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Properties of extruded cowpeas-cassava composite flour

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ABSTRACT

The aim of this study was to develop a composite flour from cassava and cowpeas and determine the functional and pasting properties. Particle size distribution, functional and pasting properties of the composite flours were determined using standard methods. Blending cassava and cowpeas flours showed a significant effect on functional and pasting of flour blends. Reduction in the proportion of extruded cassava flour in composite blends increased Bulk Density (BD) from 4.7-5.2g/ml, Water Absorption Capacity (WAC) 609-628%, Oil Absorption Capacity (OAC) 202-224% and Water Absorption Index (WAI) 3.5-3.8% while increment of cassava substitution increased Swelling Power (SP) from 5.8-6.3g/g and Water Solubility Index (WSI) 40-43%. Pasting temperature increased from 50-53oC with reduction in the proportion of extruded cassava flour while the rest of the pasting properties increased as the proportion of extruded cassava flour was increased in the blends. The pasting and functional properties of the composite flours shows that they have appropriate potential for partial or complete replacement of wheat in baking applications.

Keywords: Cassava, Cowpeas, Composite flour, functional and pasting properties

RÉSUMÉ

L'objectif de cette étude était de développer une farine composite à base de manioc et de niébé et de déterminer les propriétés fonctionnelles et de collage. La distribution de la taille des particules, les propriétés fonctionnelles et de collage des farines compositesont été déterminées à l'aide de méthodes standard. Le mélange des farines de manioc et de niébé a montré un effet significatif sur les propriétés fonctionnelles et de collage des mélanges de farines. La réduction de la proportion de farine de manioc extrudée dans les mélanges composites a augmenté la BD de 4,7-5,2 g/ml, le WAC de 609-628 %, le OAC de 202-224 % et le WAI de 3,5-3,8 % tandis que l'augmentation de la substitution du manioc a augmenté le SP de 5,8-6,3 g/g et le WSI de 40-43 %. La température de collage a augmenté de 50-53(oC) avec la réduction de la proportion de farine de manioc extrudée tandis que le reste des propriétés du collage ont augmenté à mesure que la proportion de farine de manioc extrudée augmentait dans les mélanges. Les propriétés fonctionnelles et collantes des farines composites montrent qu'elles ont un potentiel approprié pour le remplacement partiel ou complet du blé dans les applications culinaires.

Mots clés: Manioc, Niébé, Farine composite, propriétés fonctionnelles et collantes

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INTRODUCTION

Some researchers have used maize, barley, cassava and chickpea to produce composite flour for bread making (Noorfarahzilah *et al.,* 2014). Legume proteins have been used successfully in baked foods to produce protein-enriched foods with enriched amino acid balance (Noorfarahzilah *et al.,* 2014). Cassava (Manihot esculenta Crantz) is one of the most important food and feed plants globally, ranking as the third most significant staple source of calories after rice and maize (Dini *et al.,* 2014 ; Hasmadi et al., 2020). Cassava is a major part of diets in Africa and thus provides substantial amounts of dietary energy to many (Dini *et al.,* 2014 ; MO *et al.,* 2017 ; Dada *et al*., 2018) For some communities in eastern and central Africa, cassava is the single most important and available staple food (Aristizábal *et al.,* 2017; Waisundara, 2018).

In Africa and Southeast Asia, cowpea (*Vigna unuiculata* L.Walp) is an essential legume food (Dada *et al.,*, 2018 ; Naiker *et al.,* 2019). Cowpea feeds millions of people in developing countries, and have an annual global production of approximately 4.5 million metric tons on 12-14 million hectares, with West and Central Africa accounting for 70% of production (Dada *et al.,* 2018; Naiker *et al.,* 2019). It has 24% protein (Victor, 2020), 62% carbohydrate, and a trace of other nutrients (Dada *et al.,* 2018). In sub-Saharan Africa, cassava and cowpeas accounts for more than 80% and 60% of global production, respectively (Dankwa *et al.,* 2021). Cassava is very high in carbohydrate but very low in protein, minerals and vitamins (Aristizábal *et al.,* 2017; Adeoye *et al.,* 2020).

Composite flour is a combination of flours, starches, and different ingredients designed to provide improved nutrient balance and functional properties for different products (Noorfarahzilah *et al.,* 2014; Hyacinthe *et al.,* 2018; Hasmadi *et al.,* 2020). Due to mixing different foods or ingredients, composite flours would have more fiber, minerals, vitamins and protein compared to a single grain or root crop food (Hasmadi *et al.,* 2020). Several authors have documented the use of composite flour in different types of breads (Raihan and Saini, 2017). Sibian and Riar (2020) developed cookies from composite flour containing wheat, germinated kidney beans and chickpeas, that was substituted with 25% and 35% of kidney beans and chickpeas respectively. Composite flour containing wheat replacement with amaranth, sorghum and oat up to 10% was recorded to obtain high acceptability score (Raihan and Saini, 2017). Gluten-free bread produced from composite of wheat and soy flour with wheat substitution of 15% soy flour was found to improve the bread quality, nutritional properties and sensory qualities (Taghdir *et al.,* 2017). Fortification of wheat bread with 30% of maize, rice and sorghum was achieved by Pauline *et al*. (2020). Their findings showed that incorporating the cereals resulted in an increase in proximate composition of the bread. This study sought to evaluate the properties of modified cassava-cowpea composites flours in varying proportions.

MATERIALS AND METHODS

Preparation of cassava flour. Cassava flour was made according to the methods described by Kesselly *et al*. (2022). Fresh roots of the NAROCASS1 cassava variety were obtained from the National Crop Resources Research Institute (NaCRRI), Namulonge in Kampala, Uganda. The cassava was peeled, washed, and grated. The grated cassava was transferred to a tray and dried in a hot air oven (LTD-5D MULTI-LAYER DRYER, SHANDONG LIGHT M and E Co. Ltd, Shandong, China) for three hours 40 minutes at 50 oC. After drying, the cassava flakes were milled into flour and packaged in air-tight bags awaiting further treatment and analysis.

