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Functional and Pasting Characterization of Multigrain flour produced from Whole Wheat, Maize and Sorghum Grains

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***Abstract**: Multigrain flours contain different types of flours produced from grains and mixed together in certain ratio. These grains offer dietary fiber, nutrient-dense protein, and lipids high in essential fatty acids in addition to their high carbohydrate and protein content as an energy source. In order to ascertain the multigrain flour's potential application in the baking industries. This research aims to develop multigrain flour from blends of maize, whole wheat, and sorghum flour and evaluate its functional and pasting qualities. Blends of whole wheat, sorghum, and maize was used to produce multigrain flour. Standard analytical procedures were used to determine the functional and pasting characteristics. The flour sample oil absorption capacity and water absorption capacities ranged from 67.24 to 111.62% and 91.58 to 224.37%. The solubility index and swelling power ranged from 3.58 to 6.98% and 461.27 to 667.10%, respectively. The flour sample's water binding capability varied from 83 to 266%. The pasting temperature varies from 64.43^{0}C to 77.35^{0}C while the setback viscosity varies from 61.42-84.75RVU. The breakdown point of the samples falls between 0.71 and 65.04RVU while the through value falls between 46.88 and 85.00 RVU. The result of this study indicated that the functional properties of the developed composite flour vary with the ratio of the three flours blended together. The multigrain flour produced can be useful in bakery production if further research is carried out on it to improve its quality.*

***Keywords:** Grain, Multigrain Flour, Baking, Characterization, Pasting*

1. INTRODUCTION

Multigrain flour contains different types of flour produced from grains and blended together. These grains offer dietary fiber, nutrient-dense protein, and lipids high in essential fatty acids in addition to their high carbohydrate and protein content as an energy source [7]. Minerals, vitamins, including several B vitamins, and phytochemicals are other significant micronutrients found in grains.

Multigrain flour can also be referred as Composite flour which are flours produced from two or more cereals, legumes, roots and tubers or combination of these in other to replace or enrich refined wheat flour. These flours come from affordable, easily accessible local crops, unlike imported wheat that keeps depleting our foreign exchange reserves.

Multigrain flour has been reported to be suitable for production of bread and pastry product [18]. Whole-grain wheat flour, often known as whole-wheat flour, is a fully flavored flour. A staple component in baking, the flour is a powdered form obtained by crushing or grinding entire wheat grains. Whole-grain wheat flour has a rich flavor and is higher in nutrients than refined white flour since it contains higher vitamins, minerals, and protein [18].

Sorghum(S) is a common staple food crop in the tropics. Nutritionally, It is well known that sorghum contains protein, primarily in the form of "kafirins and prolamins," and polyunsaturated fatty acids, which include oleic, linoleic, and linolenic acid[19]. Sorghum play an important role in nutritional development as a primary and good source of protein (10%-16%), lipids (3.5%-5%), minerals, and phytochemicals [15] Additionally, it contains dietary fiber, phytochemicals like flavonols and flavones, fat-soluble vitamins A, D, E, and K, as well as water-soluble vitamins like riboflavin, pyridoxine, and thiamine 2.3%–2.9%, also minerals such as Ca, P, K, Fe, Zn, Mg and Cu. However, the presence of a substance known as "tannin" prevents these vitamins from being absorbed[4]. Among food grains, maize (Zea mays) is recognized as the least expensive cereal. It provides both good quality protein as well as energy. Consequently, consumption of these items can only provide trace amounts of minerals, dietary fiber, and proteins; consequently, there will be a higher chance of nutritional deficiencies linked to celiac disease [12].

There is need for the development of multigrain flour because refined wheat is low in some essential nutrients which are lost during refining processes, also there is under-utilization of locally grown crops at the industrial level especially in baking industries. This work examined the functional and pasting properties of flour blends from maize, whole wheat and sorghum intended to be used in bread production.

