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Functional and pasting characteristics of *pupuru* and *pupuru* analogues from cassava (*Manihot esculenta*) and breadfruit (*Artocarpus altilis*) blends

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Abstract. *Pupuru* and *pupuru* analogues are fermented, smoked food products usually produced from cassava or cassava substituted with a varying ratio of breadfruit. This study aims at determining and comparing the functional and pasting characteristics of *pupuru* and *pupuru* analogues with a view to expanding the utilization of breadfruit as *pupuru* analogue. The functional properties (water absorption capacity (%), swelling power (g/g), solubility (%)) and pasting characteristics were determined using standard methods. The results showed that the yield of the products ranged between 24.66 and 29.65%, and it was not affected by the amount of breadfruit substituted. The water absorption capacities of the *pupuru* and *pupuru* analogues ranged between 216.0 and 449.0%; this parameter increased with temperature increase. Both swelling power and solubility had a rapid increase from 80 °C to 90 °C. Pasting temperature ranged between 73.15 and 83.66 °C, with peak time between 4.58

Keywords and phrases: breadfruit, cassava, *pupuru* analogue, swelling power, pasting, viscosity, water absorption capacity

and 5.33 min. The final viscosity ranged between 94.08 and 391.83 RVU, and it decreased with increase in breadfruit substitution. The study concluded that adding breadfruit to cassava in *pupuru* analogue production improved some of the functional and pasting properties of the product.

1 Introduction

Pupuru is a fermented cassava-based food product (*Daramola et al.*, 2010). *Pupuru* and other cassava products are widely accepted and consumed in Nigeria, the consumption of which is steady and increasing in this country and beyond its borders too (*Adejuyitan et al.*, 2018). *Pupuru* is traditionally prepared by soaking cassava in water for about 3–5 days to become soft. After fermentation, the wet mash is packed into sacks and dewatered using a mechanical press. The fibres are handpicked from the mash and the mash is moulded into ball or circular shape and placed over fire to be smoke-dried. The resulting products are spherical materials with brown, appealing appearance (*Alaba et al.*, 2013). The outer covering is then scraped off with knife, and the inner white component is milled and sieved into *pupuru* flour.

Previous studies (*Ikujenlola & Lawson*, 2005; *Osundahunsi & Oluwatoyin*, 2005; *Ayodeji et al.*, 2005; *Sanni et al.*, 2003; *Osunsami et al.*, 1989) were focused on the various aspects of *pupuru* processing and rheological properties. However, there is no information on the substitution of cassava with breadfruit for the production of *pupuru* analogues. Breadfruit (*Artocarpus altilis*) is a widely cultivated crop in south-western Nigeria. It is grown mainly as a subsistence crop and is a popular staple food in Polynesia, Jamaica, and the Caribbean (*Ajatta et al.*, 2016). Breadfruit is nutritious, cheap, and highly available during its season, but it has found limited applications in the food industries (*Omobuwajo*, 2003). It has been processed to starches (*Akanbi et al.*, 2009) and flour (*Adepeju et al.*, 2011). The quality and nutritional properties of starch-based foods are largely determined by the changes that starch undergoes during processing/cooking and subsequent storage (*Ojo et al.*, 2017). However, its utilization in *pupuru* analogue production has not been exploited. Therefore, the aim of this study was to produce *pupuru* analogues by blending cassava with breadfruit in different proportions and to determine the functional and pasting characteristics of the products.

2 Materials and methods

Matured unripe breadfruits (*Artocarpus altilis*) were purchased at Ilode market, Ile-Ife, Osun State, and matured cassava roots (*Manihot esculenta*) were bought from Tonkere, Osun State, Nigeria.

Preparation of *pupuru* meals

Cassava tubers and matured unripe breadfruits were washed, peeled, and sliced. The sliced breadfruit and cassava roots were steeped in water at ambient temperature ($30 \pm 2\,^{\circ}$C) inside a plastic container for 72 hrs; after fermentation, the fermented and softened mash was dewatered, and the fibres were sorted out. Thereafter, the mash was packed inside bags, pressed using hydraulic press for 30 min, and moulded into balls of 5–10 cm in diameter. The moulded balls were smoked in the kiln dryer at $80\,^{\circ}$C for 6 hrs, pulverized and toasted for 10 min. It was milled and sieved ($d = 630\ \mu$m) to obtain *pupuru* meal. This method was repeated for blends of cassava and breadfruit in the production of *pupuru* analogues at different proportions (90:10, 80:20, 50:50, 20:80, and 10:90).

