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Research Article

Evaluation of Proximate Composition, Antioxidant and Pasting Properties of Optimized Flour Blends from Pearl Millet, Green Gram and Tigernut Pomace

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Abstract: Flour blends produced from pearl millet, green gram, and tigernut pomace were evaluated for their chemical composition and pasting characteristics. Sixteen runs (flour blends) were generated using optimal mixture design of response surface methodology and used for the determination of functional properties. Four blends were thereafter chosen for the evaluation of the proximate composition, antioxidant, and pasting characteristics. The functional properties of the flour blends had significant ($p < 0.05$) Analysis of Variance (ANOVA), R^2, and Adjusted R^2 values. An increase in green gram and tigernut pomace flour addition resulted in higher values of ash, crude protein, crude fat, crude fiber, carbohydrate and energy values. The antioxidant properties of the flour blends especially in run 13 (85% pearl millet flour, 5% green gram flour and 10% tigernut pomace flour) showed increases in total phenol, flavonoid and DPPH contents. The pasting profile viscosities were generally low. Pearl millet, green gram and tigernut pomace flour blends could effectively be utilized in the production of complementary food as well as baked products that required low viscosity.

Keywords: green gram, optimization, formulation, flour blends, antioxidant, viscosity

1. Introduction

Researchers have continued to pay more attention to the use of composite flour in the development of food products, particularly in bakery goods and infant formulations. Diverse flours from cereal, legume, or root crops are combined to produce composite flour, which meets nutrient composition and functional requirements. It may contain less than 20% of other flours like millet, maize, sorghum, etc. or a blend with more than 80% wheat flour [1]. In an effort to reduce protein-energy malnutrition, especially in young children, legumes, nuts, and vegetables are now being included in food formulation as a recent advance in the nutrient diversification strategy.

Pearl millets (*Pennisetum glaucum*) are mostly found in arid and semi-arid parts of the world with good sources of energy, minerals, vitamins, dietary fiber and polyphenols. Some potential health benefits of the millet include antioxidative and antidiabetic activity [2]. An edible seed and sprout are produced from the green gram (*Vigna radiata* L.). It is a legume mostly grown for its grains that are high in protein in Southern and Eastern Asia, Central Africa, some

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of China, South and North America, Australia, and some regions of Nigeria. Most extreme dry and semi-arid conditions are good for its growth. Its seed is made up of 60.40% carbohydrates, 1.30% fat, and 24.20% protein [3].

Tigernuts (*Cyperus esculentus*) are valued for their high carbohydrate contents, dietary fiber mineral, and vitamins and are a source of antioxidants. Tigernut pomace is a by-product (residue) of the production of tigernut milk. A lot of attention has been generated by recent developments involving the utilization of by-products from food processing industries with high nutritional content due to their high-value products [4]. Pomace is known to have significant concentrations of bioactive ingredients, such as dietary fiber and antioxidants. Therefore, the objective of this study was to assess the proximate composition, antioxidant, and pasting characteristics of optimized flour blends made from pearl millet, green gram, and tigernut pomace.

2. Materials and methods

2.1 *Procurement of materials*

Pearl millet and fresh yellow tigernut tubers were bought from Itam Market in Uyo Metropolis, Akwa Ibom State. Green gram was purchased from the Michael Okpala University of Agriculture, Agronomy Department in Umudike, Abia State. The utilized reagents are of analytical grade.

2.2 *Preparation of materials*

2.2.1 *Preparation of pearl millet flour*

The pearl millet flour was prepared by steeping clean 3 kg millet grains in water (1:4 w/v) for 24 h. The soaked millet grains were drained, boiled for 20 min, drained and dried in an air oven (KX350A, Kenxin International Co. Ltd., Japan) at 65 °C for 18 h. The dried grains were milled using a Panasonic Mixer Grinder (MX-AC210S, Japan Premium), sieved using a 425 µm mesh size, and then packaged in an airtight container.