2. MATERIAL AND METHODS

2.1 Production of De-germed maize, sorghum and whole wheat flour

De-germed maize, sorghum(S) and whole wheat (W) flour were produced using modified method. Sorghum grain was cleaned manually by winnowing and handpicking to remove foreign materials. After this, it was tempered by sprinkling with water in a tray, allowed to stand for 5minutes and air-dried to remove excess moisture. Then it was de-germed using dehulling machine in a local mill and then winnowed using a tray. After which it was milled using a laboratory grinder and sieved to give de-germed sorghum flour, maize flour and wheat flour [8]

2.2 Formulation of multigrain flour blends

The various blends were formulated using Box –Behnken rotatable design where experimental variables were of three levels as shown in Table1 and Table 2. The flour blend ratio is shown in Table 3.

Table 1: Experimental variable used in the Box-Behnken rotatable design

Independent Variables	**Variable level**		
	-1	**0**	**+1**
Maize level(%)X_1	25	50	75
Sorghum level(%)X_2	25	50	75
Whole wheat(%)X_3	12.5	25	37.5

Table 2: Experimental design

Run	**X_1(%Maize)**	**X_2(%Sorghum)**	**X_3(%Whole wheat)**
A	-1	0	+1
B	-1	0	-1
C	-1	+1	0
D	-1	-1	0
E	+1	0	+1
F	+1	0	-1
G	+1	+1	0
H	+1	-1	0
I	0	-1	+1
J	0	+1	-1
K	0	-1	-1
L	0	+1	+1
M	0	0	0×3

2.3 Determination of functional properties

2.3.1 Swelling power and Solubility Index

Swelling power and solubility index of the flour samples was determined. For one hour, while being continually shaken, a pre-weighed and dried centrifuge tube containing one gram of flour and ten milliliters of distilled water was heated up to ninety degrees Celsius. The suspension was centrifuged at 5,000 rpm for duration of ten minutes. After the sediment was carefully weighed, and the supernatant was decanted [14]. The swelling power was determined as follows:

$$\text{Swelling power} = \frac{\text{weight of sediment} \times 100}{\text{Weight of sample} \times (100-\%\text{solubility})} \quad (1)$$

$$\text{Solubility} = \frac{\text{final weight of the can} - \text{initial weight of the can} \times 100}{\text{Weight of sample}} \quad (2)$$

2.3.2 Water and oil absorption capacity

Water absorption capacity (WAC) and Oil absorption capacity of the flours was determined by measuring One gram of flour was put in 5ml distilled water/ olive oil in a pre-dried centrifuge tube. It was then shaken at room temperature for 1minute with the aid of mechanical shaker after which it was centrifuged for 30 min at 3,000 rpm. The centrifuge tubes were weighed after the supernatant has been decanted [14]. Then the WAC and OAC was determined as follows:

$$\text{WAC /OAC} = \frac{\text{weight of bound water/oilx100}}{\text{Weight of sample}} \quad (3)$$

Table 3: Percentage flour blend

Sample	Maize	Sorghum	Whole Wheat
A	25	50	37.5
B	25	50	12.5
C	25	75	25
D	25	25	25
E	75	50	37.5
F	75	50	12.5
G	75	75	25
H	75	25	25
I	50	25	25
J	50	75	12.5
K	50	25	12.5
L	50	75	37.5
M	50	50	25
N	50	50	25
O	50	50	25
P	100% Refined wheat		
Q	100% Maize		
R	100% Sorghum		
S	100% Whole wheat		

2.3.3 Bulk density (Bd)

The bulk density was calculated by measuring 100 g of the flour sample into a 250 mL measuring cylinder. After then, the cylinder was tapped on a level surface until the volume stopped decreasing. Then the bulk density was calculated based on weight and volume [12].

2.3.4 Determination of pasting properties of flour

The pasting qualities were ascertained by use of the Rapid Visco Analyzer. The parameters that were obtained were the following: pasting temperature, peak viscosity, hold viscosity, final viscosity, breakdown viscosity, and setback viscosity.