Yield of *pupuru* and *pupuru* analogue meal from breadfruit and cassava

The yield of the *pupuru* meals produced from cassava and breadfruit was determined using the method proposed by *Apea-Bah et al.* (2011). The total yield of *pupuru* meals was determined by recording/monitoring the material balance of each unit operation until the final product (*pupuru*) was obtained.

$$\text{Yield of } \textit{pupuru} \text{ meal} = \frac{\text{Weight of } \textit{pupuru} \text{ meal}}{\text{Weight of whole roots}} \cdot 100 \tag{1}$$

Functional properties of the products

Determination of least gelling concentration

The method of *Sathe & Salunkhe* (1981) was employed for the determination of the gelling concentration. Sample suspensions of 1–17% (step 2%) and 20% (w/v) were prepared in 5 ml of distilled water, and the test tubes were heated in a boiling water bath for 1 hr followed by rapid cooling under cold tap water flow. The test tubes were further cooled for 2 hrs at $4\,^{\circ}$C. Least gelling concentration was determined as that concentration when the sample from the inverted test tube did not fall down or slip.

Determination of water absorption capacity (WAC)

The WAC was determined at room temperature and at temperatures ranging between 60 to 90 °C using a combination of the AACC (1995) method and those of *Sosulski* (1962) and *Rutkowski* & *Kozlowska* (1981). A 2 g sample was dispersed in 20 ml of distilled water. The contents were mixed for 30 s every 10 min using a glass rod; after mixing it five times, it was centrifuged at 4,000 g for 20 min. The supernatant was carefully decanted, and then the contents of the tube were allowed to drain at a 45 ° angle for 10 min and then weighed. Water absorption capacity was expressed as the percentage increase of the sample weight.

Determination of swelling power and solubility

Swelling power and solubility were determined using the modified methods of *Takashi* & *Sieb* (1988) and *Sathe* & *Salunke* (1981). Exactly 3 to 5 g sample was weighed into a tared 50 ml centrifuge tube. About 30 ml of distilled water was added and mixed gently. The slurry was heated at a constant temperature (60, 70, 80, and 90 °C) in a water bath for 15 min. During heating, the slurry was stirred gently to prevent clumping of the starch. Upon completion of the 15 min, the tube containing the paste was centrifuged at 3000 × g for 10 min. The supernatant was decanted immediately after centrifugation. The tubes were dried at 50 °C for 30 min, cooled, and then weighed (W_2). Centrifuge tubes containing sample alone were weighed prior to adding distilled water (W_1). From the supernatant, 10 ml was dried in the air oven at 120 °C for 4 hrs in a crucible to constant weight, and swelling power was calculated as follows:

$$\text{Swelling power} = \frac{W_2(\text{g}) - W_1(\text{g})}{\text{Weight of sample(g)}} \cdot 100 \tag{2}$$

$$\text{Solubility (\%)} = \frac{\text{Dry weight at } 120\,^{\circ}\text{C}}{\text{Weight of sample(g)}} \cdot 100 \tag{3}$$

Determination of pasting properties

Pasting properties of *pupuru* and *pupuru* analogue meals were determined using the Rapid Visco Analyser (RVA) (model 3D, Newport Scientific, Warriewood, Australia). *Pupuru* meal (3 g, 14% moisture basis) was mixed with 25 g of accurately weighed water in the aluminium canister. During the programmed heating and cooling cycle, the mixture was held at 50 °C for 1 min, heated to 95 °C for 7.5 min at 6 °C/min, held at 95 °C for 5 min before cooling to 50 °C for 7.5 min and holding at 50 °C for 1 min. Peak viscosity, temperature at peak viscosity, temperature at initial viscosity rise, time from initial to peak viscosity, hot-paste viscosity, cold-paste viscosity, trough, breakdown, and setback were recorded (*Bhattacharya et al.*, 1997).