2.2.2 *Preparation of green gram flour*

The green gram flour was prepared following the method described by Akaerue and Onwuka [5]. Two (2) kg Green gram seeds were hand-picked, dirt and chaff were removed and the clean seeds were soaked in water for 12 h (1:10 w/v). Dehulling was done by rubbing the soaked grains against each other using hands. The dehulled beans were boiled at 100 °C for 30 min, drained and then dried in an air oven at 60 °C for 8 h, milled into flour using a Panasonic Mixer Grinder (MX-AC400), sieved using a 425 µm mesh size and packaged in an airtight container.

2.2.3 *Preparation of tigernut pomace flour*

One (1) kg of fresh yellow tigernut was visually inspected and defective tubers were manually removed and discarded. The sound fresh tigernut tubers (900 g) were cleaned, milled with 3.2 L water and sieved using a muslin cloth (425 µm mesh size). The resulting milk was thrown away, and the leftover material (pomace) in the muslin cloth was washed with 400 ml water to further remove the milk. The pomace was dried in an air oven at 60 °C for 6 h, milled using a Panasonic Mixer Grinder, sieved to pass through a 425 µm mesh size, and packaged in an airtight polythene bag.

2.3 *Experimental design for the preparation of the flour blends*

Using the D-optimal mixture design of response surface methodology (Design expert 12.0.3.0), the experimental design for the production of blends of pearl millet, green gram, and tigernut pomace flour was carried out. There were 16 experimental runs, and for each combination of treatments, the proportion of each flour was expressed as a fraction of the blend form, providing the sum of the component ratio as 100 as shown in Table 1. The independent variables were pearl millet (70.00-85.00 g/100 g), green gram (5.00-25.00 g/100 g) and tigernut pomace (5.00-10.00 g/100 g) while the responses were functional properties (bulk density, gelation temperature, swelling capacity, foaming capacity, water and oil absorption capacities).

Table 1. Flour blends formulation

Run	A (g/100 g)	B (g/100 g)	C (g/100 g)
1	70.00	20.00	10.00
2	85.00	7.50	7.50
3	70.00	22.50	7.50
4	70.00	25.00	5.00
5	85.00	10.00	5.00
6	77.50	12.50	10.00
7	73.75	20.00	6.25
8	85.00	10.00	5.00
9	70.00	25.00	5.00
10	70.00	20.00	10.00
11	77.50	15.00	7.50
12	81.25	10.00	8.75
13	85.00	5.00	10.00
14	85.00	5.00	10.00
15	70.00	20.00	10.00
16	77.50	17.50	5.00

A: Pearl millet flour, B: Green gram flour, C: Tigernut pomace flour

2.4 *Functional properties of the flour blends*

The bulk density of the flour samples was determined according to Onwuka [6]. Determination of water absorption capacity, oil absorption capacity, swelling capacity, and gelation temperature were carried out following the method of Olawuni et al. [7]. The foaming capacity was determined following the method described by Onimawo [8].

2.5 *Determination of proximate composition and energy value of the flour blends*

Moisture, ash, crude protein, crude fat, and crude fiber contents were determined following the method described by AOAC [9]. The carbohydrate content of the flour samples was calculated by subtracting the percentage of proximate components addition (moisture, ash, crude protein, crude fat, and crude fiber) from 100% (g/100 g) as shown in Eq. (1). Total energy values were calculated as shown in Eq. (2).

$$\%\text{CHO} = 100 - \% \left(\begin{matrix} \text{Moisture} + \text{Crude protein} \\ \text{Crude fat} + \text{Ash} + \text{Crude fiber} \end{matrix} \right) \tag{1}$$

$$\%\text{Total energy} = (\%\text{protein} \times 4) + (\%\text{fat} \times 9) + (\%\text{CHO} \times 4) \tag{2}$$

2.6 *Determination of antioxidant properties of the flour blends*

The total phenolic content of the flour blends was evaluated using the method provided by Singleton et al. [10]. The method of Zhishen et al. [11] was used to evaluate the total flavonoid content of flour blends and the procedure as described by De Ancos et al. [12] was followed to determine the 1,1-diphenyl-2-picrylhydrazyl (DPPH) scavenging activity of the flour blends.