3. RESULT AND DISCUSSIONS

3.1 Functional Characteristic of the Flour

The functional properties of the multigrain flours are shown in Table 4. The packed bulk density ranged between 0.61 and 0.73gcm^{-3}. The bulk density was highest in sample S which is de-germed whole wheat flour while sample P which is refined wheat flour sample had the lowest value. The result agrees with the findings of [1] that the bulk density of the flour samples produced from various ratio of sorghum and wheat flour ranged from 0.67 to 0.77 g cm^{-3}.As a function of particle size, bulk density plays an indispensable role in the food industry's raw material handling and packaging requirements [1].

The flour samples' swelling power and solubility index range from 3.58 to 6.98% and 461.27 to 667.10%, respectively. Sample B has the greatest swelling power, whereas sample R has the lowest. The degree of associative forces inside flour grains is indicated by their swelling power [2]. The sample with highest solubility is sample J while the lowest is sample D. The water binding capacity of the flour sample ranged between 83 to 266%. Sample S which is de-germed whole wheat flour has the lowest water binding capacity while sample P which is refined wheat flour has the highest value. Sample B has the value that is closer to that of refined wheat flour. A food product's water absorption capacity is the amount of water it can hold onto after filtration and imparting a little amount of centrifugal pressure [7]. The flour samples had a range of 91.58 to 224.37% for water absorption and 67.24 to 111.62% for oil absorption, respectively.

Compared to the multigrain flour, the 100% refined wheat flour had a lower WAC. The ability of flour to absorb water allows the processor to add more water during the production process, which enhances handling properties. Increased flour water absorption contributes to bread freshness preservation). The oil absorption capacity is lowest in sample D while sample R which is 100% Sorghum has the highest oil absorption capacity. The amount of oil that can be absorbed by a sample during frying and its emulsifying ability are both reflected in oil absorption capacity [7]. The capacity to absorb water and oil increases as the amount of de-germed whole wheat flour decreases. This is in agreement with the findings of[12]. High water absorption capacity of starch polymers may be caused by their loose structure, while low water absorption capacity values signify the tightly packed nature of the structure[1].