Statistical analysis

The data obtained were expressed as mean ± standard deviation and were characterized by one-way analysis of variance (at the significance level of $\alpha = 0.05$). For mean value comparison, Tukey's least significant difference test was used. All statistical procedures were carried out using SPSS 17.0 (SPSS, Chicago, IL, USA) software.

3 Results and discussion

Yield of the *pupuru* and *pupuru* analogues

The yield (24.66–29.65%) of the *pupuru* and *pupuru* analogues produced from cassava and breadfruit blends is presented in *Table 1.* The peels of both cassava and breadfruit accounted for the bulk of the waste. The values of the peels ranged between 12.46% and 17.59%. The peel loss is lower than the 22% peel loss reported by *Ikujenlola* & *Opawale* (2007) for cassava products. According to *Opara* (1999), hand peeling losses and mechanized peeling losses are on average between 25 and 30% and 30 and 40% respectively.

The percentages of chaff, water, and other waste materials accounted for losses between 54.53 and 61.26%. Water losses entailed the removal of hydrogen cyanide and starch from the product, while the losses of other materials included the removal of chaff, fibre, and the dark surface covering of smoked balls. *Hahn* (1992) reported that the dry matter content of cassava roots is affected by season, type, and variety.

The yields (24.66–29.65%) of the *pupuru* and *pupuru* analogues obtained were comparable to the range of 12.8–32.3% reported by *Oyewole* & *Ogundele* (2001) for *fufu*. To obtain a higher yield, increasing the monitoring of all production operations is indicated. For waste reduction, peeling must be carried out with care.

Table 1. Yields of the *pupuru* and *pupuru* analogues (%)

Sample	**Starting material**	**Peeled material**	**Peeled material losses**	**Water, chaff, and other**	**Yield of *pupuru***
100% PF	100	85.56	14.44	58.70	26.86
100% BP	100	86.72	13.28	61.26	25.46
90:10 PF/BP	100	82.41	17.59	54.53	27.88
80:20 PF/BP	100	87.54	12.46	57.89	29.65
50:50 PF/BP	100	84.35	15.65	57.74	26.61
20:80 PF/BP	100	84.40	15.60	57.88	26.52
10:90 PF/BP	100	85.68	14.32	61.02	24.66

Keys: **100% PF** – 100% cassava; **100% BP** – 100% breadfruits; **90:10 PF/BP** – 90% cassava co-processed with 10% breadfruits; **80:20 PF/BP** – 80% cassava co-processed with 20% breadfruits; **50:50 PF/BP** – 50% cassava co-processed with 50% breadfruits; **20:80 PF/BP** – 20% cassava co-processed with 80% breadfruits; **10:90 PF/BP** – 10% cassava co-processed with 90% breadfruits

Functional properties of *pupuru* and *pupuru* analogues

The least gelation concentration of the products increased (7–11%) with increase in the level of substitution with breadfruit (*Table 2*). This result compared favourably with the least gelation concentration (10–13%) of composite flour reported by *Ajatta et al.* (2016) but was lower than (30–50%) the least gelation concentration for *Dioscorea alata* reported by *Udensi et al.* (2008). The ability of protein to form gels and provide a structural matrix for holding water, flavours, sugars, and food ingredients is useful in food application and in new product development (*Aremu et al.*, 2006). The differences observed in the gelling concentration may be a result of the relative proportion of different flour constituents such as carbohydrates, proteins, lipids, and fibres and the interactions between the components (*Sathe et al.*, 1982).

The effect of temperature on the water absorption capacity, swelling power, and solubility of *pupuru* and *pupuru* analogues are presented in *Figures 1*, *2*, and *3* respectively. The water absorption capacity represents the ability of a product to associate with water under conditions where water is limited.