2.7 *Determination of pasting properties of the flour blends*

The Rapid Visco-Analyzer was used to evaluate the sample's pasting properties (Model RVA series 4; Newport Scientific Property Limited, Warriewood, Australia). Three (3) g of sample were mixed in 25 mL of distilled water in an aluminum canister. The flour-water suspension was held at 50 °C for 1 min before being heated to 95 °C, held for 10 min, and then cooled to 50 °C for another 2 min according to Standard Profile 1. Peak, trough, breakdown, final, and setback viscosities, as well as peak time and pasting temperature, were all measured for starch viscosity.

2.8 *Statistical analysis*

The data were analyzed with SPSS version 20.00; one-way Analysis of Variance (ANOVA) was used to find the significant ($p < 0.05$) differences between the means, and the Duncan's New Multiple Range Test was used to separate the means.

3. Results and discussion

3.1 *Functional properties of pearl millet, green gram, and tigernut pomace flour blends*

The result of the functional properties of pearl millet, green gram, and tigernut pomace flour blends is presented in Table 2 while its ANOVA is summarized in Table 3. The bulk density of the flour blends varied between 0.79 and 0.95 g/ml, with run 3 having the highest result. The results of the present investigation exceeded the 0.57-0.63 g/ml range values for yam-cowpea composite flour reported by Okorie et al. [13]. The ANOVA result showed that the bulk density model (quadratic) and model terms were significant ($p < 0.05$). The R^2 value was 0.88, while the adjusted R^2 value was 0.83. It showed that tigernut pomace flour lowered the bulk density of the flour blends whereas the inclusion of green gram flour had a beneficial impact by enhancing the bulk density.

The Gelation Temperatures (GT) of the flour blends ranged from 62 °C (run 13) to 84 °C (run 7). The study found that the flour with a higher starch content required the lowest temperature to gelatinize. The GT for these flour blends was higher than the range values (56.22-60.56 °C) reported for composite flour blends made with rice, green gram, potato, and wheat [14]. The ANOVA result showed that the model terms for GT and the special quartic model were significant ($p < 0.05$). GT was influenced by all the variables.

The swelling capacity (14.00-17.00 ml) of the flour blends was found to be higher in samples with a larger proportion of green gram and tigernut pomace flours than in samples with a lower proportion. The quantity of amylose and amylopectin in the tigernut pomace and green gram flours is influenced by swelling capacity, which is a sign of the availability of amylase. The finding of Ratnawati et al. [15] that green gram flour (10.52 g/g) had a higher swelling capacity due to its higher amylose content of 23.45% is supported by the findings of the current investigation. The model (special quartic) and model terms for swelling capacity were significant ($p < 0.05$), according to the ANOVA. The R^2 value was 0.92, while the adjusted R^2 value was 0.83. With tigernut pomace flour having the biggest contribution, all the variables influenced the blends' capacity to swell.

The foaming capacities of the flour blends ranged from 1.89-3.92%, with the samples having highest amount of green gram flour (runs 4 and 9) recording the highest value. The poor foaming capability of the flour blends obtained in this investigation may be due to higher fiber content. This is in agreement with the low foaming capacity recorded for whole millet flour compared to brown type millet [16]. The ANOVA result showed that the model terms for foaming capacity and the special quartic model were significant ($p < 0.05$). The model is properly fitted as indicated by the R^2 and adjusted R^2 values of 0.98 and 0.96, respectively. The impact of the variables on foaming capacity supported green gram flour's greater contribution.

The Water Absorption Capacity (WAC) ranged between 280% and 390%. The findings of this investigation were comparable with the range of values (199.60-336.58%) for unripe banana, pigeon pea, and sweet potato flour blends reported by Ohizua et al. [17]. All of the flour blends had significant WAC, making them appropriate as functional components or raw materials in the production of baked goods, soups, and other ready-to-eat foods. The quadratic model and model terms were significant ($p < 0.05$), according to the ANOVA result. The Oil Absorption Capacity (OAC) ranged from 20 to 280%, with runs 13 and 14 having the highest value.

