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*Research Article*

# Effect of cowpea and coconut pomace flour blend on the proximate composition, antioxidant and pasting properties of maize flour

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## Abstract

A study was conducted to improve yellow maize flour through the addition of cowpea and coconut pomace flour blends. The flours were optimized using the optimal mixture design of response surface methodology and functional properties were determined. The bulk density, swelling, water absorption, and oil absorption capacity were all significantly ($p < 0.05$) different. Run 1 (75% maize flour, 23.75% cowpea flour, and 1.25% coconut pomace flour), Run 2 (95% maize flour and 5% cowpea flour), Run 7 (70% maize flour and 30% cowpea flour) and Run 8 (90% maize flour, 5% cowpea flour and 5% coconut pomace flour) were selected as best overall functional properties. The selected flour blends were assessed for proximate composition, antioxidant properties, and pasting properties. Cowpea flour significantly ($p < 0.05$) increased crude protein content, while coconut pomace flour enhanced ash, crude fat, fiber, and energy content. The antioxidant and pasting properties showed Runs 2 and 8 with improved DPPH value and pasting properties. These flour blends might be suitable for developing complementary foods and ready-to-eat foods due to their low pasting properties.

## Keywords

by-products, complementary, coconut pomace, indigenous crops, cowpea, mixture design

## Abbreviations

BV – breakdown viscosity; CF – cowpea flour; CHO – carbohydrate; CP – crude protein; CPF – coconut pomace flour; DPPH – 2,2 diphenyl picrylhydrazyl; ENE – energy; FV – final viscosity; MC – moisture, PT – pasting time; PV – peak viscosity; SV – setback viscosity; TFLA – total flavonoid; TPHE – total phenolic; TV – trough viscosity; YMF – yellow maize flour

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## Introduction

Flour blends from indigenous crops have been found to improve the functionalities and nutritional value of foods (Dushkova et al. 2023; Vasileva et al. 2023). The interplay between the dependent (responses) and independent variables (components) in optimal mixture design leads to a suitable blending of each formulation (Zlateva et al. 2022). Maize, also known as corn (*Zea mays*), is the world's third most significant crop cultivated across many countries after wheat and rice (Orhun 2013). It is the main food crop in Africa that is consumed by people of various taste preferences and socioeconomic backgrounds (Bello and Udo 2018). Maize is abundant in carbohydrates, dietary fiber, micronutrients, and polyphenols (Žilic et al. 2012; Bello and Oluwalana 2017; Akaffou et al. 2018). To promote the use of indigenous crops, maize flour can partially replace wheat flour in product formulations (Hasmadi et al. 2014). It has been reported that it can be used as a weaning/complementary diet when combined with other ingredients that have higher protein content (Aderonke et al. 2014; Onwurafor et al. 2017; Ukeyima et al. 2019; Gemede 2020). The total replacement of wheat flour with that of maize flour and other ingredients have been demonstrated in the production of bread (Mesfin and Shimelis 2013; Olunlade et al. 2013) and cookies (Adeyeye et al. 2017).

Bojňanská et al. (2012) and Mohammed et al. (2012) found that legume proteins can be utilized effectively in food formulation to give consumers a product rich in protein with balanced amino acids. Cowpea (*Vigna unguiculata*) is a grain legume that is grown throughout Africa, as well as areas of North America and Asia (Boukar et al. 2019). They contain substantial quantities of protein, vitamins, and minerals notably potassium, iron, calcium, zinc, and phosphorus (Devi et al. 2015). The importance of cowpea flour in producing high-protein diets to suit the demands of the population's most vulnerable groups is now widely acknowledged (Olapade and Adeyemo, 2014; Ritika et al. 2016; Dankwa et al. 2021).

Coconut fruit has a diverse range of macro and micronutrients and can be processed into milk, oil, and meat (Igbabul et al. 2014; Li and Yang 2018; Kaur et al. 2019). Because coconut processing companies generate a large amount of waste (both food and non-food by-products), it is critical to reuse these by-products in order to improve the quality of human nutrition. Coconut pomace, the leftovers after extracting coconut milk, is high in dietary fiber and antioxidants (Bello et al. 2021). It has been discovered that it greatly impacts human health, supporting numerous physiological and metabolic benefits (Raninen et al. 2011). This study assesses the functional properties of the optimized flour blends of yellow maize, cowpea, and coconut pomace. It also assesses the pasting properties, proximate composition, and antioxidant activity of the selected samples.