Table 2. Least gelation concentration of *pupuru* and *pupuru* analogues (%)

Samples	**Partial gelation (%)**	**LGC** (%)
100% PF	7.00	9.00
100% BP	9.00	11.00
90:10 PF/BP	9.00	11.00
80:20 PF/BP	9.00	11.00
50:50 PF/BP	7.00	9.00
20:80 PF/BP	11.00	13.00
10:90 PF/BP	9.00	11.00

Keys: **100% PF** – 100% cassava; **100% BP** – 100% breadfruits; **90:10 PF/BP** – 90% cassava co-processed with 10% breadfruits; **80:20 PF/BP** – 80% cassava co-processed with 20% breadfruits; **50:50 PF/BP** – 50% cassava co-processed with 50% breadfruits; **20:80 PF/BP** – 20% cassava co-processed with 80% breadfruits; **10:90 PF/BP** – 10% cassava co-processed with 90% breadfruits. **LGC (%)** – least gelation concentration

The water absorption capacity of the meal ranged from 216% to 449% and was observed to increase with increase in temperature. The *pupuru* analogues containing 20:80 PF/BP, 50:50 PF/BP, 100% BP, and 10:90 PF/BP showed marginal increase at varying temperatures. This range was higher than the one (240.0–275%) reported by *Ajatta et al.* (2016) for composite flours but comparable to 330–367% for *Altocarpus altilis* pulp flour reported by *Appiah et al.* (2011). According to *Adetuyi et al.* (2009), the increase in water absorption capacity could be attributed to the increase in the protein content of the co-processed flour; hence the flour could be used as thickener in liquid and semi-liquid foods since the flour has the ability to absorb water and swell for improved consistency in food. Increase in the water absorption capacity would be advantageous to food processors as little dry matter could produce reasonable volume of the reconstituted meal.

Figures 2 and *3* present the influence of temperature on swelling power and solubility. Generally, the swelling power increased with temperature increase. The *pupuru* (100% cassava) and *pupuru* analogues 10% and 90% breadfruit exhibited significant ability to swell more than 100% BP, 20:80 PF/BP, 80:20 PF/BP, and 50:50 PF/BP over a range of temperatures between 80 °C and 90 °C. This result is similar to the findings of *Adepeju et al.* (2011). The swelling power obtained ranged between 3.12 g/g and 8.5 g/g, and this is within the range of 8.70 g/g–15.00 g/g for corn starch flours reported by *Makanjuola* & *Makanjuola* (2018). Meanwhile, the swelling power was comparable with the one (7.84–9.25) reported by *Osungbaro et al.* (2010).

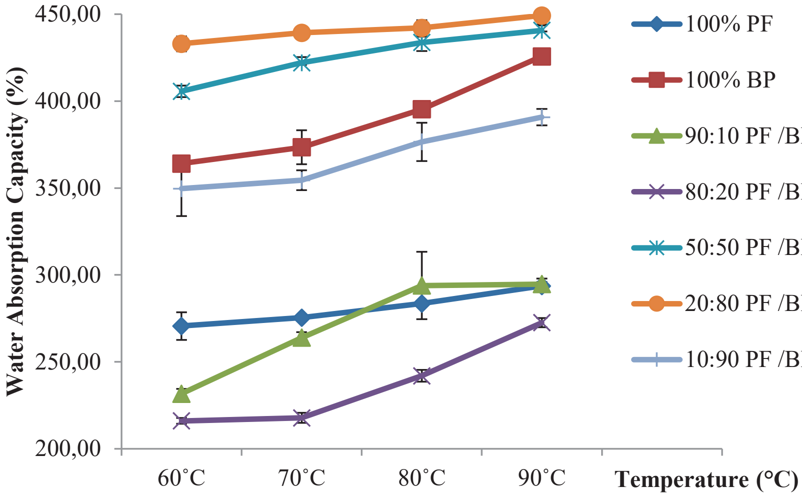

Figure 1. Effect of temperature on the water absorption capacity of *pupuru* and *pupuru* analogue meals