Table 2. Functional properties of millet, green gram and tigernut pomace flour blends

Run	A (g/100g)	B (g/100g)	C (g/100g)	BD (g/ml)	Gelation temp.(°C)	Swelling capacity (ml)	Foaming capacity (%)	Water abs. capacity (%)	Oil abs. capacity (%)
1	70.00	20.00	10.00	0.87	71.00	17.00	3.88	280.00	80.00
2	85.00	7.50	7.50	0.87	65.00	14.40	3.85	350.00	140.00
3	70.00	22.50	7.50	0.95	72.00	16.00	3.85	280.00	120.00
4	70.00	25.00	5.00	0.84	77.00	16.00	3.92	300.00	60.00
5	85.00	10.00	5.00	0.91	76.00	15.00	3.77	280.00	20.00
6	77.50	12.50	10.00	0.82	66.00	14.90	3.88	320.00	140.00
7	73.75	20.00	6.25	0.88	84.00	14.80	3.92	320.00	120.00
8	85.00	10.00	5.00	0.89	75.00	14.50	3.77	300.00	50.00
9	70.00	25.00	5.00	0.87	77.00	16.40	3.92	280.00	60.00
10	70.00	20.00	10.00	0.92	71.00	17.00	3.84	300.00	81.00
11	77.50	15.00	7.50	0.89	76.00	15.00	3.85	300.00	20.00
12	81.25	10.00	8.75	0.84	71.00	15.20	3.77	290.00	40.00
13	85.00	5.00	10.00	0.79	62.00	14.00	1.89	390.00	280.00
14	85.00	5.00	10.00	0.79	63.00	15.00	1.89	385.00	280.00
15	70.00	20.00	10.00	0.90	71.00	16.80	3.88	290.00	80.00
16	77.50	17.50	5.00	0.87	75.00	16.50	3.90	280.00	60.00

A: Pearl millet flour, B: Green gram flour, C: Tigernut pomace flour

The samples with the small amount of green gram flour and the largest amount of tigernut pomace flour were found to have the highest OAC. The model (special quartic) and model terms for OAC were significant ($p < 0.05$), according to the ANOVA.

Table 3. ANOVA for functional properties of pearl millet, green gram and tigernut pomace flour blends

	A	B	C	AB	AC	BC	A^2BC	AB^2C	ABC^2	R^2	AR^2
BD	0.95	0.86	-1.13	-0.14	1.91	2.86	--	--	--	0.88	0.83
GT	72.39	77.36	153.11	5.80	-160.89	-134.57	310.18	1,052.64	-2,121.16	0.90	0.78
SC	12.57	16.17	52.83	6.81	-43.48	-44.73	113.77	-150.48	-143.30	0.92	0.83
FC	3.82	3.92	0.48	-1.13	-5.73	4.21	79.23	-20.66	19.26	0.98	0.96
WAC	320.20	295.64	288.39	-110.02	357.52	-30.22	--	--	--	0.80	0.70
OAC	34.29	61.54	-3,417.98	17.05	5,938.25	4,723.11	-20,360.21	-5,025.52	31,562.04	0.93	0.86

A: Pearl millet flour, B: Green gram flour, C: Tigernut pomace flour, BD: Bulk Density, GT: Gelation Temp., SC: Swelling Capacity, FC: Foaming Capacity, WAC: Water absorption capacity, OAC: Oil absorption capacity, AR^2: Adjusted R^2

3.2 *Proximate composition and energy value of the selected flour blends*

Table 4 presents the results of the proximate composition and energy value of the selected flour blends produced from tigernut pomace, green gram, and pearl millet. There was no significant ($p > 0.05$) difference in the moisture content of the selected blends, which varied from 6.03-6.52 g/100 g. The moisture content was within the acceptable range of below 10% to guarantee the stability of flours over a long period of time. This could indicate that the composite flour may be kept at room temperature for extended periods of time without microbial spoilage [18]. The ash content ranged between 1.43 g/100 g and 1.60 g/100 g. Runs 4 and 7 having the highest value were not significantly ($p > 0.05$) different. The amount of ash in the flour samples provides an approximation of their mineral composition. The low values recorded for runs 1 and 13 were shown to be largely caused by an increase in the tigernut pomace flour content. This implies that the flour blends contain little in the form of minerals. These results were less than the millet-carrot composite flour values (1.19-2.69%) reported by Adebanjo et al. [19].