## Materials and Methods

**Samples procurement.** Yellow maize, local cowpea and coconut were bought in Uyo at Itam market, Akwa Ibom State, Nigeria. All the chemicals utilized were of analytical grade.

**Samples preparation.** The method of Bello and Udo (2018) was modified (steeping was done for 24 h instead of 72 h) and used for the production of yellow maize flour. The grains were hand cleaned by sorting and winnowing to remove the stone and other foreign objects. Three kg of grains were weighed, steeped for 24 h in 6 L of tap water, then rinsed and dried in an air oven (model pp, 22 US, Genlab, England) at 60℃ for 24 h to a moisture content of 6%. The maize grains were dry milled in a locally made attrition mill, sieved using a 425 μm aperture screen, packaged in a labeled airtight polyethylene bag, and kept at 4℃ for later use.

Cowpea flour was produced according to the procedure outlined by Bassey et al. (2013) with a slight change in blanching time. The cowpea seeds were thoroughly cleaned and sorted by removing stones and debris. The cleaned seeds (2 kg) were soaked in tap water for 3 h, then decanted, blanched for 5 min at 100℃, cooled, and the hull was removed by rubbing between palms. The clean seeds were oven dried at 60℃ for 24 h to a moisture content of 6% in an air oven (model pp, 22 US, Genlab, England), milled with a locally manufactured mill, passed through a 425 μm aperture sieve, packaged in a labeled air-tight polyethylene bag and kept at 4℃ for later use.

Coconut pomace flour was prepared by washing ripe coconuts in water, breaking them apart, and shelling them with a kitchen knife. To make handling easier, the sizes were reduced. The milk was removed by sieving using muslin cloth after the coconut meat was rinsed and grated by hand. The pomace recovered was rinsed with water to remove any remaining milk, oven-dried for 6 h at 60℃ to a moisture content of 6%, milled, and sieved (425 μm screen size). The flour was packaged in a labeled airtight polyethylene bag prior to flour mixing and analysis (Bello et al. 2021).

**Experimental design and formulation of flour blends.** The experimental design employed for the blending formulation of the flour blends was a D-optimal mixture design (Design Expert version 12.0.3.0). Yellow maize flour, cowpea flour, and coconut pomace flour were the independent variables, with low and high constraints of 65-95%, 5-30%, and 0-5%, respectively. Twelve runs (formulations) were generated and the individual flours were mixed thoroughly into homogenous flour blends. Blending was done using a mechanical blender (Panasonic (MX-AC210S), China) and samples were packaged in a labeled airtight plastic bag.

**Determination of functional properties of flour blend samples.** The procedure of Onwuka (2005) was adopted in determining the water absorption capacity, oil absorption capacity and bulk density of the samples. The foaming capacity was evaluated according to Abbey and Ibeh (1988) method. The swelling capacity was analyzed following the procedure outlined by Olawuni et al. (2013).

**Assessment of pasting properties of flour blend samples.** Pasting properties were assessed following the manual as stated using a rapid visco analyzer (Model RVA series 4; Newport Scientific Pty Ltd., Wari wood, Australia). Each flour sample (3 g) was mixed in a canister that already contained 25 ml of distilled water. According to Standard Profile1, the suspension of flour and water was maintained for 1 min at 50℃, kept for 10 min after heating to 95℃, and then the temperature was finally brought down to 50℃ for a period of 2 min. The viscosity of the starch was determined at peak, breakdown, trough, setback, and final alongside peak temperature and time.

**Determination of proximate composition and energy value of flour blend samples.** Moisture, crude protein, crude fat, crude fiber, and ash contents of the samples were determined according to the procedure outlined by AOAC (2005). The method of difference was adopted to calculate % carbohydrate of the flour blend samples i.e., the total sum of % moisture, % crude protein, % crude fat, % crude fiber, and % ash was subtracted from 100. Energy values were also determined by calculation where % crude protein, % crude fat and % carbohydrate were multiplying by 4 kcal, 9 kcal, and 4 kcal, respectively and then added together.

**Antioxidant determination of flour blend samples.** The method as outlined by Singleton et al. (1995) was adopted for the analysis of the phenolic content of the flour blends. The flavonoid content was evaluated following the procedure provided by Zhishen et al. (1999), and the DPPH was analyzed using the outlined method of De Ancos et al. (2002).