Preparation of cowpeas flour. Cowpeas flour was made according to the method described by Naiker *et al*. (2019) with a few modifications. Dry seeds of Secow2 cowpeas variety were obtained from the National Crop Resources Research Institute (NaCRRI), Namulonge, Kampala, Uganda. The dry seeds were sorted to remove non-cowpeas materials and soaked in water for 72 hours. During the period of soaking, the seeds were washed on a daily basis and fresh water was added. The soaked seeds were dehulled by gently rubbing between the hands. The dehulled cowpeas were then transferred to a tray and dried in a hot air oven (LTD-5D MULTI-LAYER DRYER, SHANDONG, LIGHT MandE Co., Ltd) for three hours at 50 oC. After drying, the cowpeas were milled into flour and packaged in air-tight bags awaiting further treatment and analysis.

Extrusion of cassava flour. Extrusion was carried out according to the methods of Kesselly *et al.,* (2022) using a twin-screw extruder (LT70-L Twin Screw Extruder, Shandong Light MandE Co. Ltd, Shandon, China). The extruder was operated at the following conditions: temperature (60 °C) and screw speed (40 rpm). For each run, cassava flour was fed into the extruder at 20 kg/hr. After extrusion, the extrudates were dried in a hot air oven (LTD-5D Multi-Layer Dryer Shandong Light MandE Co. Ltd, Shandong, China) at 50 °C for five hours. After drying, the extrudates were cooled to 25 °C, then milled into flour and stored in air-tight bags for further analysis.

Extrusion of cowpeas flour. Extrusion was carried out according to the method of Kesselly *et al*. (2022) using a twin-screw extruder (LT70-L TWIN SCREW EXTRUDER, SHANDONG LIGHT Mand E Co., Ltd). The Extruder had three temperature zones and extrusion temperature was set at 60 oC and 70 oC for the three zones, respectively; screw speed at 40 rpm while varying added moisture content at 10% and 15%. The amount of flour loaded per run was 20 kg. After extrusion, the extrudates were cooled to room temperature (25 °C), then milled into flour and stored in zip lock bags until further analysis.

Treatments. Cowpea-cassava composite flours were prepared in ratios of 50:50, 40:60, 30:70, 20:80 and 10:90, respectively on a weight by weight basis. The composite flours were prepared in two sets. One set of the composite flours was modified by extrusion as described by Kesselly *et al*. (2022). The second set of composite flours was made from unmodified flours so as to discern the effect of modification. Both modified and unmodified cassava and cowpea only flours were included as the controls. After mixing, the flours were packaged in air-tight bags awaiting analysis. These experimental treatments were done in duplicate.

Analyses

Bulk Density. Bulk density was determined using a method described by Atukuri *et al.,* (2019). About 4 g of each flour sample was weighed into a 10ml cylinder in triplicates. The cylinder was gently tapped on a laboratory bench until no further diminution and flour filled to the volume mark. This was done to eliminate air spaces. Volume was recorded after taping, and the results were calculated and expressed as a weight-to-volume ratio using equation (1).

Bulk density (g/ml) = weight of sample (g) ÷Volume of sample (ml) Equation (1)

Water Absorption Capacity. Water absorption capacity was determined by the method described by Chandla *et al*. (2017). About 2.5 g of flour was measured and placed in a 50 ml falcon tube, 30 ml distilled water was added to the tube and mixed. The sample was agitated for 10 minutes and centrifuged (Thermo SCIENTIFIC, MEGAFUGE 8) at 3,000 rpm for 10 minutes. The free water recovered from the sentimental flour sample was removed and the tube was drained for 10 minutes to separate the surface water, and water absorption capacity was calculated using equation (2).

WAC = weight of sediment ÷ weight of sample

× 100 Equation (2)

Oil Absorption Capacity. Oil absorption capacity was determined using the method of Chandla *et al.* (2017). About 2.5 g of each flour sample was measured and placed in a 50 ml falcon tube, and 30 ml of vegetable oil was added to the tube and mixed. The sample was then agitated for 10 minutes and centrifuged (Thermo SCIENTIFIC, MEGAFUGE 8) at 3,000 rpm for 10 minutes. The free oil recovered from the sentimental flour sample was removed and the tube was drained for 10 minutes to separate the surface oil, and oil absorption capacity was calculated using equation (3):

OAC = weight of sediments ÷ weight of sample × 100 Equation (3)

Water Absorption and Solubility Index. Water absorption and solubility index were determined using the method of Atukuri *et al.* (2019). A portion (3 g) of each flour sample was measured and mixed with 25ml of distilled water in a 50ml falcon tube and heated in a water bath (Grant, SUB Aqua 18) for 15 minutes at 90 °C. The cooked paste was cooled at room temperature and centrifuged (Thermo SCIENTIFIC, MEGAFUGE 8) at 1,500 rpm for 20 minutes. Afterward, the supernatant was decanted into a pre-weighed moisture dish to determine the solid content and the sediment weight. The weight of dry solids was obtained by evaporating the supernatant overnight at 105 C, and the Water absorption Index and Water solubility were calculated using equations (4) and (5) respectively.

WAI=weight of sediment÷ weight of sample Equation (4)

WSI=weight of dissolved solid in supernatant ÷ weight of sample Equation (5)

Swelling Power. Swelling power was analyzed following the method described by Chandla *et al.* (2017). About 0.5g of each sample was placed in a 50 ml falcon tube, mixed with 25ml of distilled water, and heated in a water bath (Grant, SUB Aqua 18) at 60 oC for 30 minutes, with gentle shaking. Afterward, the samples were centrifuged (Thermo SCIENTIFIC, MEGAFUGE 8) at 1600 rpm for 15 minutes. The precipitated part was weighed and calculated using equation (6):

SP=sediment weight (wet mass) ÷ weight of sample Equation (6)

Particle size distribution. Particle size distribution was determined according to the methods described by Sonaye and Baxi (2012). Approximately 100 g of each flour sample was weighed and poured into the top sieve containing the screen opening of 0.35 mm. Each lower sieve in the column had a smaller opening than the one above and a receiver at the base. The column was then placed in a mechanical shaker (MRC Laboratory Equipment, model TSS-200, Hz 50; Serial No. 108041502) and shaken for 10 minutes at 3 rpm. After the shaking was completed, the material on each sieve was weighed, calculated, and recorded as particle size distribution using equation (7).