Table 4. Proximate composition and energy value of the selected pearl millet, green gram and tigernut pomace flour blends

Sample blend (PMF:GGF:TPF)	Moisture (g/100 g)	Ash (g/100 g)	Crude protein (g/100 g)	Crude fat (g/100 g)	Crude fiber (g/100g)	Carbohydrate (g/100 g)	Energy value (kcal/100 g)
Run 1 (70:20:10)	$6.30^a \pm 0.06$	$1.49^b \pm 0.02$	$14.63^b \pm 0.07$	$12.06^c \pm 0.13$	$1.75^b \pm 0.01$	$63.77^b \pm 1.04$	$422.14^b \pm 2.76$
Run 4 (70:25:5)	$6.52^a \pm 0.19$	$1.60^a \pm 0.00$	$14.95^b \pm 0.64$	$8.17^b \pm 0.09$	$0.17^d \pm 0.04$	$68.59^a \pm 1.55$	$407.69^c \pm 5.14$
Run 7 (73.75:20:6.25)	$6.03^a \pm 0.05$	$1.60^a \pm 0.04$	$15.57^a \pm 0.26$	$11.63^b \pm 0.28$	$1.25^c \pm 0.08$	$63.92^b \pm 1.04$	$422.63^b \pm 6.38$
Run 13 (85:5:10)	$6.08^a \pm 0.04$	$1.43^b \pm 0.05$	$13.18^c \pm 0.02$	$13.45^a \pm 0.08$	$2.18^a \pm 0.05$	$63.68^b \pm 2.09$	$428.49^a \pm 5.03$

Values are represented as means ± standard deviation of three determinations. Data in the same column bearing different superscript differed significantly ($p < 0.05$). PMF: Pearl Millet Flour, GGF: Green Gram flour, TPF: Tigernut Pomace Flour

Runs 13 and 7 showed a significant ($p < 0.05$) increase in crude protein content (13.18-15.57 g/100 g, respectively). This increase corresponds with an increase in the inclusion of green gram flour. It was higher than the range values (6.29-9.52%) reported for blends of yellow maize, soybean, and jackfruit seed flours [20] and 5.15-8.10% reported for blends of sprouted sorghum and defatted pumpkin seed flours [21]. The crude fat content ranged significantly from 8.17

g/100 g (run 4) to 13.45 g/100 g (run 13). Since tigernut flour was found to have a fat level of 28.77% [22], and green gram flour was reported to have a low-fat content of 1.31% [15], it is possible that the tigernut pomace flour contributed to the increase in fat content in the current study.

The crude fiber content of the flour blends increased significantly when tigernut pomace flour was added, ranging from 0.17 to 2.18 g/100 g for runs 4 and 13, respectively. It is anticipated that crude fiber content would rise. The results of Awolu and Olabiran [23] for rice, carrot and defatted soybean flours were compared favorably with the values. The formulated flour blends are a perfect source of crude fiber because of this. The carbohydrate content varied from 63.77 g/100 g to 68.59 g/100 g. The greatest value was in run 4, while runs 1, 7, and 13 did not significantly ($p > 0.05$) differ from each other. The energy value significantly ranged from 407.69 to 428.49 kcal/100 g, with run 13 having a higher value. It was discovered that the increased contributions of both the pearl millet flour and tigernut pomace flour were the cause of the higher energy value seen in the flour blends. These values were greater than the range values (356.18-368.75 kcal) in the earlier study for wheat, pigeon pea, and plantain composite flour reported by Bello et al. [24].