Table 4: Functional properties of the flour sample

SAMPLE	PBD	LBD	WAC	OAC	WBC	SP	MC	SOL
A	0.72±0.00^{ef}	0.49±0.00^{a}	165.57±0.84^{e}	85.73±0.77^{b}	186.91±1.25^{h}	628.05±1.76^{l}	8.61±3.07^{a}	3.61±0.02^{ab}
B	0.67±0.00^{c}	0.49±0.00^{a}	224.37±1.93^{k}	85.64±4.95^{b}	207.97±3.81^{j}	667.10±0.74^{m}	9.57±0.36^{abc}	4.47±0.60^{abcdef}
C	0.72±0.01^{de}	0.53±0.01^{f}	163.60±3.73^{de}	83.76±1.61^{b}	211.97±4.63^{k}	626.23±1.96^{l}	11.62±0.11^{def}	5.32±0.23^{fg}
D	0.62±0.01^{a}	0.50±0.00^{b}	162.65±0.35^{de}	67.24±3.37^{a}	126.23±0.49^{b}	556.62±1.70^{h}	10.42±0.16^{bcd}	3.99±0.37^{abcd}
E	0.69±0.00^{d}	0.52±0.00^{e}	185.27±3.18^{f}	84.56±0.28^{b}	181.63±2.02^{g}	605.93±3.58^{j}	10.05±0.45^{bc}	4.94±0.03^{defg}
F	0.64±0.01^{b}	0.49±0.00^{a}	218.54±2.08^{j}	87..69±4.40^{bc}	210.24±0.54^{jk}	616.60±1.26^{k}	9.83±0.05^{abc}	3.82±0.47^{abc}
G	0.62±0.01^{a}	0.50±0.00^{b}	211.35±1.13^{i}	84.18±1.63^{b}	198.46±2.08^{i}	605.17±2.91^{j}	9.40±0.22^{ab}	4.20±0.79^{abcde}
H	0.70±0.01^{de}	0.56±0.00^{h}	159.66±2.00^{d}	94.83±2.00^{ef}	179.94±2.69^{fg}	617.22±0.46^{k}	10.57±0.18^{bcde}	3.58±0.07^{a}
I	0.70±0.01^{de}	0.51±0.00^{d}	147.59±2.00^{c}	85.39±1.51^{b}	174.93±2.67^{de}	516.21±0.06^{d}	10.42±0.09^{bcd}	5.17±0.23^{efg}
J	0.69±0.00^{d}	0.54±0.00^{g}	202.61±3.94^{g}	90.35±1.82^{cd}	176.49±0.68^{ef}	526.16±3.35^{e}	10.78±0.21^{bcde}	4.41±0.87^{abcdef}
K	0.64±0.01^{b}	0.53±0.00^{f}	202.61±1.69^{g}	98.64±1.71^{fg}	176.70±2.16^{ef}	533.65±2.26^{f}	9.95±0.32^{abc}	5.09±0.20^{efg}
L	0.69±0.00^{d}	0.50±0.00^{b}	232.71±0.88^{i}	92.98±2.39^{de}	171.69±0.35^{d}	494.73±2.94^{b}	10.01±0.20^{bc}	4.61±0.10^{cdef}
M	0.61±0.01^{a}	0.50±0.00^{b}	208.69±4.68^{hi}	87.21±2.39^{bc}	160.86±0.31^{c}	554.32±3.01^{h}	10.12±0.27^{bc}	5.87±0.12^{g}
N	0.64±0.01^{b}	0.51±0.00^{c}	206.12±1.81^{ghi}	86.86±2.08^{bc}	160.57±1.04^{c}	554.91±2.54^{h}	10.99±0.01^{cde}	3.62±0.03^{ab}
O	0.67±0.00^{c}	0.53±0.00^{f}	209.12±0.02^{hi}	86.25±0.27^{bc}	161.16±0.27^{c}	558.28±2.64^{h}	10.96±0.46^{cde}	4.57±0.12^{bcdef}
P	0.69±0.00^{d}	0.54±0.00^{g}	91.58±2.31^{b}	93.07±2.86^{de}	266.09±2.08^{l}	549.16±0.82^{g}	13.00±0.05^{g}	6.74±1.02^{h}
Q	0.73±0.01^{f}	0.54±0.00^{g}	205.81±4.20^{g}	100.22±1.84^{g}	198.63±1.36^{i}	588.33±2.67^{i}	10.27±0.17^{bcd}	5.56±0.30^{g}
R	0.71±0.00^{ef}	0.53±0.00^{f}	152.01±4.00^{c}	111.62±1.33^{h}	138.12±1.51^{h}	461.20±2.47^{a}	11.86±0.39^{efg}	4.30±1.15^{abcde}
S	0.73±0.01^{f}	0.53±0.00^{f}	83.94±4.32^{a}	94.23±0.79^{de}	83.99±0.97^{a}	496.28±2.08^{c}	12.35±0.10^{fg}	6.98±0.44^{h}

KEY: PBD-packed bulk density, LBD-Loosed bulk density, WAC-water absorption capacity, OAC- oil absorption capacity, WBC-water binding capacity, SP-swelling power, MC- moisture content, SOL-solubility A- 25M: 50S: 37.5W, B- 25M: 50S: 12.5W, C- 25M: 75S: 25W, D-25M: 25S: 25W, E- 75M: 50S: 37.5, F- 75M: 50S: 12.5W, G-75M: 75S: 25W, H-75M: 25S: 25W, I-50M: 25S: 25S, J-50M: 75S: 12.5W, K- 50M: 25S: 12.5W, L- 50W: 75S: 37.5W, M-N-O-50M:50S:25W, P- Refined wheat, Q-100%Maize, R-100% Sorghum, S-100%Whole wheat

