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EFFECT OF GREEN GRAM FLOUR ADDITION ON THE CHEMICAL COMPOSITION AND PASTING PROPERTIES OF COCOYAM FLOUR AS POTENTIAL INGREDIENTS IN FOOD PRODUCT DEVELOPMENT

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ABSTRACT

Background. Indigenous crops are known to help people in the tropics improve their food security. However, due to a lack of knowledge about their compositions, these advantages are not completely realized. Cocoyam and green gram are examples of underutilized crops rich in carbohydrate and protein content, respectively. This research looked at the functional characteristics, nutritional and antinutrient composition, and pasting properties of composite flours made from cocoyam and green gram.
Materials and methods. A red variety of cocoyam tubers were processed into dried slices, milled, sieved, and packaged. The experimental design was performed by applying the response surface methodology. Eight (8) runs were formulated for the cocoyam and green gram flour blends. The independent variables were cocoyam flour and green gram flour with design constraints of 85.00–100.00% and 0.00–15.00%, respectively, while the dependent variables are the functional characteristics.
Results. The addition of green gram flour significantly ($p < 0.05$) increases the bulk density, foaming capacity, gelation temperature, and oil absorption capacity of the blends. The proximate composition also showed that the addition of green gram flour enhanced the nutritional value, with run 2 having the overall best proximate composition of 18.29% crude protein, 1.44% crude fat, and 2.85% ash. Flour blends showed low antinutrient contents, while run 3 competes favorably with 100% cocoyam flour for pasting properties.
Conclusion. The selected flour blends revealed a potential for value-added products like snacks and complementary foods.

Keywords: processing, nutritional, food security, responses, indigenous, value addition

INTRODUCTION

Composite flour is a blend of flours produced from cereals, roots, tubers, and legumes, with or without the incorporation of wheat flour. It promotes the use of indigenous agricultural products such as flour, and the acceptance of these native crops would increase their usage via processing and value addition. Cocoyam (*Colocasia* sp.) is a tropical perennial plant cultivated for its delicious starchy corm as a root vegetable. Cocoyam is a significant root and tuber crop all over the world (Ejoh et al., 2015). The *Colocasia esculenta* and *Xanthosoma sagittifolium* genera are the most widely consumed and grown in Nigeria, with white and red varieties (Ukom et al., 2018). Cocoyam corms are a rich source of carbohydrates that supply

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energy, increase satiety in consumers, and give meals favorable functional qualities (Ejoh et al., 2015). Cocoyam is still consumed by a small number of people in Nigeria, owing to its reputation as a poor man's diet. Due to a lack of information about the crop's nutritional qualities and its high moisture content, which contributed to a high rate of degradation after harvest, it is no longer popular in urban households. On the other hand, processing fresh cocoyam corms into flours, will contribute to food security while increasing adaptability and use in food formulations (Falade and Okafor, 2015).

Plant-based proteins have been employed as functional ingredients in food formulations to increase the nutritional quality and sensory characteristics. Green gram (*Vigna radiata*) is a grain legume that matures in 70–90 days and is also known as mungbean or golden gram in some places around the world. It is commonly cultivated in the tropics and subtropics. It is consumed as cooked beans, broth, or pancakes and is an essential dietary source for people. Green gram seeds are high in protein (20.97–31.32%), and their carbohydrates are easier to digest, resulting in less flatulence in humans as related to other legumes (Nair et al., 2013). Recent studies have shown the effect of green gram flour in food product development as a means of enhancing nutrition (Thongram et al., 2016; Onwurafor et al., 2019). Therefore, the study aims to evaluate the functional properties, proximate, antinutrients, and pasting properties of cocoyam and green gram flour blends.

MATERIALS AND METHODS

Raw materials procurement

Cocoyam (red variety) was bought in Akpan Andem market in Udo Umana, Uyo metropolis. Green gram was purchased from Umudike, Abia State. Analytical grade reagents were used.

Samples production

Production of cocoyam flour. Cocoyam flour was produced according to the method described by Ukonze and Olaitan (2010). The tubers were washed and cleaned well to remove debris, then peeled and thinly sliced using a knife. The sliced tubers were soaked for 20 min in water containing sodium metabisulphite (to prevent enzymatic browning), blanched for 5 min at 70°C, and dried for 10 h at 65°C in a typical air oven (model pp, 22 US, Genlab, England). The dried cocoyam slices were milled using a locally constructed attrition mill (made in Nigeria), and the fine cocoyam flour produced was packaged in an airtight container and stored at refrigeration temperature (4°C) prior to the analysis.