3.3 *Antioxidant properties of the selected flour blends*

The Total Phenolic Content (TPC) of the flour blends varied from 0.44 to 0.62 mg GAE/100 g (Figure 1a). Run 13 with larger proportions of tigernut pomace flour and pearl millet flour had the highest TPC value. The TPC obtained in this investigation was higher than the range values (2.65-4.95 mg GAE/g) reported for pearl millet and tigernut flour blends [25] but lower than the value of 4.56-4.73 mg GAE/100g recorded for maize-based soybean and tigernut composite flour [26]. As illustrated in Figure 1b, the total flavonoid concentration (TFC) of the flour blends varied considerably ($p < 0.05$) and ranged from 0.13 to 0.46 mg QE/100 g. It followed the same trend with TPC with run 13 having a higher value.

The DPPH scavenging ability of the flour blends demonstrated a significant ($p < 0.05$) difference ranging between 4.38% and 5.20% (Figure 1c). The flour sample DPPH scavenging ability values were low. The low concentration of polyphenolic compounds in the flour blends may be the cause of this. This result is consistent with the values (4.89% and 3.29%) obtained for wheat flour and wheat-banana peel flour blends, respectively [27]. There is a direct relationship between the ability of phenolic compounds to scavenge DPPH and the level of hydroxylation that these compounds undergo as DPPH levels increase. This was seen in run 13, which had a high amount of total phenolic and flavonoids.

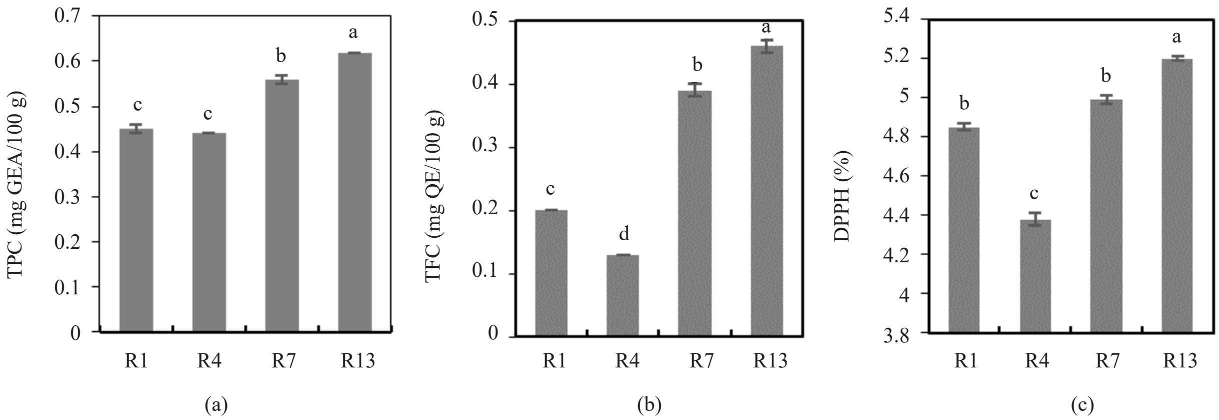

Figure 1. The TPC (a), TFC (b) and DPPH (c) of pearl millet, green gram and tigernut pomace flour blends where R1 (run 1): 70% PMF, 20% GGF, 10% TPF; R4 (run 4) 70% PMF, 25% GGF, 5% TPF; R7 (run 7): 73.75% PMF, 20% GGF, 6.25% TPF; R13 (run 13): 85% PMF, 5% GGF, 10% TPP. PMF: Pearl Millet Flour, GGF: Green Gram Flour, TPF: Tigernut Pomace Flour

3.4 *Pasting properties of the selected flour blends*

All of the pasting parameters of the flour blends, with the exception of the peak time, varied significantly ($p < 0.05$)

(Table 5). The highest values were often seen in run 7, whereas run 1 had the lowest value. The pearl millet and green gram flours contributed to the observed increase in values. The range values (1,186-1,520 cP) reported for rice, carrot, and defatted soybean flours [21] were higher than the peak viscosity (108.00-280.50 cP) attained in this study. With the exception of green gram flour, which has a high starch and amylose concentration and a peak viscosity of 909.00 cP as reported by Ratnawati et al. [15], the protein and fat levels in legume flours can prevent the swelling of starch granules and lower viscosity. This explains why the value recorded for run 1 is so low as a result of high-fat content in tigernut pomace flour.