The flour samples' solubility index and swelling power varies between 461.27 to 667.10% and 3.58 to 6.98%, respectively. The sample with highest swelling power is sample B containing 25M: 50S: 12.5W while the lowest is sample R which is de-germed sorghum flour. The swelling power of flour granules is an indication of how close is associative forces within the granule[2]. The sample with highest solubility is sample J while the lowest is sample D.

The Flour sample has water binding capacity which varies between 83 to 266%. Sample "S" which is de-germed whole wheat flour has the lowest water binding capacity while the sample with highest value is sample P which is the refined with flour. Sample "B" has the value that was closer to that of refined wheat flour.

3.2 Pasting Properties of the Flour Samples

The pasting properties of the various flour samples are shown in the Table 5. The range of Pasting temperature is between 64.43 -77.35 ^{0}C. It was reported that the range of pasting temperature is between 61.41^{0}C to 61.80^{0}C [5]. The peak temperature is highest in sample "C" and lowest in sample "S" which is de-germed whole wheat flour. Sorghum content rises and wheat content falls as pasting temperature rises. The resistance of smaller starch granules to breakage and molecular order loss is higher; hence pasting temperature is influenced by their size in the flour [21]. The pasting temperature is the main factor that determines the starch's capacity to absorb water and swell. Pasting qualities show the tendency for paste to form; the tendency for paste to form more quickly increases with pasting temperature. It was reported that starch granules absorb water and expand to form paste when there is heat and water present. [16]

Table 5: Pasting properties of flour samples

Test	Peak 1	Trough 1	Breakdown	Final Visc	Setback	Peak Time	Pasting Temp
A	56.1667	47.5000	8.6667	111.7500	64.2500	5.1333	77.40
B	47.5833	45.9167	1.6667	104.5833	58.6663	5.4667	77.30
C	72.5000	70.3333	2.1667	153.9167	83.5837	7.0000	77.45
D	56.4167	48.9167	7.5000	114.2500	65.3333	5.0000	75.05
E	57.2500	54.0833	3.1667	119.2500	65.1667	5.0667	73.45
F	62.7500	60.1667	2.5833	127.1667	67.0003	5.4000	75.85
G	54.4167	52.2500	2.1667	116.4167	64.1667	5.2667	75.05
H	69.4167	68.9167	0.5000	143.5000	74.5833	5.2000	74.95
I	64.1667	56.6667	7.5000	127.1667	70.5003	5.1333	72.60
J	76.5000	74.3333	2.1667	156.5833	82.2500	6.9333	76.60
K	63.0000	60.8333	2.1667	127.6667	66.8337	5.4000	76.60
L	53.7500	48.4167	5.3333	114.0000	65.5833	5.0667	75.80
M-N-O	57.6667	53.6667	4.0000	121.1667	67.5003	5.1333	75.05
P	142.4167	77.0833	65.3333	148.3333	71.2500	5.8000	66.00
Q	75.4167	74.5833	0.8333	141.2500	66.6667	6.0000	73.45
R	89.5000	86.0833	3.4167	171.4167	85.3337	5.5333	73.50
S	98.9167	65.0000	33.9167	136.3333	71.3333	5.4000	64.45

KEY: PBD-packed bulk density, LBD-Loosed bulk density, WAC-water absorption capacity, OAC- oil absorption capacity, WBC-water binding capacity, SP-swelling power, MC- moisture content, SOL-solubility A- 25M: 50S: 37.5W, B- 25M: 50S: 12.5W, C- 25M: 75S: 25W, D-25M: 25S: 25W, E- 75M: 50S: 37.5, F- 75M: 50S: 12.5W, G-75M: 75S: 25W, H-75M: 25S: 25W, I-50M: 25S: 25S, J-50M: 75S: 12.5W, K- 50M: 25S: 12.5W, L- 50W: 75S: 37.5W, M-N-O-50M:50S:25W, P- Refined wheat, Q- 100%Maize, R-100% Sorghum, S-100%Whole wheat