%=sample retained ÷ sample weight measured 100 Equation (7)

Pasting properties. Pasting properties were determined using Rapid Visco Analyzer (RVA 4500 Perten) (Newport Pty. Ltd. Warriewood, Australia) as described by Atukuri *et al.* (2019). About (3.5 g) of each sample were weighed and added to 25 ml of distilled water in a canister and mixed, the mixture was loaded to the RVA and ran. Test runs were carried out using the standard 1 profile. Stirring and warming up were done in 1 minute at 50 °C, heating for 3.7 minutes at 11.16 °C/minutes up to 95 °C; 2.5 minutes of holding at 95 oC; 3.8 minutes of cooling down to 50 oC at 11.84 °C/minutes, and two minutes of holding at 50 °C. Stirrer speed

(160 rpm) was used throughout the analysis and the entire process lasted approximately 13 minutes. The following parameters were determined: Peak viscosity, trough, breakdown, final viscosity, setback, peak time, and pasting temperature.

Data Analysis. Mean effects of treatments on functional and pasting properties were subjected to a one-way analysis of variance (ANOVA) at a 95% confidence interval using SPSS software version 20. The comparison of means was performed by the Tukey test at a 5% significant level. The same data used for means and standards deviation were subjected to Principal Component Analysis (PCA) using XLSTAT (2022 Version) to generate a biplot for functional and pasting properties.

Results and Discussion

Effect of extrusion and cowpeas flour ratios on functional properties. The Functional Properties of the composite flours are presented in Table 1. Functional properties describe the behavior of food ingredients during processing and it affects the possible application and end use of the flour (Ocheme *et al*. 2018; Bamidele and Fasogbon, 2020). Bulk density (BD) measures the amount of load a sample can carry when resting on each other and it is used as a criterion to select its packaging (Akinwale *et al.,* 2017; Hasmadi *et al*., 2020; Otondi *et al*., 2020). The Bulk density for the flours ranged from 4.74-5.21 g/ml. Composite flours in the ratio of 10:90 and 20:80 was not significantly different while those of 50:50 was different. Composite flour in the ratio of 30:70 and 40:60 was also not significantly different. Composite flour 50:50 recorded the highest BD (5.2) followed by 40:60 (4.99), 30:70 (4.93) and 20:80 (4.79) respectively. The lowest BD was recorded by 10:90. The BD as the percentage of extruded cowpeas flour was increased; a similar increase was observed by Hasmadi *et al*. (2020). The bulk density in the present day study is higher than that recorded by Akinwale *et al*. (2017) for cassava-starch based custard and Adeoye *et al*. (2020) for composite flour of cassava, rice and soybean. Increased bulk density suggests that the composite flour in the present day study is suitable for the preparation of liquid, semisolid and solid foods (Hasmadi *et al.,* 2020). The flour can also be used as pasta thickness reducer during food processing (Pauline *et al*., 2020).

Water Absorption Capacity (WAC) measures a flours ability to absorb and swell for the improvement and stability of food (Adeoye *et al.,* 2020). It is a required characteristic in food system which increases yield and consistency in food processing (Akinwale *et al.,* 2017; Kacou *et al.,* 2018; Adeoye *et al.,* 2020). WACs for the composite flours ranged from 589 to 628%. All WAC were not significantly different; this is in agreement with the report of Julianti et al., (2016). Composite flour 40:60 recorded the highest WAC (628%) followed by 30:70 (620%). Also, WAC was decreased at 20:80, increased at 30:70 and further increased at 40:60. The high WAC observed in this study indicates that the flour may have had extra hydrophilic elements such as polysaccharides (Chandra *et al.,* 2015). Increased WAC is also linked to an increase in amylose discharge, solubility, and damage to crystalline structure (Amadou., 2017; Hasmadi *et al.,* 2020). Higher WAC in composite flours means that the flour is suitable for backed products (Iwe *et al.,* 2016), meat and dairy products (Hasmadi *et al.,* 2020). Oil absorption capacity (OAC) measures the amount of oil entrapment by starch under a specific condition (Adeoye *et al*., 2020). It is an important aspect to consider in food processing because fats act as flavor retainers and improve the mouth feel of foods (Julianti *et al.,* 2016; Wang, 2018; Hasmadi *et al*., 2020). The OACs for the composite flours ranged from 200 to 224%. Composite flours of 10:90 and 20:80 was not significantly different while the rest of the flours were significantly different. Composite flour of 50:50 recorded the lowest value. The OAC showed an increasing trend as percentage of cowpeas flour was increased; a similar trend was observed by Adeoye *et al*. (2020) for cassava-rice-soy composite flour. Low OAC by the composite flours is required for food produced from flour products (Ilesanmi, 2016; Iwe *et al.,* 2016).

The water Absorption Index (WAI) measures the volume starch occupies after swelling in excess water and is an indicator of starch integrity (Atukuri *et al.,* 2019). The water absorption index ranged from 3.4 to 3.8%. Composite of 40:60 recorded the highest WAI (3.8%) followed by 30:70 (3.64%), 20:80 (3.54%) and 10:90 (3.53%), respectively. All WAIs were not significantly different; similar observation was recorded by Guerra-Oliveira *et al*. (2022). An increasing trend was observed as the percentage of cowpeas flour increased.