Production of green gram flour. The method of Opoku et al. (2003) was used to make green gram flour. Two (2) kg of cleaned green gram seeds were soaked in distilled water (1:3 w/v) for 12 h, then washed and dried for 10 h at 65°C in a typical air oven (model pp, 22 US, Genlab, England). The seeds were abrasively dehulled and winnowed to remove the hull from the seeds, milled in a locally constructed attrition mill (produced in Nigeria), then sifted to obtain a fine flour using a sieve size of 425 µm. The green gram flour was packaged in an airtight container and stored at 4°C.

Experimental design and formulation of samples

The experimental design was performed by applying response surface methodology using a mixture design (Design Expert 12.0.3.0, Stat-Ease Inc., Minneapolis, U.S.A). The independent variables (components) were cocoyam flour and green gram flour with design constraints of 85.00–100.00% and 0.00–15.00%, respectively. The dependent variables (responses) are the functional characteristics. Eight (8) runs were formulated for the cocoyam and green gram flour blends, thoroughly mixed, and packaged in a sealed container prior to analysis.

Determination of functional properties of cocoyam and green gram flour blends

The determination of bulk density was carried out using the method of Jones et al. (2000). The foaming capacity, gelation temperature, swelling, water, and oil absorption capacities of the flour blends were evaluated following the procedure of Onwuka (2005).

Determination of proximate composition and energy value of the flour blends

The moisture, crude protein, crude fat, ash, and fiber were determined by following the method of AOAC (2005). The difference between 100 and the total content of moisture, crude protein, crude fat, ash, and crude fiber was used to calculate the total carbohydrate content.

Determination of the antinutrient composition of cocoyam and green gram flour blends

Phytate was evaluated using the method given by Russel (1980). Tannin and saponin were determined using the method of Jaffe (2003).

Pasting properties of cocoyam and green gram 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.

Statistical analysis

Data were collected and subjected to analysis of variance employing the Statistical Package for the Social Sciences version (SPSS, Inc., Chicago, USA). Duncan's new multiple range test was used to determine the differences between treatment means at a significant level of $p < 0.05$.

RESULTS AND DISCUSSION

Functional properties of cocoyam and green gram flour blends

Table 1 shows the results of the functional properties of cocoyam and green gram flour blends, while Figure 1 illustrates the model graph. The bulk density of the flour blends varied significantly between 0.94 and 1.09 g/ml. The lower the bulk density, the lighter the flour, and the observed increase in run 2 indicates the heaviness of the flour blend. From the graph (Fig. 1a), the highest bulk density was found where cocoyam flour was 85% and green gram flour was 15%. As a result, the addition of 15% green gram flour enhances the bulk of the blends. This demonstrates that, while there was an increase in bulk density due to the addition of green gram flour, the increase was not significant ($p > 0.05$).

Awolu (2017) made a similar finding for the blends of pearl millet, kidney bean, and tigernut flours. The foaming capacity of runs 2 (5.99%) and 7 (6.03%) was significantly higher ($p < 0.05$) than the other flour blends. Protein content has a positive correlation with

Table 1. Design experiment for two mixture components and their responses (functional properties)

