.00^{b}	43.00 ± 1.73^{c}
$H_{0.0}M_{0\cdot0}P_{100.0}$	124.00 ± 0.57^{b}	290 ± 10.00^{a}	0.74 ± 0.00^{a}	110.07 ± 0.15^{a}	31.82 ± 2.76^{d}
$H_{0}M_{50.0}P_{50.0}$	102.00 ± 0.00^{c}	177 ± 19.62^{b}	0.66 ± 0.00^{b}	80.00 ± 0.26^{b}	43.33 ± 1.15^{c}
$H_{50.0}M_{0.0}P_{50.0}$	94.00 ± 1.44^{d}	137 ± 12.50^{c}	0.69 ± 0.01^{a}	83.33 ± 0.28^{c}	56.66 ± 0.57^{b}
$H_{16.7}M_{16.7}$ $P_{66\cdot7}$	96.33 ± 5.77^{d}	164 ± 10.06^{b}	0.63 ± 0.01^{b}	100.00 ± 0.43^{b}	32.33 ± 0.57^{c}
$H_{66.7}M_{16\cdot7}$ $P_{16\cdot7}$	93.33 ± 0.00^{d}	173 ± 8.88^{b}	0.65 ± 0.02^{b}	$78\ .33 \pm 0.20^{c}$	56.33 ± 0.57^{b}
$H_{16.7}M_{66.7}$ $P_{16\cdot7\cdot}$	100 ± 0.00^{b}	127 ± 2.51^{d}	0.66 ± 0.00^{b}	88.33 ± 0.12^{c}	43.00 ± 1.00^{c}
$W_{100.00}$	153 ± 2.64^{a}	173 ± 3.60^{b}	0.63 ± 0.01^{c}	105 ± 1.00^{b}	37.66 ± 0.57^{d}

Means ± standard deviation of triplicate determinations with different superscripts along the same column are significantly different ($p \leq 0.05$).**Key:** WAC=Water Absorption Capacity SI= Swelling Index BD= Bulk Density OAC= Oil Absorption Capacity EC= Emulsion Capacity$H_{100}M_{0.00}p_{0.00}$ = (100: 0:0: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{50}M_{50.0}P_{0.00}$ = (50: 50:0: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{0\cdot00}M_{100.0}P_{0.00}$ =(0: 100:0: ratios of *H. barteri*- Malted Maize-Blanched Plantain, $H_{33.3}$ $M_{33.3}P_{33.3}$ =(33.3: 33.3:33.3 ratios of *H. barteri*- Malted Maize-Blanched Plantain, $H_{0.0}M_{0.0}P_{100.0}$ =(0: 0:100: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{0.0}M_{50.0}P_{50.0}$ = (0: 50:50: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{50.0}M_{0.0}P_{50.0}$ = (50: 0:50: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{16.7}M_{16.7}$ $P_{66\cdot7}$ = (16,7: 16.7:66.7: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{66.7}M_{16\cdot7}$ $P_{16\cdot7}$ = (66,7: 16.7:16.7: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{16.7}M_{66.7}$ $P_{16\cdot7}$ = (16,7: 66.7:16.7: ratios of *H. barteri*- Malted Maize-Blanched Plantain), W_{100} = 100 % wheat flour (Control sample)