The peak time for the samples ranges between 5.03 and 6.97s. Sample "J" has the highest peak time of 6.97s while sample "D" has the lowest peak time of 5.03s. There is no significant difference between sample A, C, D, and L ($P \leq 0.05$). Additionally, there is no statistically significant difference ($P \leq 0.05$) between sample B, G, I, K, M, N, O, and S's peak times. According to the results, the peak time rises as the sample's sorghum proportion climbs. A sample's capacity to cook quickly is indicated by its low peak time [5].

The flour sample setback is between the ranges of 61.42 to 84.75 RVU. It was reported that the setback phase of the pasting curve occurs as the starch cools and involves the re-association, retro gradation, or reorganization of starch molecules. This is the capacity of starch to bind and deteriorate when cooled [5].

Amylose has a high molecular weight, thus flours with low setback may have low levels of it. The lower the retrogradation during cooling of starch, the higher the setback value [10]. High setback rates are also linked to syneresis. Sample B has the lowest set back value while sample R which is 100% maize flour has the highest setback value. There is no significant difference between sample A.D, L, M, N and O. The setback increase with reduction in percentage de-germed whole wheat flour and increase in percentage maize flour. Higher setback values correlate with less retrogradation during cooling and decreased staling rate of flour-derived products [7].

The breakdown point for the flour samples ranges from 0.71 -65.04RVU. Sample H has the lowest value of 0.71 while sample P which is refined wheat flour has the highest value of 65.04. Sample S which is de-germed whole wheat has the value of 33.88 which is closer to that of refined wheat flour. The measurement of swollen starch granules' propensity to rupture under high temperatures and constant shearing is known as breakdown viscosity. Breakdown viscosity also indicates paste stability [6]. There is significant difference within all the samples except sample M, L and N which comprises of 50M: 50S: 25W at P≤0.05.

The through viscosity for the flour sample ranges between 46.88 -85.00RVU. Sample B has the lowest value of 46.88 while sample R which is de-germed sorghum flour has the highest value of 85.00. Sample J and sample Q has the value that is comparable with that of refined wheat thou there is significant difference between the samples. Peak viscosity ranges between 48.83 -142.22RVU. The result is comparable with the result of[6] with value ranges between 102-123RVU. Peak viscosity depends on the swelling index, whereas low peak viscosity, which results from dextrinization or starch breakdown, implies increased solubility [17.

Sample B has the lowest value of 48.83 w while sample P which is refined wheat flour has value of 142.22. De-germed whole wheat flour has the value which is closer to that of refined wheat.The range of the final viscosity value is 108.29 to 169.75 RVU. The viscous load experienced during mixing is indicated by the final viscosity [13]. Sample B has the lowest value of 108.29, while sample R, which is 100% sorghum, has the highest value of 169.75. The Figure 1 displays the graphical image. Samples D and L do not significantly differ from one another. Additionally, there is no discernible difference between samples H, P, and Q—which are 100% maize and 100% refined wheat, respectively.

CONCLUSION

The study's findings showed that the ratio of the three flours that are blended together affects the functional qualities of the developed multigrain flour. In comparison to refined wheat flour, the multigrain flour generated has a reduced peak viscosity and breakdown viscosity due to the multigrain flour's pasting characteristics. The findings of this study suggest that whole wheat, sorghum, and maize can be used to make multigrain flour, which might be used as a raw material by the baking industry. Thus, it is advised that future studies concentrate on enhancing the characteristics of multigrain flour to make it more beneficial for baking procedures.

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