Water Solubility Index (WSI) accounts for components that starch release after extrusion (Otondi et al., 2020). The water solubility index ranged from 36 to 45%. Composite of 30:70 recorded the highest WSI (45%) followed by 10:90 (43%), 20:80 (41%) and 50:50 (40%), respectively. Composite of 40:60 recorded the lowest WSI (36%). The WSI showed a decrease, rather than increase among the flours as percentage of cowpeas flour was increased. No significant difference was observed among WSI of the flours. These findings agree with those of Pauline *et al*. (2020). All WSI in the present study was higher than those recorded by Pauline *et al*. (2020) for composite flour. Increased Water Solubility Index is a result of weak interaction of starch granule's structure and depolymerization (Adeoye *et al.,* 2020).

Swelling power (SP) is a physical characteristic that determines the ability of starch granules to increase when hydrated (Adeoye *et al.,* 2020; Otondi *et al.,* 2020). The Swelling power of the composite flours ranged from 5.82 to 6.36 g/g. Composite flour of 10:90 recorded the highest SP and was not significantly different from the one for 20:80. Flours of 30:70 and 40:60 was not significantly different while those of 50:50 was significantly different. The SP showed a decreasing trend as the percentage of cowpeas flour was increased. A similar trend was observer by Akinwale *et al*. (2017) with increase in experiment temperature, Amadou (2017) when the percentage of sweet potato flour was increased during the experiment and Adeoye *et al*. (2020) for cassava-rice-soybean composite flour. According to Kusumayanti *et al*. (2015), greater swelling power is an indication of higher solubility, which is apparent in Table 1.

Table 1. Functional properties of composite flour

Sample code	Bulk density (g/ml)	Water absorption capacity (%)	Oil absorption capacity (%)	Swelling Power (g/g)	Water absorption index (%)	Water solubility index (%)
10% Cowpeas: 90% Cassava	4.74 ± 0.05[a]	609.33 ± 47.75[a]	202.35 ± 5.81[a]	6.36 ± 0.06[b]	3.53 ± 0.27[a]	43.07 ± 5.70[a]
20% Cowpeas: 80% Cassava	4.79 ± 0.05[a]	589.78 ± 13.94[a]	200.78 ± 0.38[a]	6.30 ± 0.16[b]	3.54 ± 0.07[a]	41.51 ± 3.49[a]
30% Cowpeas: 70% Cassava	4.93 ± 0.03[b]	620.32 ± 46.13[a]	207.45 ± 6.84[ab]	6.08 ± 0.07[ab]	3.64 ± 0.15[a]	45.03 ± 1.14[a]
40% Cowpeas: 60% Cassava	4.99 ± 0.06[b]	628.83 ± 37.84[a]	213.22 ± 0.15[b]	6.08 ± 0.15[ab]	3.84 ± 0.19[a]	36.94 ± 3.39[a]
50% Cowpeas: 50% Cassava	5.21 ± 0.06[c]	602.17 ± 21.39[a]	224.25 ± 0.15[c]	5.82 ± 0.24[a]	3.45 ± 0.04[a]	40.97 ± 2.68[a]

Values are means ± SD of samples; mean values with different super-scrip in the same column are significantly different ($P < 0.05$). While those with the same super scrip are not significantly different

Table 2. Pasting properties of composite flour

Sample	Peak viscosity (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback (RVU)	Peak time time	Pasting Temperature (°C)
10%Cowpeas: 90% Cassava	863.3 ± 132.3[b]	666.0 ± 134.4[a]	357.3 ± 9.1[c]	160.0 ± 7.6[d]	1.1 ± 0.1[a]	50.1 ± 0.0[a]
20%Cowpeas: 80% Cassava	122.7 ± 25.5[a]	644.0 ± 444.0[a]	330.0 ± 9.6[c]	144.7 ± 3.5[c]	1.1 ± 0.0[a]	50.2 ± 0.1[a]
30%Cowpeas: 70% Cassava	117.7 ± 14.5[a]	365.3 ± 441.4[a]	281.0 ± 9.6[b]	130.3 ± 3.8[b]	1.1 ± 0.0[a]	50.3 ± 0.3[a]
40%Cowpeas: 60% Cassava	123.3 ± 17.6[a]	379.7 ± 449.8[a]	265.3 ± 16.3[b]	121.3 ± 1.2[b]	1.1 ± 0.0[a]	51.2 ± 1.5[a]
50%Cowpeas: 50% Cassava	117 .3± 3.2[a]	379.7 ± 449.9[a]	217.3 ± 1.5[a]	160.0 ± 1.0[a]	1.1 ± 0.0[a]	53.8 ± 0.5[b]

Values are means ± SD of samples; mean values with different super-scrip in the same column are significantly different (P < 0.05). While those with the same super scrip are not significantly different

Effect of extrusion and cowpeas flour ratios on particle size distribution. The particle size distribution for the composite flours is shown in Figure 1. All flours showed similar trend for particle size distribution and were not significantly different. Composite flour of 40:60 recorded the highest particle size followed by that of 50:50 composite. The result shows that composite of 40:60 had a larger portion (40%) of the flour at 0.21mm and decreases at smaller sieve size followed by composite of 50:50 with 39% of the flour at 0.21mm. This means that the composite flour is composed of less fine particles. The rest of the samples followed a similar trend with 38% of the flour at 0.21mm. It was also observed that about 80% of the flour particles for all composite flours were found below 0.21mm. Increasing the percentage of cowpeas flour resulted into an increase in large particle size at sieve size of 0.21mm. A similar trend was observed by Desalegn and Hailu (2020) for composite flour. The increase in larger particle size could be because cassava and cowpeas contain fiber (Desalegn and Hailu, 2020) which can resist milling. Finer particle size in flour is largely dependent on low protein and fiber content (Agrahar-Murugkar *et al.,* 2015). The composite flour in the present study had more coarse particles which is appropriate for making hard dough biscuits (Agrahar-Murugkar *et al.,* 2015).