Run	A %	B %	Bulk density g/ml	Foaming capacity %	Gelation temperature °C	Swelling capacity %	Water absorption capacity %	Oil absorption capacity %
1	100.00	0.00	0.98 ±0.01[cd]	1.90 ±0.02[e]	64.00 ±0.01[c]	43.67 ±0.57[a]	491.33 ±1.15[a]	100.00 ±0.00[d]
2	85.00	15.00	1.09 ±0.01[a]	5.99 ±0.01[a]	68.33 ±0.57[a]	38.33 ±0.58[c]	421.00 ±2.89[e]	136.67 ±1.00[a]
3	92.50	7.50	1.03 ±0.01[a]	3.87 ±0.03[c]	66.67 ±0.58[b]	41.00 ±0.00[b]	441.67 ±2.87[d]	121.67 ±1.52[b]
4	96.25	3.75	1.06 ±0.02[ab]	3.76 ±0.01[d]	63.33 ±0.58[c]	41.67 ±1.15[b]	459.00 ±2.00[b]	111.00 ±1.73[c]
5	88.75	11.25	1.01 ±0.02[bcd]	5.75 ±0.12[b]	66.67 ±1.14[b]	41.00 ±1.00[b]	450.67 ±1.15[c]	132.67 ±2.52[a]
6	100.00	0.00	0.98 ±0.01[cd]	1.90 ±0.02[e]	63.67 ±0.58[c]	44.33 ±0.58[a]	490.33 ±3.57[a]	111.33 ±2.31[c]
7	85.00	15.00	1.09 ±0.01[a]	6.03 ±0.03[a]	68.33 ±0.58[a]	39.33 ±0.58[c]	420.67 ±2.50[e]	136.67 ±1.77[a]
8	92.50	7.50	1.03 ±0.01[a]	3.85 ±0.01[c]	66.67 ±0.58[b]	40.67 ±0.58[b]	440.33 ±2.58[d]	121.67 ±2.89[b]

Data are mean ±standard deviation of 3 replicates. Values having different superscripts in columns differ significantly ($p < 0.05$).
A – cocoyam flour, B – green gram flour.

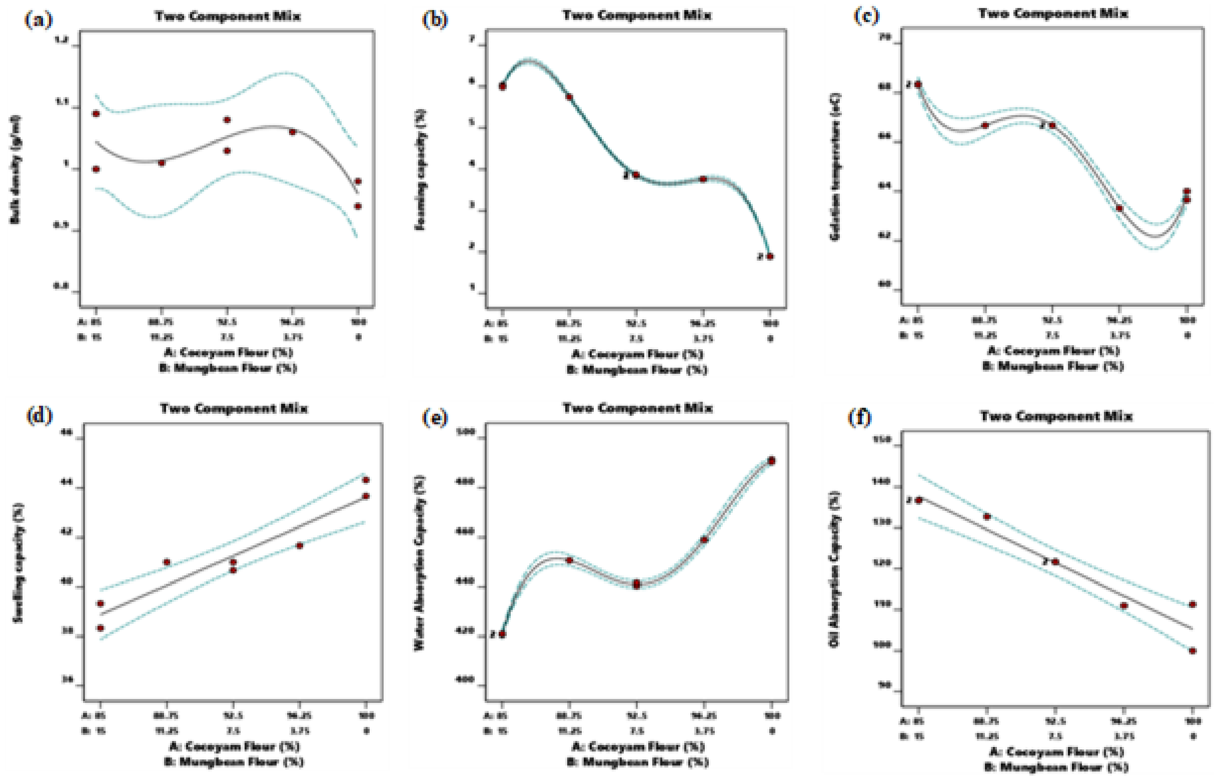

Fig. 1. Two components mixture plot of cocoyam and green gram flour blends for: a – bulk density, b – foaming capacity, c – gelation temperature, d – swelling capacity, e – water absorption capacity, f – oil absorption capacity