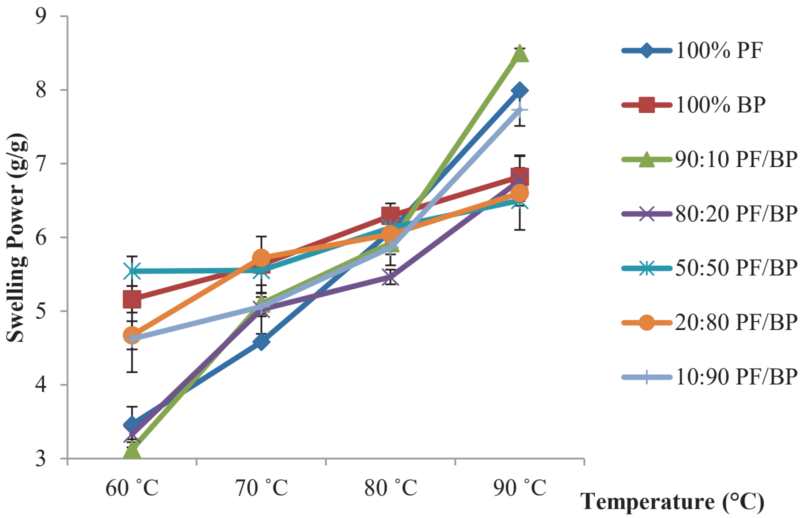

Figure 2. Effect of temperature on the swelling power of *pupuru* and *pupuru* analogue meals

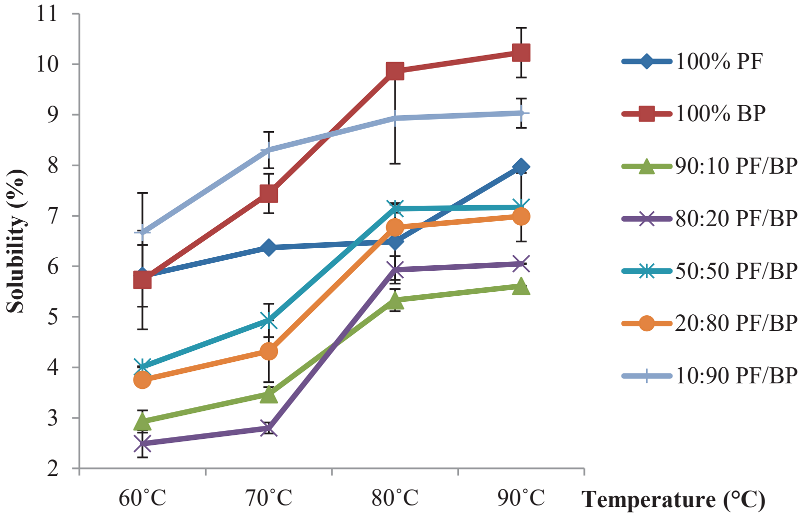

Figure 3. Effect of temperature on the solubility of *pupuru* and *pupuru* analogue meals

According to *Hoover* & *Maunal* (1996), the temperature increase allows the amylose (water-soluble fraction) molecules located in the bulk amorphous regions to interact with the branched segment of amylopectin (water-insoluble fraction) in the crystalline regions. This implies that high temperature weakens the starch granules of flour, thus leading to improved solubility. As a result of swelling, there is an increase in the solubility, showing the highest value at 70 °C and 80 °C, with 100% BP having the highest solubility. The solubility of the starch is believed to be affected by factors such as inter-associative forces, swelling power, presence of surfactants, and other associative compounds (*Sibanda* & *Sychawska*, 2000).

Pasting properties of *pupuru* and *pupuru* analogues

Figure 4 (*a–g*) shows the pasting characteristics of *pupuru* and *pupuru* analogues. The peak viscosity is the maximum viscosity developed by a starch-water suspension during heating (*Adebowale et al.*, 2005). The peak viscosity of the 100% PF (276.38 RVU) was the highest, while 100% BF (38.75 RVU) recorded the lowest value of peak viscosity. Higher peak viscosity may be attributed to differences in protein content (*Sandhu* & *Singh*, 2007). The peak viscosity of co-processed meal decreased as the proportion of breadfruit increased; this agrees with the study of *Oluwamukomi* & *Jolayemi* (2012), who reported a significant decrease in the peak viscosity of soy-melon-enriched gari semolina.