3.3 Pasting characteristics of the Composite Flour

Table 4 shows the pasting behavior of the maize-*Hildegardia barteri*-plantain composite flours. The Pasting properties of food refer to the ability of starch based foods to act in paste-like manner when heat is applied in the presence of water. These changes imparts on the texture, digestibility and end use of the food product. The peak viscosity of the various flour samples ranged from 20 RVA to 3314 RVA. Pure sample (100 %) plantain flour had the highest value while pure (100 %) *Hildegardia barteri* flour had the lowest peak viscosity. Peak viscosity increased with increase in plantain and maize flour (from 20 RVA to 3314 RVA). Sample $H_{33.3}M_{33.3}P_{33.3}$ showed the best peak viscosity value of 151 RVA followed by sample $H_{16.7}M_{66.7}P_{16{\cdot}7}$ which recorded 90 RVA when compared with control sample. High values indicated the suitability of the blends for products requiring moderate viscosity such as cookies. The peak viscosity has been reported to be closely associated with the degree of starch damage. High starch damage results in high peak viscosity and starch binding capacity of the granules [25]. Flour samples with high level of maize and plantain inclusion ($H_{16.7}M_{66.7}P_{16{\cdot}7,}$ $H_{33.3}M_{33.3}P_{33.3,}$ $H_{66.7}M_{16.7}P_{16{\cdot}7,}$ $H_{16.7}M_{16.7}P_{66{\cdot}7}$) showed higher peak, trough, break down, final and set viscosities than samples with low substitution. The temperature was also observed to be high. This may be due to high water binding observed in the blends. Samples $H_{66.7}M_{16}P_{16.7,}$ $H_{50.0}M_{50}P_{0.00,}$ and $H_{50.0}M_{50}P_{0.00.}$ which have higher level of *Hildegardia barteri* flour addition recorded reduction in the peak, trough, breakdown, set back, and final viscosities as well and lower pasting temperatures. The differences were significantly (≤0.05) high. This might be attributed to high protein content of the flour and is in line with the report of Derycke et al [26] which stated that protein substantially affected the pasting properties of rice probably by reducing heat-induced swelling of the starch. This observation is also similar to reports of Ohizua et al. [27] and Kiin-Kabari [28] This same observation was reported by Awolu et al. [29] (2016) in composite flour consisting high soy beans (75 % wheat, 20 % soybean and 5 % tigernut flours) where the breakdown viscosity was 5 RVU. The significantly high trough viscosity observed indicates the tendency of the composite flours to breakdown during cooking. Trough viscosity (TV) is the minimum viscosity value which measures the ability of paste to withstand breakdown during cooling. The breakdown viscosity is the measure of the susceptibility of the cooked starch sample to disintegration. Starch with lower breakdown viscosity had been reported to possess higher capacity to withstand heating and shearing during cooking. The high breakdown viscosity values recorded might be attributed to their high peak viscosities which in turn, are related to the degree of swelling of the starch granules during heating. The variations in the final viscosity might be due to the simple kinetic effect of cooling on viscosity and the reassociation of starch molecules in the flour samples. Final viscosity defines the particular quality of starch and stability of cooked paste. Lower final viscosity signifies reduced ability to form viscous pastes after cooking and cooling. It also gives a measure of the resistance of the paste to shear force during stirring [30]**.** The final viscosity obtained in this work is better than what were obtained by wheat-plantain-tigernut flour composite flour [31]**.** Pasting time is the measure of the cooking time. The pasting time of all the composite fours ranged from 5.8 to 7.0 min. It indicates the minimum time required to cook flour. Pasting time values reported in this work are similar to the peak time values of 5.13–5.80 min and 5.01–6.30 min reported for instant yam–breadfruit composite flour and germinated tigernut flour, respectively]30]. Sample $H_{0.0}M_{0.0}P_{100}$ had the best pasting time of 5.8 min among all the composite flours and so compared very favorably with the control sample (100 % wheat). The pasting temperature is a measure of the minimum temperature required to cook a given food sample (the minimum temperature at which starch granules in the composite flour swells). Pasting temperature was higher in sample $H_{50}M_{50}\,P_{0.0}$ (70.42 ^{0}C) closely followed by $H_{100}M_{0.0}$ $P_{0.0,}$ sample (flour with 100 % *Hildegardia barteri)* (73.6 ^{0}C). Sample $H_{33.3}M_{33.3}P_{33.3}$ had the moderate pasting temperature (85.3 ^{0}C) and also had consistently displayed better pasting characteristics at 6.4 pasting time. A higher pasting temperature indicates high water-binding capacity, higher gelatinization tendency and lower swelling property of starch-based flour due to high degree of associative forces between starch granules (Adebowale 2005). Pasting temperature is one of the properties which provide an indication of the minimum temperature required for sample cooking, energy costs involved and other components stability. It is evident that substitution up to 33.3% from the results (Table 4), will cook faster and less energy will be consumed, thus saving time and cost when compared to other flour blends. Flour blends with higher pasting temperature may not be recommended for certain products due to high cost of energy.

Table 4.5 Pasting Properties of Flour Blends (RVU)