foaming capacity. The higher the proportion of green gram flour, the better the foaming capacity. The highest foaming capacity was found in the model graph (Fig. 1b), with 86.47% cocoyam flour and 13.53% green gram flour. This suggests that green gram flour contributed to the flour blends' increased foaming capacity.

The gelation temperature (GT) of the flour blends ranged between 63.33°C (run 4) and 68.33°C (run 2). The flour blend with the highest starch content (run 4) required the lowest temperature for gelatinization. Suresh and Samsher (2013) findings are supported by this result. At a 15% green gram flour substitution level, the graph model (Fig. 1c) shows the highest GT. This indicates that mixing green gram flour with cocoyam flour elevated the gelation temperature. As seen in run 6 (44.33%), the swelling capacity increases as the quantity of cocoyam flour in the flour blends increases. Sweet potato-soybean flour blends showed a similar tendency (Omoniyi et al., 2016). At 100% cocoyam flour and 0% green gram flour, the model graph (Fig. 1d) demonstrates an increase in the swelling capacity of flour blends. Water absorption capacity (WAC) varied significantly between 420.67 and 491.33% (runs 7 and 1, respectively), with formulations containing a high amount of cocoyam flour (carbohydrate) possessing a greater WAC. The results are consistent with the findings of Ukom et al. (2018) for cocoyam processing using various methods. Cocoyam flour's high WAC makes it a useful thickening or gelling agent in a variety of foods. The increase in WAC of the blends was found at 100% cocoyam flour and 0% green gram flour, according to the model graph (Fig. 1e). Because starch lacks nonpolar sites compared to proteins, the oil absorption capacity (OAC) is based mainly on the physical trapping of oil within the starch structure. The OAC of samples containing green gram flour was found to be greater than that of 100% cocoyam flour. The OAC of the flour blends increased when green gram flour was raised to 15% and cocoyam flour was reduced to 85%, as shown in the model graph (Fig. 1f).

Proximate composition and energy value of selected flour blends

The result of the proximate composition of the flour blend samples is presented in Table 2. The flour blends showed low moisture content, ranging from 6.28–7.93%. The samples' moisture level was within the permissible range for long-term flour storage. Low moisture content in food reduces moisture-dependent metabolic processes, improving flour storage stability. As the proportion of green gram flour in the flour blends increased, the crude protein content increased significantly from 10.18–18.29%. Protein is important for bodybuilding since it is a good source of amino acids.

The use of cocoyam-green gram flour blends in complementary foods and baked products would help to alleviate nutritional deficiencies (Bello et al., 2021). A similar increasing trend was reported for the flour blends of yellow yam, plantain, and pumpkin seed (Bello et al., 2018). The crude fat content of flour blends was low, ranging from 1.09% (run 1) to 1.44% (run 2). Low-fat content in cocoyam (Ukom et al., 2018) and green gram (Ratnawati et al., 2019) could explain these low values. Low-fat products have a longer shelf life because they are less susceptible to oxidative rancidity. The results are consistent with the range values of 1.32–1.71 g/100 g for cocoyam and Bambara groundnut flour blends (Awolu and Oseyemi, 2016). The ash content of the flour blends increased significantly ($p < 0.05$) as the proportion of green gram flour substituted increased, ranging from 1.52–2.85%, with run 2 having the highest value. The ash content of food could be used to determine the mineral composition of the food. The values obtained were within the range of 2.62–2.84% as reported by Agugo et al. (2019) for mungbean-garri diets. The crude fiber content was lowered from 4.59% in run 1 to 3.41% in run 2. Crude fiber content decreased as the amount of green gram flour increased. According to Inyang et al. (2018), dietary fiber has a significant impact on consumer health. Oloye et al. (2019) showed a similar result for yam, plantain, and soybean flour blends, which decreased from 6.25–3.00%. The carbohydrate content ranged from 67.73–74.69%, with the highest value being 100% cocoyam flour (run 1). Carbohydrate content reduced as green gram flour content increased, which is consistent with Makanjuola and Ajayi (2017) findings for yam-soy-plantain flour blends.