**Statistical analysis.** The data generated were subjected to a one-way analysis of variance (ANOVA) to discover the significant ($p < 0.05$) differences among the means. These differences were then separated using Duncan's new multiple-range test (SPSS version 20.00).

## Results and Discussion

**Functional properties of yellow maize, cowpea, and coconut pomace flour blend samples.** Table 1 presents the functional properties of the flour blends of yellow maize, cowpea, and coconut pomace. The bulk density ranged between 0.71 $g.ml^{-1}$ and 0.96 $g.ml^{-1}$, with the highest value found in runs 2 and 5 which was significantly ($p > 0.05$) similar to runs 8, 10, and 11. Bulk density is employed to determine how heavy flour is, how it should be handled, and what kinds of containers are best for transporting it. The sample with the low bulk density has the highest amount of cowpea flour. The development of complementary foods has been found to benefit from low bulk density. In a similar manner, Adegunwa et al. (2015) observed a decrease in bulk density as the proportion of maize flour to pigeon pea flour was lowered. It was also revealed in the present study that coconut pomace flour significantly improves the bulk density of flour blend samples.

Oil absorption capacity varied significantly between 1.30 and 2.15 $g.ml^{-1}$. The results of this study were higher than those (1.43-1.82 $g.ml^{-1}$) reported by Chaparro Acuna et al. (2012). According to Oluwalana et al. (2011), the hydrophobic nature of the protein in flour was the cause of oil absorption capacity. Due to increased hydrophobicity and increased exposure of non-polar amino acids to fat as a result of the presence of protein, more oil can be absorbed by the flour. It was discovered that the oil absorption capacity of the flour blends was increased by the presence of cowpea flour and coconut pomace flour.

The water absorption capacity ranged from 1.78 to 3.67 g.ml$^{-1}$, with run 8 exhibiting the highest value. The lowest water absorption capacity found in run 7 might be linked to the low starch and fiber content present in the flour blends, which is explained by starch fibber's potent capacity to interact with water (Akubor 2008). Awolu et al. (2017) found equally low values of water absorption capacity for rice, millet, soy, and tiger nut flour blends (1.53-2.16 g.ml$^{-1}$). Thinner gruels can be made with these flour combinations.

The foaming capacity of flour is as a result of the flexible protein molecules that reduce the surface tension of water (Asif-UI-Alam et al. 2014). As the proportion of cowpea flour increased, foaming capacity (12.00-18.30%) of the flour blends increased significantly.

**Table 1.** Functional properties of yellow maize, cowpea and coconut pomace flour blends

| Components | | | | Responses | | | | |
|---|---|---|---|---|---|---|---|---|
| **Run** | **YMF, %** | **CF, %** | **CPF, %** | **Bulk density, g.ml$^{-1}$** | **Oil absorption capacity, g.ml$^{-1}$** | **Water absorption capacity, g.ml$^{-1}$** | **Foaming capacity, %** | **Swelling capacity, g.ml$^{-1}$** |
| 1 | 75.00 | 23.75 | 1.25 | 0.80±0.02$^{c}$ | 1.85±0.03$^{cd}$ | 2.17±0.15$^{cd}$ | 18.00±0.00$^{a}$ | 13.00±0.80$^{d}$ |
| 2 | 95.00 | 5.00 | 0.00 | 0.96±0.01$^{a}$ | 1.38±0.08$^{f}$ | 3.52±0.20$^{b}$ | 15.67±0.58$^{bc}$ | 12.30±0.76$^{e}$ |
| 3 | 65.00 | 30.00 | 5.00 | 0.73±0.05$^{d}$ | 2.15±0.03$^{a}$ | 2.13±0.12$^{cd}$ | 14.60±1.15$^{c}$ | 13.60±0.58$^{d}$ |
| 4 | 67.50 | 30.00 | 2.50 | 0.72±0.09$^{d}$ | 2.05±0.05$^{b}$ | 2.20±0.15$^{cd}$ | 15.00±0.32$^{bc}$ | 12.52±0.58$^{e}$ |
| 5 | 95.00 | 5.00 | 0.00 | 0.96±0.01$^{a}$ | 1.38±0.08$^{f}$ | 3.51±0.20$^{b}$ | 15.67±0.58$^{bc}$ | 12.00±0.40$^{e}$ |
| 6 | 80.00 | 17.50 | 2.50 | 0.86±0.06$^{bc}$ | 1.78±0.03$^{d}$ | 2.53±0.13$^{c}$ | 12.00±0.00$^{e}$ | 14.00±0.20$^{c}$ |
| 7 | 70.00 | 30.00 | 0.00 | 0.71±0.05$^{d}$ | 1.90±0.08$^{c}$ | 1.78±0.10$^{d}$ | 18.30±0.58$^{a}$ | 11.30±0.58$^{f}$ |
| 8 | 90.00 | 5.00 | 5.00 | 0.94±0.01$^{a}$ | 1.30±0.14$^{f}$ | 3.67±0.13$^{a}$ | 15.00±0.00$^{bc}$ | 16.60±0.05$^{a}$ |
| 9 | 85.00 | 11.25 | 3.75 | 0.88±0.03$^{b}$ | 1.66±0.05$^{e}$ | 2.90±0.12$^{c}$ | 16.00±0.00$^{b}$ | 14.33±0.58$^{c}$ |
| 10 | 92.50 | 5.00 | 2.50 | 0.91±0.02$^{a}$ | 1.34±0.17$^{f}$ | 2.20±0.10$^{cd}$ | 13.30±0.58$^{d}$ | 15.25±0.00$^{b}$ |
| 11 | 90.00 | 5.00 | 5.00 | 0.94±0.01$^{a}$ | 1.30±0.04$^{f}$ | 3.60±0.23$^{a}$ | 15.00±0.00$^{bc}$ | 16.51±0.15$^{a}$ |
| 12 | 65.00 | 30.00 | 5.00 | 0.73±0.01$^{d}$ | 2.15±0.13$^{a}$ | 2.10±0.12$^{cd}$ | 14.60±1.16$^{c}$ | 13.41±0.58$^{d}$ |