The peak viscosity of the samples ranged between 38.75 and 276.33 RVU; this range was within the range of 203.34–340.22 RVU reported by *Nwokeke et al.* (2013) for cassava–African yam bean fufu flours. Two factors interact to determine the peak viscosity of a cooked starch paste: the extent of granule swelling (swelling power) and solubility. Higher swelling capacity is indicative of higher peak viscosity, while higher solubility due to starch degradation or dextrinization results in reduced paste viscosity (*Shittu et al.*, 2001; *Zobel et al.*, 1984). These were corroborated by results of swelling power and solubility reported in *Figures 2* and *3*. This suggests that the presence and interaction of components, such as fats and protein, from breadfruit with cassava starch lowers the peak viscosity of the blends (*Egounlety et al.*, 2002). According to *Iwe et al.* (2017), values for peak viscosity for the five cassava varieties blended with wheat ranged from 66.08 to 358.08 RVU. Peak viscosity increased with increase in the ratio of cassava flour to wheat flour, and this could be attributed to the high degree of swelling of cassava starch granules.

Trough is sometimes called shear thinning, hot-paste viscosity, or holding strength due to the accompanied breakdown in viscosity. It measures the strength of the paste to withstand breakdown during cooling. This ranged between 39.58 and 240.33 RVU, which is comparable with the range (63.08–202.33 RVU) obtained for fermented cassava-sorghum blend reported by *Osungbaro et al.* (2010).

The breakdown viscosity, which is a measure of cooked starch disintegration, ranged from 1.75 to 60.34 and was observed to be lower than the range of 692.50–924.00 for the corn starch flour sample reported by *Makanjuola* & *Makanjuola* (2018). Higher values of breakdown are associated with higher peak viscosities, which in turn are related to the degree of swelling of starch granules during heating (*Ragaee* & *Abdel-Aal*, 2006). The breakdown was the highest in 80:20 PF/BP (60.34 RVU) and the lowest in 100% BP (1.75 RVU). This implies that 100% BP is more stable to heat and mechanical shear than 80:20 PF/BF. Breakdown viscosity decreased with the increasing level of breadfruit flour substitution; therefore, breakdown viscosity is indicative of paste stability (*Akanbi et al.*, 2009).

The final viscosity ranged between 94.08 and 391.83 RVU, with 100% PF having the highest 391.83 RVU and 100% BP having the lowest 94.08 RVU. The value is comparable with 180.33–332.24 RVU for cassava-African yam bean fufu flour reported by *Nwokeke et al.* (2013). The final viscosity, according to *Iwe et al.* (2017), is a parameter commonly used to determine a sample's ability to form a gel after cooking and cooling. The difference between final viscosity and trough gives rise to a pasting property known as setback viscosity. Setback value is the tendency of starch to associate and retrograde upon cooling (*Peroni et al.*, 2006). It is the phase of the pasting curve after cooling the starches to 50 °C. This stage involves re-association, retrogradation, or re-ordering of starch molecules. A higher setback value is synonymous to reduced dough digestibility (*Shittu et al.*, 2001), while a lower setback of the starch granule during the cooling indicates lower tendency for retrogradation (*Sanni et al.*, 2004; *Sandhu et al.*, 2007) and lower rate of staling of the product from starch (*Adeyemi* & *Idowu*, 1990). Among the studied *pupuru* and *pupuru* analogues, 100% PF had the highest retrogradation tendency, yielding 151.50 RVU for setback viscosity, while the 50% inclusion of breadfruit reduced it to 55.58 RVU.

The peak time, a measure of the cooking time, ranged between 4.58 and 5.33 min for the *pupuru* samples. The time to attain peak viscosity is considerably higher than the range (3.93–4.07 min) reported by *Oluwamukomi* & *Jolayemi* (2012) for soy-melon-enriched gari semolina but comparable to the 5.33–5.53 min obtained for corn starch flours reported by *Makanjuola* & *Makanjuola* (2018). However, it fell within the range (5.02–9.00 min) reported by *Osungbaro et al.* (2010), who worked on fermented cassava–sorghum flour. The result obtained might be due to the fact that *pupuru* and *pupuru* analogues were partially gelatinized during smoking and toasting.