Sample code	Peak Viscosity	Trough Viscosity	Breakdown Viscosity	Final viscosity	Set Viscosity	Peak time (Min.)	Pasting (^{0}C) temperature
$H_{100}M_{0.00}P_{0.00}$	20.5 ± 1.41^i	15.5 ± 0.70^h	5.0 ± 0.21^e	21.0 ± 1.41^j	5.5± 2.10^j	6.5 ± 0.47^a	73.6 ± 0.00^c
$H_{50.0}M_{50}P_{0.00}$	27.5 ± 0.00^i	24.5 ± 0.70^g	3.0 ± 0.07^g	46.05 ± 0.70^i	22 ± 2.12^i	6.7 ± 0.42^a	$70.42±0.03^c$
$H_{0.00}M_{100}P_{0.00}$	78.5 ± 2.10^g	72.5 ± 2.12^f	6.0 ± 0.00^e	181 ± 4.24^f	108 ± 1.40^e	$7.00±0.00^a$	83.1± 0.70^b
$H_{33.3}M_{33.3}P_{33.3}$	151 $±7.7^d$	136.0 ± 3.53^e	15 $±10.60^b$	245.5 ± 4.94^d	$109±2.12^e$	6.4 ± 0.79^a	95.3 ± 0.42^a
$H_{0.00}M_{0.00}P_{100}$	334 ± 55.15^b	280.15 ± 28.9^b	54 ± 26.16^a	475.0 ± 31.8^b	$194.9±2.82^a$	5.8 ± 0.00^b	$84.1±0.00^b$
$H_{0.00}M_{50.0}P_{50.0}$	956 ± 4.20^a	940.5 ± 4.94^b	15.5 ± 0.70^b	163.6 ± 30.4^d	$69.5±26.45^b$	6.8 ± 0.00^a	$85.6±0.03^b$
$H_{50.0}M_{0.0}P_{50.0}$	270.5 ± 9.10^c	266.0 ± 9.89^c	5.0 ± 0.70^e	341 ± 8.40^c	75.0± 1.41^h	6.7 ± 0.42^a	$85.95±0.6^b$
$H_{16.7}M_{16.7}P_{66.7}$	866 $±16.97^f$	855 ± 16.97^a	11.0 ± 0.00^c	117.7 ± 26.8^a	322 ± 9.89^c	7.0 ± 0.05^a	$85.57±0.1^b$
$H_{66.7}M_{16.7}P_{16.7}$	50.5 ± 3.53^h	46.50 ± 2.12^e	4.0 ± 5.00^e	64 ± 5.65^h	175 ± 7.70^d	6.5 ± 0.56^a	$85.52±0.1^b$
$H_{16.7}M_{66.7}P_{16.7}$	90.5 ± 2.12^f	86.00 $±1.282^f$	5.0 ± 0.70^e	190 ± 9.12^e	104.5± 6.30^g	6.8 ± 0.04^a	84.5± 1.27^b
W_{100} (Control)	$141.00±11.3^e$	88.00 ± 8.40^f	53.05 ± 1.9^d	152.91 ± 31^g	61.5 ± 44.0^c	$5.85±0.21^b$	$86.96±1.5^b$

Means ± standard deviation of triplicate determinations. Means with different superscripts along the same column are significantly different ($p≤0.05$). **Key:** $H_{100}M_{0.00}p_{0.00}$ = (100: 0:0: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{50}M_{50.0}P_{0.00}$ = (50: 50:0: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{0\cdot00}M_{100.0}P_{0.00}$ = (0: 100:0: ratios of *H. barteri*- Malted Maize-Blanched Plantain, $H_{33.3}$ $M_{33.3}P_{33.3}$ = (33.3: 33.3:33.3 ratios of *H. barteri*- Malted Maize-Blanched Plantain, $H_{0.0}M_{0.0}P_{100.0}$ = (0: 0:100: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{0.0}M_{50.0}P_{50.0}$ = (0: 50:50: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{50.0}M_{0.0}P_{50.0}$ = (50: 0:50: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{16.7}M_{16.7}$ $P_{66\cdot7}$ = (16,7: 16.7:66.7: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{66.7}M_{16\cdot7}$ $P_{16\cdot7}$ = (66,7: 16.7:16.7: ratios of *H. barteri*- Malted Maize-Blanched Plantain), $H_{16.7}M_{66.7}$ $P_{16\cdot7}$ = (16.7: 66.7:16.7: ratios of *H. barteri*- Malted Maize-Blanched Plantain), W_{100} = 100 % wheat flour (Control sample)

4. Conclusion

This research revealed the effect of composting different no what flours on the proximate, functional and pasting properties of the flour blends. The protein, fat, ash and crude fiber contents of the composite flours were enhanced with increased addition of *Hildegardia barteri* flour while carbohydrate and moisture decreased. The functional properties such as WAC, BD, SWI and OAC of the flour blends decreased with increased *Hildegardia barteri* flour addition while emulsifying capacity increased. Peak, final, Trough, set back and breakdown viscosities of the composite flours reduce with increased addition of *H. barteri* flour while pasting time and pasting temperature increased. The pasting characteristics- final, peak, trough, breakdown and set viscosities of the composite flour increased with increased inclusion maize and plantain flour. The reverse was the case with increased addition of *Hildegardia barteri* flour. Pasting time and pasting temperature increased with increase in *Hildegardia barteri* inclusion. Generally, Maize-*H.barteri*-plantain composite flour displayed satisfactory nutritional, functional and pasting properties and so could be applied in food systems (food formulations) such as soups, bakery products, pastries and confectionary products. It could be good alternative means of optimizing their usage and so add value to them thereby contribute to curbing protein –energy malnutrition.

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