Table 5. Pasting properties of the selected pearl millet, green gram and tigernut pomace flour blends

Sample blend (MF:GGF:TPF)	Peak viscosity (cP)	Trough viscosity (cP)	Breakdown viscosity (cP)	Final viscosity (cP)	Setback viscosity (cP)	Peak time (min)
Run 1 (70:20:10)	$108.00^{d} \pm 12.02$	$96.00^{d} \pm 2.89$	$12.50^{c} \pm 2.12$	$194.00^{c} \pm 19.21$	$98.00^{c} \pm 4.31$	$7.00^{a} \pm 0.00$
Run 4 (70:25:5)	$217.50^{c} \pm 12.34$	$194.50^{c} \pm 11.24$	$22.50^{d} \pm 4.61$	$355.50^{b} \pm 21.21$	$161.00^{b} \pm 7.80$	$6.97^{a} \pm 0.05$
Run 7 (73.75:20:6.25)	$280.50^{a} \pm 19.09$	$253.05^{a} \pm 12.16$	$27.00^{a} \pm 4.25$	$460.50^{a} \pm 27.58$	$207.00^{a} \pm 12.73$	$6.97^{a} \pm 0.05$
Run 13 (85:5:10)	$238.50^{b} \pm 13.08$	$217.00^{b} \pm 14.85$	$21.50^{b} \pm 3.19$	$396.50^{b} \pm 20.64$	$179.00^{b} \pm 10.45$	$6.97^{a} \pm 0.05$

Values are expressed as means ± standard deviation of three determinations. Data in the same column bearing different superscript differed significantly ($p < 0.05$). PMF: Pearl Millet Flour, GGF: Green Gram Flour, TPF: Tigernut Pomace Flour

The trough viscosity range values (96.00-253.05 cP) found in this study were low compared to previous findings pearl millet, kidney bean and tigernut flour blends [28]. The trough is a measure of the least viscosity that a paste can have while still remaining stable upon cooling. The breakdown viscosity ranged from 12.50 cP to 27.00 cP. The higher breakdown for run 7 shows a low level of stability. The final viscosity of the flour blends ranged from 194.00 to 460.50 cP for runs 1 and 7, respectively. Final viscosity, which reflects a flour's capacity to transform into a viscous paste upon cooking and cooling, is frequently used to describe a starch-based flour's quality. As the amount of tigernut pomace flour inclusion increased, the final viscosity was reduced. The setback viscosity was between 98.00 to 207.00 cP. The cooking time is judged by the peak time. The peak time across the flour blends did not differ significantly ($p > 0.05$).

4. Conclusions

The prospective application of green gram and tigernut pomace flour-enhanced pearl millet flour was assessed for its nutritional, antioxidant properties, and pasting characteristics. The inclusion of green gram flour and tigernut pomace flour at 5-10% and 5-25%, respectively, improved the functional properties. In run 7 (73.75% pearl millet flour, 20% green gram flour and 6.25% tigernut pomace flour), the inclusion of green gram flour led to an enhancement in the crude protein and ash contents, and in run 13 (85% pearl millet flour, 5% green gram flour and 10% tigernut pomace flour), the inclusion of tigernut pomace flour resulted in higher values for crude fiber, crude fat, and energy value. Tigernut pomace flour also increased the antioxidant activities while generally lowering the pasting properties. The study has demonstrated that combining flours from tigernut pomace, green gram, and pearl millet utilizing the best mixture design will improve the food products' nutritional value and functional qualities. Utilizing these local crops would lessen dependence on wheat, and would also encourage the use of underutilized agro-industrial byproducts.

Conflict of interest

The authors declare no conflicts of interest.

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