Effect of extrusion and cowpeas flour ratios on pasting properties. The pasting properties of the composite flours are presented in Table 2. Pasting properties of food describe the changes that take place in food when heat is applied in the presence of water (Ocheme *et al.,* 2018). These changes affect the texture and digestibility of the final product (Ocheme *et al.,* 2018). Pasting temperature ranged from 50.1 to 53.8 °C. Pasting temperature increased as the percentage of cowpeas flour increased; a similar trend was observed by Julianti *et al.* (2016). Increased pasting temperature is linked to high WAC (Ocheme *et al.,* 2018) which is apparent in Table 1. Composite flour of 50:50 recorded the highest pasting temperature and was significantly different from the rest of the samples. Composite flour of 10:90 exhibited the lowest pasting temperature but was not significantly different from composite flours of 20:80, 30:70 and 40:60, respectively. All pasting temperatures in the present day study was lower than the one recorded by Akinwale *et al*. (2017) for composite flour blend of cassava starch powder and soy protein isolate and Adeoye *et al*. (2020) for cassava-rice-soybean composite flour. Effect of extrusion and cowpeas flour ratios on particle size distribution. The particle size distribution for the composite flours is shown in Figure 1. All flours showed similar trend for particle size distribution and were not significantly different. Composite flour of 40:60 recorded the highest particle size followed by that of 50:50 composite. The result shows that composite of 40:60 had a larger portion (40%) of the flour at 0.21 mm and decreases at smaller sieve size followed by composite of 50:50 with 39% of the flour at 0.21 mm. This means that the composite flour is composed of less fine particles. The rest of the samples followed a similar trend with 38% of the flour at 0.21mm. It was also observed that about 80% of the flour particles for all composite flours were found below 0.21mm. Increasing the percentage of cowpeas flour resulted into an increase in large particle size at sieve size of 0.21 mm. A similar trend was observed by Desalegn and Hailu (2020) for composite flour. The increase in larger particle size could be because cassava and cowpeas contain fiber (Desalegn and Hailu, 2020) which can resist milling. Finer particle size in flour is largely dependent on low protein and fiber content (Agrahar-Murugkar *et al*., 2015). The composite flour in the present study had more coarse particles which is appropriate for making hard dough biscuits (Agrahar-Murugkar *et al*., 2015).

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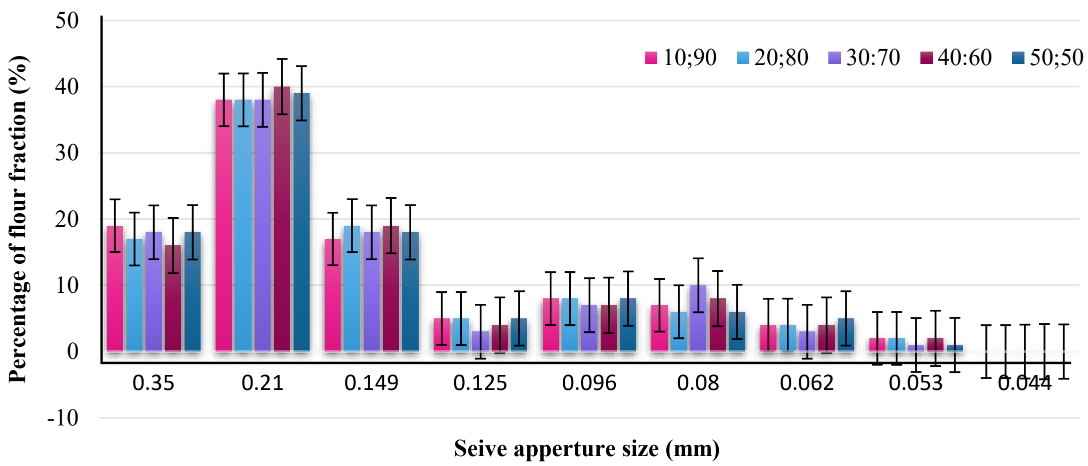

Figure 1. Particle size distribution of the Composite flours: 10:90, cowpeas/cassava 10:90; 20:80, cowpeas/cassava 20:80; 30:70, cowpeas/cassava 30:90; 40:60, cowpeas/cassava 40:60; 50:50, cowpeas/cassava 50:50

Peak viscosity is the highest viscosity attained by starch granule before physical rupture (Akinwale *et al.,* 2017; Chandla *et al.,* 2017). The Peak Viscosity ranged from 117.3 to 863.3 Relative Value Units (RVU). Composite flour of 10:90 had high peak viscosity which was significantly different from the rest of the samples. Composite flour of 50:50 recorded the lowest peak viscosity but was not significantly different from that of composite 40:60, 30:70 and 20:80. Peak viscosity decreased as the percentage of cowpeas flour increased; a similar decrease in peak viscosity was observed by Akinwale *et al*. (2017) when the concentration of cassava flour was decreased, Adeoye *et al.,* (2020) for cassava-rice-soybean composite flour and Julianti *et al*. (2016) for rice and sweet potato composite flour. The low peak viscosity recorded among the flours could be a result of low starch content and interaction between starch and protein in the flour blends (Ocheme *et al.,* 2018). Reduced peak viscosity of flour means the flour has better stability during baking operations (Lm and Huan, 2013), which is appropriate in foods that require reduced gel strength and elasticity (Julianti *et al.,* 2016).

Breakdown Viscosity. Breakdown viscosity determines the stability of starch when heated (Andriansyah *et al.,* 2017). Breakdown values ranged from 106 to 666 RVU. Composite of 10:90 recorded the highest breakdown but was not significantly different from the rest of the flours. Breakdown in the present day study showed a decreasing trend as the percentage of cowpeas flour increased. A similar trend was recorded by Akinwale *et al*. (2017) for cassava and soy protein isolate flour. Low breakdown among the blends means they had the ability to resist breakdown during shearing and heating (Ocheme *et al.,* 2018).