Antinutrient composition of selected cocoyam and green gram flour blends

The predominant antinutrient in the flour blends was phytate (4.78–5.06 mg/100 g), which varied significantly among the samples (Table 3). The addition of green gram flour increased the phytate level of the blends significantly. It has been claimed that legumes contain phytate and other components that impair mineral and vitamin absorption (Agugo et al., 2019).

Table 2. Proximate composition of the selected cocoyam and green gram flour blends

Parameters	Run 1 (100% CF)	Run 2 (85% CF/15% MF)	Run 3 (92.5% CF/7.5% MF)	Run 5 (88.75% CF/11.25% MF)
Moisture, %	7.93 ±0.04^{a}	6.28 ±0.16^{d}	7.52 ±0.04^{b}	7.13 ±0.06^{c}
Crude protein, %	10.18 ±0.03^{d}	18.29 ±0.42^{a}	11.06 ±0.04^{c}	16.59 ±0.07^{b}
Crude fat, %	1.09 ±0.00^{d}	1.44 ±0.00^{a}	1.16 ±0.01^{c}	1.36 ±0.00^{b}
Ash, %	1.52 ±0.01^{d}	2.85 ±0.01^{a}	2.31 ±0.01^{c}	2.39 ±0.01^{b}
Crude fiber, %	4.59 ±0.01^{a}	3.41 ±0.17^{c}	4.48 ±0.02^{a}	3.62 ±0.04^{b}
Carbohydrate, %	74.69 ±0.03^{a}	67.73 ±0.69^{d}	73.47 ±0.01^{b}	68.91 ±0.06^{c}

Data are mean ±standard deviation of 3 replicates. Values having different superscripts in rows differ significantly ($p < 0.05$).
CF – cocoyam flour, MF – green gram flour.

Table 3. Antinutrient composition of the selected cocoyam and green gram flour blends

Parameters	Run 1 (100% CF)	Run 2 (85% CF/15% MF)	Run 3 (92.5% CF/7.5% MF)	Run 5 (88.75% CF/11.25% MF)
Phytate, mg/100 g	4.78 ±1.01[c]	5.06 ±1.01[a]	4.94 ±1.00[b]	4.96 ±1.36[b]
Tannin, mg/100 g	1.05 ±0.03[c]	1.18 ±0.01[a]	1.13 ±0.01[b]	1.17 ±0.01[a]
Saponin, %	1.54 ±0.08[d]	2.64 ±0.26[a]	1.76 ±0.27[c]	1.87 ±1.02[b]

Data are mean ±standard deviation of 3 replicates. Values having different superscripts in rows differ significantly ($p < 0.05$).
CF – cocoyam flour, MF – green gram flour.

The current result was lower than the reported ranged values (5.00–24.06 mg/100 g) for aerial yam-soybean flour blends (Umoh, 2020) and 16.25–24.12 mg/100 g for quality protein maize flour, soya meal flour, millet flour, and cassava starch blends (Akinjayeju et al., 2019).

The tannin level of the flour blends was low, ranging from 1.05 to 1.18 mg/100 g in runs 1 and 2, respectively. Tannins are capable of binding protein, including digestive enzymes, resulting in poor protein digestibility. The values obtained in this study are appropriate and lower than the ranged values (1.76–1.78 mg/g) reported by Awolu and Oseyemi (2016) for cocoyam flour, Bambara groundnut flour, and cassava starch blends. The saponin concentration (1.54–2.64%) of the flour blends increased as the amount of green gram flour included increased. Bello et al. (2018) observed a similar effect with pumpkin seed flour increasing the saponin content of yellow yam and plantain flour blend cookies. Low saponin levels had a significant health advantage.