*Means ± SD of three replicate determinations with different alphabetical superscripts in the same columns are significantly ($p<0.05$) different. YMF - yellow maize flour, CF - cowpea flour, CPF - coconut pomace flour.*

This was expected as cowpea flour had a higher protein content than yellow maize flour and coconut pomace flour. The result is in agreement with the values (23.50-65.50%) reported for Bambara groundnut and wheat/plantain flour (Kiin-Kabari et al. 2015). It has been found that flour with a high foaming capacity improves cake functionality (Lee et al. 1993).

The swelling capacity of various food products is a key attribute in the production and retention of structure both during and after processing. It ranged from 11.30 g.ml$^{-1}$ (run 7) to 16.60 g.ml$^{-1}$ (run 8). The flour blends have a higher swelling capacity than those reported by Makanjuola and Makanjuola (2018). The observed increase in swelling capacity was through the addition of coconut pomace flour and yellow maize flour.

**Selection of the best flour blends.** The four best (selected) flour blends from the functional properties of the optimized blends were run 1 (75% yellow maize flour, 23.75% cowpea flour, and 1.25% coconut pomace flour), run 2 (95% yellow maize flour, 5% cowpea flour, 0% coconut pomace flour), run 7 (70% yellow maize flour, 30% cowpea flour, 0% coconut pomace flour) and run 8 (90% yellow maize flour, 5% cowpea flour, 5% coconut pomace flour). The choice was based on high water absorption, swelling, and foaming capacities.

**Proximate composition and energy value of selected flour blends.** The proximate composition and energy value of the selected blends of yellow maize, cowpea, and coconut pomace flour are shown in Table 2. Moisture content was observed to be significantly ($p < 0.05$) different ranging from 4.80 to 5.15% for runs 1 and 2, respectively. The moisture contents were less than 10% which is advantageous for a prolonged shelf-life. The crude protein content (10.21-13.42%) was significantly enhanced with an increase in the percentage of cowpea flour having run 7 the highest value. A similar trend was reported for wheat, pigeon pea, and plantain composite flour (Bello et al. 2019). The crude fat content ranged between 4.39 and 7.39%, with the highest result being run 7. The fat content of the flour blends increased as a result of the incorporation of coconut pomace flour. The present result is in agreement with the findings of Yalegama et al. (2013), who found that after milk extraction, the fat bonded to the coconut fiber remains within the cell wall which resulted in high-fat pomace.