Final viscosity is the ability of starch to form gel during heating (Andriansyah *et al.,* 2017; MO *et al.,* 2017)). The final viscosity for the flours ranged from 217 to 357 RVU. Composite flour of 10:90 recorded the highest final viscosity and was not significantly different from composite of 20:80. Composite 0f 50:50 recorded the lowest final viscosity which was significantly different from composite of 40:60 and 30:70. Final viscosity values in the present study showed a decreasing trend as the percentage of cowpeas flour increased. A similar trend was recorded by Akinwale *et al*. (2017) for cassava-soy protein isolate flour and Ocheme *et al*. (2018) for wheat-groundnut concentrate flour. Low final viscosity flours are suitable for infant food because of the less thick paste viscosity (Akinwale *et al.,* 2017) as in the case of the 50:50 composite flour.

Setback Viscosity provides information about starch retrogradation values (Andriansyah *et al.,* 2017; Afoakwa *et al.,* 2021). The setback Viscosity for the flours ranged from 106-160 RVU. Composite of 10:90 recorded the highest setback, which was significantly different from the rest of the samples. Composites of 30:70 and 40:60 were not significantly different but different from composite of 20:80 and 50:50. The Setback values showed a decreasing trend as percentage of cowpeas flour was increased. A similar trend was recorded in the findings of Akinwale *et al*. (2017). The decrease in setback viscosity in this study could be linked to high starch swelling capacity (Table 1) during extrusion cooking as suggested by Leonard *et al*. (2020). A low setback value shows that the flour can be used in products that require a high level of starch stability (Zhang *et al.,* 2020) while a high setback shows a lower retrogradation tendency during cooling and consequently, a lower staling rate of products (Chisenga *et al.,* 2019; Afoakwa *et al.,* 2021).

Peak time provides information on the amount of energy and time required to cook a flour suspension (Shittu *et al*., 2016). The peak time for the composite flours was 1.1 minutes. All Peak times values were not significantly different. This indicates that cowpeas ratio had no effect on peak time of the composite flours. All the recorded peak times in the present study were lower than the peak time recorded by Akinwale *et al*. (2017). The similar peak times observed for all the composite flours in the present day study suggest that all the flours had the same preparation time (Akinwale et al., 2017; Adeoye *et al.,* 2020) and less energy is needed to cook (Ajatta *et al.,* 2016; Imoisi *et al*., 2020).

Principle Component Analysis. The principle component analysis results are presented in Figure 2. The principal component analysis was conducted to determine the relationship between extrusion parameters and functional properties. The first two PCs explained 67.57% of the variation in the data. PC2 was a contrast between composite flour of 30:70 and 40:60 with positive loadings and composite of 40:60 and 50:50 with negative loadings. Composite of 40:60 was associated with high WAI, WAC and OAC while composite of 50:50 was associated with high BD, PT and WSI. The PC1 showed a contrast between WAI, WAC, OAC, BD and PT with negative loadings, while WSI, SP and pasting properties (accept PT) with positive loadings. The OAC and BD were observed to be highly correlated while SP and pasting properties were highly correlated. Greater swelling power is an indication of higher solubility (Table 1) and higher solubility means the flour can absorb water and dissolve easily (Byaruhanga *et al.,* 2014). Pasting properties (peak 1, trough 1, breakdown, final viscosity, setback, and peak time) and SP were highly correlated.

Pasting properties (peak 1, trough 1, breakdown, final viscosity, setback, and peak time) and SP were highly correlated. The BD and WSI had a negative relationship; a similar observation was recorded by Gulati *et al*. (2016) while extruding proso millet. It was also observed that WSI and OAC had a negative relationship.

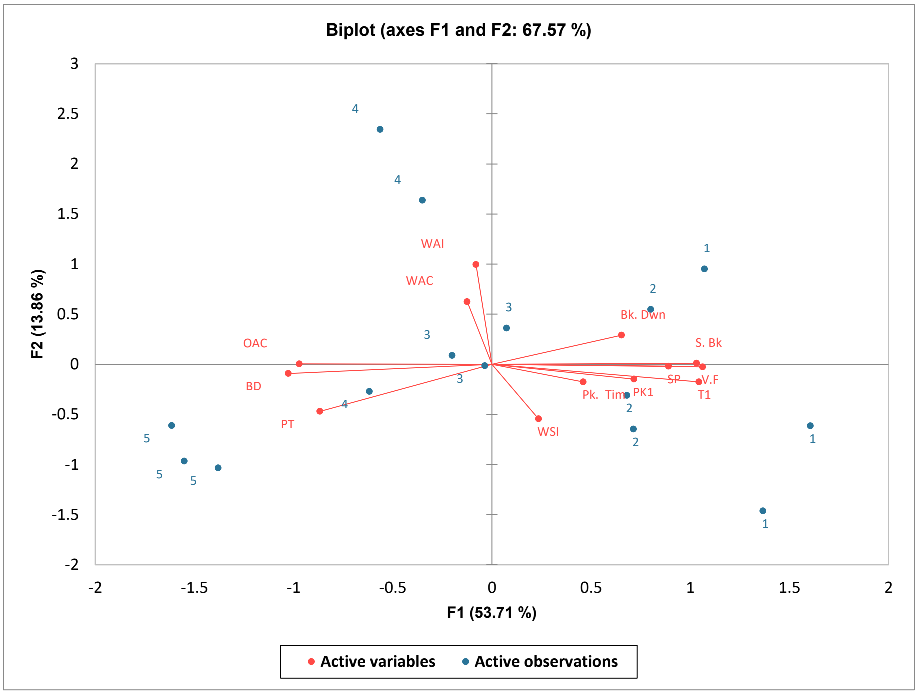

Figure 2. Bi-plot showing Functional and pasting properties and loadings for processing variables BD, Bulk density; WAI, Water absorption index; WSI, Water solubility index; WAC, Water absorption capacity; OAC, Oil absorption capacity; SP, Swelling power; PT, Pasting temperature; Pk.Tim, Peak time; Bk. Dwn, Breakdown; Pk1, Peak 1; S. bk, setback; T1, Trough 1; F.V, Final viscosity; 1, 10:90; 2, 20:80; 3, 30:70; 4, 40:60; 5, 50:50.