Pasting properties of selected flour blends from cocoyam and green gram

Table 4 shows the findings of the pasting properties of the flour blends. As the proportion of green gram flour in the mixture increased, the peak viscosity (720.67–1068.33 cP) decreased significantly ($p < 0.05$). Peak viscosity refers to the starch's capacity to swell freely before breaking down. All of the flour samples had low peak viscosity, indicating minimal starch concentration. The peak viscosity of 100% cocoyam flour (run 1) was the highest, although it was not significantly ($p > 0.05$) different from run 3. The results (128.50–166.25 RVU) were lower than those reported by Kalu et al. (2019) for water yam, yellow maize, and African yam bean flour blends. The trough viscosity of the flour blends ranged from 653.33 cP to 1033.67 cP, with run

Table 4. Pasting properties of the selected cocoyam and green gram flour blends

Parameters	Run 1 (100% CF)	Run 2 (85% CF/15% MF)	Run 3 (92.5% CF/7.5% MF)	Run 5 (88.75% CF/11.25% MF)
Peak viscosity, cP	1 068.33 ±16.02[a]	720.67 ±15.00[c]	1 028.33 ±18.22[a]	889.67 ±11.61[b]
Trough viscosity, cP	1 033.67 ±16.16[a]	653.33 ±12.34[c]	1 002.33 ±10.42[a]	865.67 ±9.43[b]
Breakdown, cP	34.66 ±5.50[b]	67.34 ±3.06[a]	26.00 ±5.29[c]	24.00 ±5.33[c]
Final viscosity, cP	1 513.00 ±12.24[a]	982.00 ±9.10[c]	1 519.00 ±19.12[a]	1 287.00 ±15.33[b]
Setback, cP	479.33 ±8.99[b]	328.67 ±10.22[c]	516.67 ±12.44[a]	421.33 ±9.35[b]
Pasting temperature, °C	86.37 ±0.11[b]	88.42 ±0.38[a]	86.67 ±0.47[b]	87.20 ±0.05[a]
Peak time, min	5.82 ±0.04[b]	6.31 ±0.03[a]	6.00 ±0.46[ab]	6.34 ±0.12[a]

Data are mean ±standard deviation of 3 replicates. Mean values having different superscripts in rows differ significantly ($p < 0.05$).
CF – cocoyam flour, MF – green gram flour. 10 cP – 1 RVU.

1 being the highest. The trough viscosity is the lowest viscosity after the initial peak and occurs after the sample has begun to cool. It assesses the paste's ability to withstand breakdown during cooling.

It was observed that with the inclusion of green gram flour, the trough viscosity reduced. This finding agrees with that of Anuonye and Saad (2015), whose report showed that the inclusion of soybean flour into yam flour reduced the trough viscosity. The breakdown values ranged between 24.00 cP and 67.34 cP. Run 2 was observed exhibiting a higher breakdown in viscosity as the ratio of green gram flour inclusions increased, which indicates lower paste stability. The final viscosity values ranged from 982.00–1519.00 cP for runs 2 and 1, respectively. After cooking and cooling, the starch's capacity to form a viscous paste or gel is measured as the final viscosity. This could be due to the flours' high carbohydrate content. Setback viscosity gives an indication of starch retrogradation in flour samples, and it varied significantly from 328.67 cP (run 2) to 516.67 cP (run 3). This means that run 3, with a higher setback viscosity, will have a higher tendency for retrogradation when the products have cooled. Pasting temperatures and times were 86.37–88.42°C and 5.82–6.34 min, respectively. Pasting temperature means the temperature at which the first detectable increase in viscosity is measured, and it is an index defined by the initial change caused by starch swelling (Julianti et al., 2015). When compared to 100% CF (run 1), the flour blend samples took longer to gel at higher temperatures, indicating that the greater the pasting temperature, the longer the pasting time. The findings of Awolu and Oseyemi (2016) are supported by this outcome.

CONCLUSION

The functional characteristics, proximate, antinutrients, and pasting properties of varied quantities of cocoyam and green gram flour blends were investigated. The addition of green gram flour improved the bulk density, foaming, and oil absorption capacities of the flour blends, but reduced the swelling and water absorption capacities. The protein, fat, and ash contents of the selected flour blends were enhanced as the proportion of green gram flour increased, while antinutrients were at acceptable levels. The peak, trough, and final viscosities of the blends were all reduced. However, run 3 (7.5% green gram flour addition) competes favorably with 100% cocoyam flour. The usage of these indigenous cultivated crops would be extremely beneficial in enhancing consumers' nutritional value, especially for the production of short-crust pastries and food formulation for infants, aged people, and recuperating patients.

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