Significant ($p < 0.05$) low crude fiber content was observed ranging from 0.11% to 0.48% for Runs 2 and 8, respectively. Because coconut pomace flour has greater fiber content (23.2%), higher crude fiber content was expected in the blends (Yalegama et al. 2013). The low crude fiber found in this study could be due to the mixture model's upper limit (5%) of coconut pomace flour being too low to affect the fiber content of the final flour blends. However, increasing the percentage of coconut pomace flour above 5% would enhance the crude fiber of the flour blend samples. The result supports the findings of Kohajdova et al. (2012), who found that adding carrot pomace flour to wheat rolls enhanced the dietary fiber content. All samples had significantly varying ash content ranged from 0.16% (run 2) to 0.65% (run 8). The amount of ash in a food could be used as a measure of the mineral content (Fusuan et al. 2017). The present finding was within the range (0.10-1.54%) reported for wheat, breadfruit, and cassava starch composite flour (Ajatta et al., 2016). The carbohydrate content ranged from 76.21-78.36%. Runs 1, 7, and 8 did not differ significantly ($p > 0.05$) but were lower than run 2, which had the highest value. As the percentage of cowpea flour was increased, it was observed that the carbohydrate content decreased. The addition of coconut pomace flour significantly boosted the energy value (404.97-412.63 kcal) of the flour blends. The varying protein, fat, and carbohydrate contents of the samples may be responsible for the variations in the energy value of the flour blends. The enhanced energy content of the flour blends might help in the development of breakfast cereals and complementary foods.

**Antioxidant properties of selected flour blends.** The addition of coconut pomace flour significantly ($p < 0.05$) improved the antioxidant properties of the flour blends (Table 3). Antioxidants are important in the diet because they scavenge free radicals like hydrogen peroxide, altering the process of oxidation that can cause degenerative illnesses (Emad 2014). The concentrations of total phenolic, total flavonoid, and DPPH were 0.03-0.12 mg GAE.100 $g^{-1}$, 0.01-0.19 mg QE100 $g^{-1}$, and 55.24-60.19%, respectively. The highest total phenol and DPPH levels were found in run 8, which included 5% coconut pomace flour, while the highest total flavonoid level was found in run 1, which had 1.25% coconut pomace flour. Plant components such as grape seeds, pomegranate peels, onion skin, or carrot pomace were found to be significantly useful in boosting antioxidant activity in similar studies (Dziki et al. 2014; Olawuyi and Lee, 2019).

**Pasting properties of selected flour blends.** Table 4 presents the finding of the pasting properties of the selected flour blends. The peak viscosity ranged 65.32 RVU (run 7) to 162.34 RVU (run 2), with a significant ($p < 0.05$) difference between them. Peak viscosity is used to measure the capacity of starchy food to expand without breaking down physically (Oke et al. 2017). The highest viscosity attained during gelatinization which is peak viscosity significantly reduced when more cowpea flour was added, whereas it increased as more coconut

**Table 2**. Proximate composition and energy value of selected yellow maize, cowpea and coconut pomace flour blends

| Flour blends (YMF: CF: CPF) | MC, % | CP, % | Crude fat, % | Crude fibre, % | Ash, % | CHO, % | ENE, kcal |
|---|---|---|---|---|---|---|---|
| Run 1 (75: 23.75: 1.25) | 4.80±0.01[c] | 13.31±0.02[a] | 5.21±0.10[b] | 0.19±0.02[b] | 0.28±0.00[b] | 76.21±0.03[b] | 404.97±2.01[b] |
| Run 2 (95: 5: 0) | 5.15±0.03[a] | 10.97±0.40[b] | 5.25±0.10[b] | 0.11±0.40[c] | 0.16±0.00[d] | 78.36±0.03[a] | 404.57±1.00[b] |
| Run 7 (70: 30: 0) | 5.08±0.01[ab] | 13.42±0.60[a] | 4.39±0.10[c] | 0.44±0.06[a] | 0.59±0.00[b] | 76.08±0.03[b] | 397.51±1.81[c] |
| Run 8 (90: 5: 5) | 4.95±0.02[bc] | 10.21±0.06[b] | 7.39±0.02[a] | 0.48±0.06[a] | 0.65±0.00[a] | 76.32±0.03[b] | 412.63±2.31[a] |

*Results are expressed as mean ± standard deviation of two replicate determinations. Mean values having different superscript in columns differ significantly ($p < 0.05$).*
*YMF - yellow maize flour, CF - cowpea flour, CPF - coconut pomace flour, MC - moisture, CP – crude protein, CHO – carbohydrate, ENE – energy.*