CONCLUSION

Composite flour of cowpeas-cassava was mixed in the ratio of 10:90, 20:80, 30:70, 40:60 and 50:50, respectively. Blending cassava and cowpeas flours showed a significantly effect on functional and pasting properties of flour blends. Increasing the substitution of cowpeas flour in composite flours increased BD, WAC, OAC and WAI while decreasing of cowpeas substitution increased SP and WSI. Increasing the proportion of cowpeas resulted in a decrease in peak viscosity, breakdown, final viscosity and setback but increase in pasting temperature with no effect on peak time. The pasting and functional properties of the composite flours show that they have appropriate potential for partial or complete replacement of wheat in baking applications.

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STATEMENT OF NO CONFLICT OF INTEREST

The authors declares that there is no conflict of interest in this paper.

REFERENCES

Afoakwa, E. O., Sampson, G. O., Nyirenda, D., Mwansa, C. N., Brimer, L. and Chiwona-Karltun, L. 2021. Physico-functional and starch pasting properties of cassava (*Manihot esculenta* Cruntz) flours as influenced by processing technique and varietal variations. *Asian Journal of Agriculture and Food Sciences* 9 (2): 71–82. https://doi.org/10.24203/ajafs.v9i2.6556

Agrahar-Murugkar, D., Gulati, P., Kotwaliwale, N. and Gupta, C. 2015. Evaluation of nutritional, textural and particle size characteristics of dough and biscuits made from composite flours containing sprouted and malted ingredients. *Journal of Food Science and Technology* 52 (8): 5129–5137. https://doi.org/10.1007/s13197-014-1597-y

Akinwale, T. E., Shittu, T. A., Adebowale, A.,

Razaq A., Adewuyi, S. and Abass, A. B. 2017. Effect of soy protein isolate on the functional, pasting, and sensory acceptability of cassava starch-based custard. *Food Science and Nutrition* 5 (6): 1163–1169. https://doi.org/10.1002/fsn3.507

Amadou, I. 2017. Physico-functional and sensory properties of cowpea flour based recipes (Akara) and enriched with Sweet Potato. *Journal of Nutritional Health and Food Engineering* 7 (4), 325–330. https://doi.org/10.15406/jnhfe.2017.07.00243

Aristizábal, J., García, J. A. and Ospina, B. 2017. Refined cassava flour in bread making: A review. *Ingenieria e Investigacion* 37 (1): 25–33. https://doi.org/10.15446/ing.investig.v37n1.57306

Atukuri, J., Odong, B. B., Muyonga, J. H. 2019. Multi-response optimization of extrusion conditions of grain amaranth flour by response surface methodology. *Food Science and Nutrition* 7 (12): 4147–4162. https://doi.org/10.1002/fsn3.1284

B. K, A., B. A, A., A. A, A., and C. T, A. 2020. Production and evaluation of a protein-enriched meal from composite flour of cassava, rice and soybean. *SDRP Journal of Food Science and Technology* 5 (1): 18–26. https://doi.org/10.25177/jfst.5.1.ra.10594

Bamidele, O. P. and Fasogbon, B. M. 2020. Nutritional and functional properties of maize-oyster mushroom (Zea mays-Pleurotus ostreatus) based composite flour and its storage stability. *Open Agriculture* 5 (1): 40–49. https://doi.org/10.1515/opag-2020-0007

Byaruhanga, Y. B., Kassozi, V., Wafoyo, R., Mugoya, C. and Masiga, C. 2014. Properties of Extrudates From Sorghum Varieties Extrusion cooking is a modern high-temperature short-time (HTST) processing technology, which is becoming popular in certain industries because it offers several advantages over other types of cooking pro. 22: 829–836.

Chandla, N. K., Saxena, D. C. and Singh, S. 2017. Amaranth (*Amaranthus* spp.) starch isolation, characterization, and utilization in development of clear edible films. *Journal of Food Processing and Preservation* 41 (6). https://doi.org/10.1111/jfpp.13217

Chisenga, S. M., Workneh, T. S., Bultosa, G. and Laing, M. 2019. Characterization of physicochemical properties of starches from improved cassava varieties grown in Zambia. *AIMS Agriculture and Food* 4 (4): 939–966. https://doi.org/10.3934/agrfood.2019.4.939

Dada, T. A., Barber, L. I., Ngoma, L., and Mwanza, M. 2018. Formulation, sensory evaluation, proximate composition and storage stability of cassava strips produced from the composite flour of cassava and cowpea. *Food Science and Nutrition* 6 (2): 395–399. https://doi.org/10.1002/fsn3.568

Dankwa, R., Aisala, H., Kayitesi, E. and Kock, H. L. De. 2021. Cassava , and Cowpea Flour Used as Wheat Flour Alternatives.

Desalegn, A. and Hailu, D. 2020. Particle size distribution, rheological and pasting properties of wheat, anchote and their composite flour. *International Journal of Food and Nutrition Sciences* 5 (1): 131–143. www.premierpublishers.org.

Dini, C., Doporto, M. C., Vina, S. Z. and García, M. A. 2014. Cassava flour and starch as differentiated ingredients for gluten free products. Cassava: Production, Nutritional Properties and Health Effects July 2017, 87–114.

FAO and IFAD. 2005. A Review of Cassava in Africa with Country Case Studies on Nigeria, Ghana, the United Republic of Tanzania, Uganda and Benin. Proceedings of the validation forum on the global cassava development strategy. Volume 2, 357pp.