**Table 3.** Antioxidant properties of selected yellow maize, cowpea and coconut pomace flour samples

| Flour blends (YMF : CF : CPF) | TPHE, mg GAE.100g$^{-1}$ | TFLA, mg QE.100g$^{-1}$ | DPPH, % |
|---|---|---|---|
| Run 1 (75: 23.75: 1.25) | 0.10±0.00[ab] | 0.19±0.00[a] | 57.82±0.46[b] |
| Run 2 (95: 5: 0) | 0.03±0.03[c] | 0.01±0.00[c] | 59.57±0.17[a] |
| Run 7 (70: 30: 0) | 0.08±0.00[ab] | 0.09±0.00[bc] | 55.24±0.03[c] |
| Run 8 (90: 5: 5) | 0.12±0.00[a] | 0.01±0.00[c] | 60.19±0.54[a] |

*Results are expressed as mean ± standard deviation of two replicate determinations. Mean values having different superscript in columns differ significantly ($p < 0.05$).*
*YMF - yellow maize flour, CF - cowpea flour, CPF - coconut pomace flour, TPHE - total phenolic, TFLA – total flavonoid, DPPH - 2,2 diphenyl picrylhydrazyl*

**Table 4**. Pasting properties of selected yellow maize, cowpea and coconut pomace flour blends

| Flour blends (YMF : CF : CPF) | PV, RVU | TV, RVU | BV, RVU | FV, RVU | SV, RVU | PT, min |
|---|---|---|---|---|---|---|
| Run 1 (75: 23.75: 1.25) | 90.67±1.11[c] | 75.33±0.51[c] | 15.34±1.15[c] | 174.67±2.70[b] | 99.34±1.24[c] | 6.89±0.04[b] |
| Run 2 (95: 5: 0) | 162.34±2.88[a] | 126.33±1.94[a] | 36.01±1.01[a] | 296.10±2.62[a] | 167.77±2.68[b] | 5.71±0.04[a] |
| Run 7 (70: 30: 0) | 65.32±1.58[d] | 55.67±0.58[d] | 9.65±0.58[d] | 117.00±1.58[c] | 61.33±1.15[d] | 7.00±0.04[c] |
| Run 8 (90: 5: 5) | 150.31±2.58[b] | 118.32±0.57[b] | 31.99±1.15[b] | 299.33±1.15[a] | 181.01±1.73[a] | 5.25±0.00[a] |

*Results are expressed as mean ± standard deviation of two replicate determinations. Mean values having different superscript in columns differ significantly (p < 0.05). YMF - yellow maize flour, CF - cowpea flour, CPF – coconut pomace flour, PV - peak viscosity, TV - trough viscosity, BV - breakdown viscosity, FV - final viscosity, SV - setback viscosity, PT - pasting time*

pomace flour was added. This increase could be as a result of crude fiber in coconut pomace. Similar trend was discovered for blends of maize flour enriched with pigeon pea flour by Adegunwa et al. (2015). Because of their low peak viscosities, flour samples may be useful in the production of low-viscous food products alongside complementary foods. Trough viscosity (TV) is a measurement of a paste's capacity to survive breakdown upon cooling (Tharise et al. 2014). TV ranged from 55.67-126.33 RVU, with run 2 recorded as the highest value. The value of TV decreased as the blends' percentage inclusion of cowpea flour increased. The low trough viscosity observed in this study indicates high stable starch gels and the tendency of the maize flour to withstand breakdown during cooking. The breakdown viscosity varied significantly (9.65-36.01 RVU), with the lowest value in run 7. This is suitable since higher paste stability is associated with lower breakdown viscosity. The final viscosity (117.00-299.33 RVU of the flour blends was significant ($p < 0.05$), which improved as the proportion of maize flour and coconut pomace flour increased. The present result is lower than the range (782-940 RVU) values for millet, kidney beans, and tigernut flour blends reported by Awolu (2017). The finding shows that the flour samples are less suitable to produce viscous pastes because of their reduced final viscosity. The setbacks of the samples ranged from 61.33 RVU (run 7) to 181.01 RVU (run 8). The samples with the higher proportion of cowpea flour (runs 1 and 7) had the lowest setback, which was preferred. During the setback phase, starch molecule retrogrades. The product staling rate and the retrogradation of the flour paste after cooling are both inversely correlated with the setback. Peak time ranged from 5.25-7.00 min and there was a significant ($p < 0.05$) difference among the samples. The pasting time of the sample paste is observed to increase with the incorporation of cowpea flour (runs 1 and 7). The finding corresponds to the report from wheat flour supplemented with breadfruit flour and cassava starch, which took between 5.45 and 5.76 min (Ajatta et al. 2016).