Guerra-Oliveira, P., Fernández-Peláez, J., Gallego, C. and Gómez, M. 2022. Effects of particle size in wasted bread flour properties. *International Journal of Food Science and Technology* 1–10. https://doi.org/10.1111/ijfs.15656

Gulati, P., Weier, S. A., Santra, D., Subbiah, J. and Rose, D. J. 2016. Effects of feed moisture and extruder screw speed and temperature on physical characteristics and antioxidant activity of extruded proso millet (Panicum miliaceum) flour. *International Journal of Food Science and Technology* 51 (1): 114–122. https://doi.org/10.1111/ijfs.12974

Hasmadi, M., Harlina, L., Jau-Shya, L., Mansoor, A. H., Jahurul, M. H. A. and Zainol, M. K. 2020. Physicochemical and functional properties of cassava flour grown in different locations in Sabah, Malaysia. *Food Research* 4 (4): 991–999. https://doi.org/10.26656/fr.2017.4(4).405

Hasmadi, M., Noorfarahzilah, M., Noraidah, H., Zainol, M. K. and Jahurul, M. H. A. 2020. Functional properties of composite flour: A review. *Food Research* 4 (6): 1820–1831. https://doi.org/10.26656/fr.2017.4(6).419

Hyacinthe, A. A., Bedel, F. J., Elvis, E., Gbocho, S., Constant, J. and Patrice, K. L. 2018. Chemical composition and nutritional value of composite wheat flours (*triticum aestivum*) and two varieties of taro corms (*colocasia esculenta*) cultivar fouê and cultivar yatan. *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)* 12 (8): 24–28. https://doi.org/10.9790/2402-1208012428

Iwe, M. O., Onyeukwu, U. and Agiriga, A. N. 2016. Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea seeds composite flour. *Cogent Food and Agriculture* 2 (1): https://doi.org/10.1080/23311932.2016.1142409

Julianti, E., Rusmarilin, H., Ridwansyah, and

Yusraini, E. 2016. Effect of soybean flour on physico-chemical, functional, and rheological properties of composite flour from rice, sweet potato, and potato. *Tropical Life Sciences Research* 27: 133–138. https://doi.org/10.21315/tlsr2016.27.3.18

Kesselly, S. R., Mugabi, R. and Byaruhanga, Y. 2022. Effect of extrusion on the functional and pasting properties of high-quality cassava flour (HQCF). *Journal of Food Research* 11 (4): 1. https://doi.org/10.5539/jfr.v11n4p1

Lm-, F. T. F. and Huan, Z. 2013. Pasting Characteristics of Cassava at Different Extrusion Conditions.

MO, I., N, M., NE, M., NE, O., GI, O., TU, N. and JO, O. 2017. Physicochemical and pasting properties of high quality cassava flour (HQCF) and wheat flour blends. *Agrotechnology* 06 (03): https://doi.org/10.4172/2168-9881.1000167

Naiker, T. S., Gerrano, A. and Mellem, J. 2019. Physicochemical properties of flour produced from different cowpea (Vigna unguiculata) cultivars of Southern African origin. *Journal of Food Science and Technology* 56 (3): 1541–1550. https://doi.org/10.1007/s13197-019-03649-1

Noorfarahzilah, M., Lee, J. S., Sharifudin, M. S., Mohd Fadzelly, A. B. and Hasmadi, M. 2014. Applications of composite flour in development of food products. *International Food Research Journal* 21(6): 2061–2074. https://doi.org/10.15740/has/ijae/11.sp.issue/65-69

Ilesanmi O. Y. J. 2016. Functional properties of cowpea (*Vigna unguiculata*) flour preserved with mixtures of Neem (Azadichata indica A.Juss) and Moringa (Moringa oleifera) seed oils. *International Journal of Sciences* 2 (06): 142–151. https://doi.org/10.18483/ijsci.1077

Ocheme, O. B., Adedeji, O. E., Chinma, C. E., Yakubu, C. M. and Ajibo, U. H. 2018. Proximate composition, functional, and pasting properties of wheat and groundnut protein concentrate flour blends. *Food Science and Nutrition* 6 (5): 1173–1178. https://doi.org/10.1002/fsn3.670

Otondi, E. A., Nduko, J. M. and Omwamba, M. 2020. Physico-chemical properties of extruded cassava-chia seed instant flour. *Journal of Agriculture and Food Research* 2 (July) 100058. https://doi.org/10.1016/j.jafr.2020.100058

Pauline, M., Roger, P., Sophie Natacha Nina, N. E., Arielle, T., Eugene, E. E. and Robert, N. 2020. Physico-chemical and nutritional characterization of cereals brans enriched breads. *Scientific African* 7: e00251. https://doi.org/10.1016/j.sciaf.2019.e00251

Raihan, M. and Saini, C. S. 2017. Evaluation of various properties of composite flour from oats, sorghum, amaranth and wheat flour and production of cookies thereof. *International Food Research Journal* 24(6): 2278–2284.

Sibian, M. S. and Riar, C. S. 2020. Formulation and characterization of cookies prepared from the composite flour of germinated kidney bean, chickpea, and wheat. *Legume Science* 1–12. https://doi.org/10.1002/leg3.42

Sonaye, S. Y. and Baxi, R. N. 2012. Particle size measurement and analysis of flour. I*nternational Journal of Engineering Research and Application*s 2(3): 1839–1842.

Taghdir, M., Mazloomi, S. M., Honar, N., Sepandi, M., Ashourpour, M. and Salehi, M. 2017. Effect of soy flour on nutritional, physicochemical, and sensory characteristics of gluten-free bread. *Food Science and Nutrition* 5 (3): 439–445. https://doi.org/10.1002/fsn3.411

Victor, O. O. 2020. Preparation of Cowpea bean flour production and quality evaluation of biscuits made from the blend of cow peas and wheat flour. Available at http://www.johnvique.info/.

Waisundara, V. Y. 2018. Introductory Chapter: Cassava as a staple food. *IntechOpen*

Science 3–10. https://doi.org/10.5772/intechopen.70324

Wang, S. 2018. Effect of extrusion temperature and moisture on physical, functional and nutritional properties of Kabuli chickpea, sorghum, maize and their blends. *Journal of Physics A: Mathematical and Theoretical* 44 (8): 2016. https://doi.org/10.1088/1751-8113/44/8/085201

Zhang, Y., Nie, L., Sun, J., Hong, Y., Yan, H., Li, M., You, X., Zhu, L. and Fang, F. 2020. Impacts of environmental factors on pasting properties of cassava flour mediated by its macronutrients. *Frontiers in Nutrition* 7: 1–9. https://doi.org/10.3389/fnut.2020.598960