**Principal component analysis (PCA) and correlation matrix of the flour blends and their properties.** PCA was applied to assess the relationships between observations (runs) and dependent variables (proximate, energy, antioxidants, and pasting properties) as shown in Fig. 1. The observed variance could be explained by two principal components (PC1 and PC2) to the level of 87.77%. PC1 was the most important variable because it accounted for 62.37% of the variance while PC2 accounts for 25.4% of the variance. Biplot showed that runs 2 and 8 are located at the positive side on PC1, while runs 1 and 7 are located at the negative side on PC1.

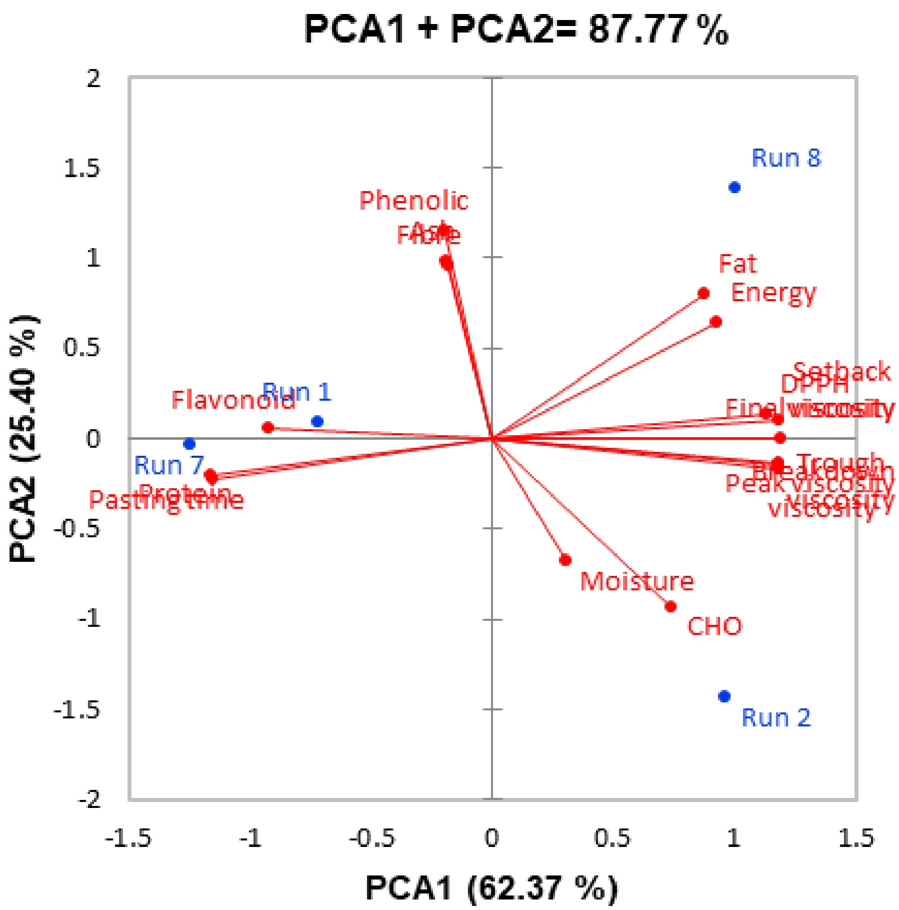


**Figure 1.** PCA biplot showing the relationship between samples and parameters analysed (chemical composition and pasting properties)

Moreover, runs 2 and 7 are positioned on the negative side of PC2, while runs 1 and 8 are positioned on the positive side of PC2. The positive contribution to the PC1 was observed for all the pasting properties variables except pasting time, and also the chemical composition except protein, ash, fiber, phenolic, and flavonoid having the negative scores on PC1. The geometrically close points in the PCA map demonstrated the similarity of the patterns that represent these points. According to Krulj et al. (2016), the angles between relevant variables show the strength of their interactions, with small angles signifying high correlations. Runs 1 and 7 were found to have higher protein and flavonoid content, respectively, and these two variables were strongly correlated. Table 5 presents the correlation matrix involving the interaction of chemical composition and pasting characteristics. Ash and fiber (r=1.00) were found to be strongly correlated, while energy was also positively correlated to fat (r=0.962), both of which were significant at the $p < 0.05$ level. Both the setback and final viscosities had negative correlations with protein (r=-0.958 and r=-0.965, respectively). All pasting properties including trough, breakdown, setback, and final viscosities, exhibited positive correlations with peak viscosity as well as among themselves, and these correlations were significant at the $p < 0.05$ level.

## Conclusions

The present study demonstrated the effect of variation in the proportion of yellow maize, cowpea, and coconut pomace flour blends using optimal mixture design. Coconut pomace flour increased the functional characteristics of the flour with the exception of its foaming capacity. While cowpea flour decreased the pasting abilities of the flour blends, the addition of coconut pomace flour greatly increased them. The crude fiber, ash, crude fat, and energy contents of selected samples were significantly improved when coconut pomace flour

**Table 5.** Correlation matrix between chemical composition and pasting properties of maize, cowpea and coconut pomace flour blend samples

| Var | MC | CP | Fat | Fibre | Ash | CHO | ENE | PHE | FLA | DPPH | PV | TV | BV | FV | SV | PT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MC | **1.00** | | | | | | | | | | | | | | | |
| CP | -0.28 | **1.00** | | | | | | | | | | | | | | |
| Fat | -0.27 | -0.81 | **1.00** | | | | | | | | | | | | | |
| Fibre | -0.05 | -0.08 | 0.37 | **1.00** | | | | | | | | | | | | |
| Ash | -0.08 | -0.07 | 0.38 | **1.00** | **1.00** | | | | | | | | | | | |
| CHO | 0.63 | -0.48 | -0.08 | -0.70 | -0.72 | **1.00** | | | | | | | | | | |
| ENE | -0.36 | -0.79 | **0.96** | 0.12 | 0.14 | 0.05 | **1.00** | | | | | | | | | |
| TPHE | -0.75 | 0.03 | 0.55 | 0.68 | 0.71 | -0.86 | 0.46 | **1.00** | | | | | | | | |
| TFLA | -0.72 | 0.85 | -0.48 | -0.21 | -0.19 | -0.54 | -0.37 | 0.30 | **1.00** | | | | | | | |
| DPPH | -0.05 | -0.89 | 0.80 | -0.23 | -0.22 | 0.49 | 0.90 | 0.01 | -0.54 | **1.00** | | | | | | |
| PV | 0.29 | -0.94 | 0.65 | -0.27 | -0.28 | 0.71 | 0.72 | -0.27 | -0.75 | 0.94 | **1.00** | | | | | |
| TV | 0.27 | -0.94 | 0.66 | -0.27 | -0.28 | 0.70 | 0.73 | -0.26 | -0.74 | 0.94 | **1.00** | **1.00** | | | | |
| BV | 0.33 | -0.94 | 0.63 | -0.27 | -0.28 | 0.73 | 0.69 | -0.30 | -0.77 | 0.92 | **1.00** | **1.00** | **1.00** | | | |
| FV | 0.20 | **-0.96** | 0.74 | -0.19 | -0.20 | 0.62 | 0.80 | -0.15 | -0.72 | **0.97** | **0.99** | **0.99** | **0.99** | **1.00** | | |
| SV | 0.14 | **-0.96** | 0.79 | -0.13 | -0.14 | 0.55 | 0.84 | -0.07 | -0.71 | **0.98** | **0.98** | **0.98** | **0.97** | **1.00** | **1.00** | |
| PT | -0.25 | **1.00** | -0.83 | -0.09 | -0.08 | -0.46 | -0.81 | 0.00 | 0.83 | -0.90 | -0.93 | -0.93 | -0.93 | **-0.96** | **-0.97** | **1.00** |

*Values in bold indicate significance at $p < 0.05$. Var - Variable, MC - Moisture, CP - Protein, CHO - Carbohydrate, ENE - Energy, TPHE – Total phenolic, TFLA – Total flavonoid, PV - Peak viscosity, TV - Trough viscosity, BV - Breakdown viscosity, FV - Final viscosity, SV - Setback viscosity, PT - Pasting time.*

was included at 5% (run 8), but the crude protein content increased when cowpea flour was added at 30% (run 7). The level of moisture fell within the acceptable range for shelf stability. The antioxidant activity of coconut pomace flours revealed that it was quite advantageous, as it enhanced total phenol and DPPH concentrations in flour blends. The research has found that flour blends are excellent potential for infant formulations in blend that contained 70% yellow maize flour and 30% cowpea flour and the development of low viscous foods in blend that contained 90% yellow maize flour, 5% cowpea flour and 5% coconut pomace flour as a promising solution to the problem of nutritional deficiencies in developing countries.

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