Pasting temperature is a measure of the minimum temperature required to cook a given food sample (*Sandhu et al.*, 2005), and it is related to paste stability – gives an indication of the strength of associative forces within the granules of the biomaterials (*Iwe et al.*, 2017). The pasting temperature of the *pupuru* samples ranged between 73.15 and 83.66 °C. The pasting temperature of *pupuru* from 100% cassava was the highest, while the *pupuru* analogue from 50% breadfruit substitution had the lowest pasting temperature. This may be due to the buffering effect of fat (from breadfruit) on starch, which interferes with the gelatinization process (*Egouletey et al.*, 2002). The pasting temperatures (61.41–61.80 °C) were higher than those of the composite flours reported by *Ajatta et al.* (2016).

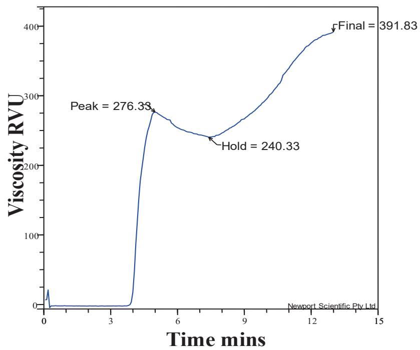

Figure 4a. Pasting property of 100% *pupuru* flour

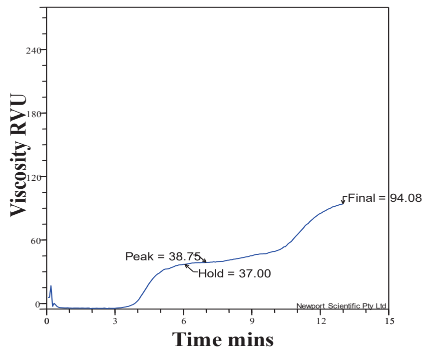

Figure 4b. Pasting property of 100% Breadfruit *pupuru* flour

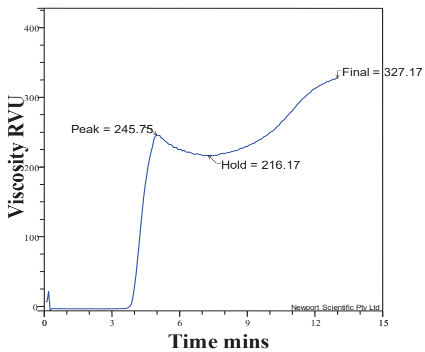

Figure 4c. Pasting property of 90:10 Cassava: Breadfruit *pupuru* flour

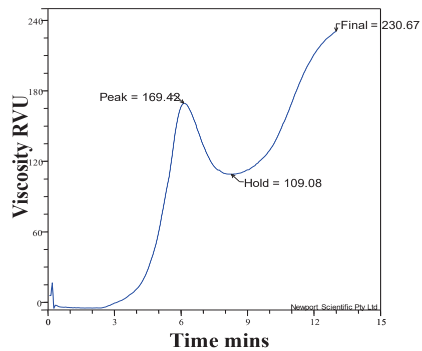

Figure 4d. Pasting property of 80:20 Cassava: Breadfruit *pupuru* flour

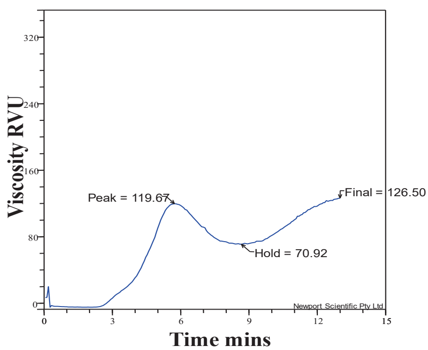

Figure 4e. Pasting property of 50:50 Cassava: Breadfruit *pupuru* flour

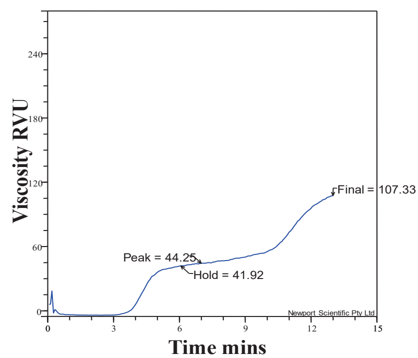

Figure 4f. Pasting property of 20:80 Cassava: Breadfruit *pupuru* flour

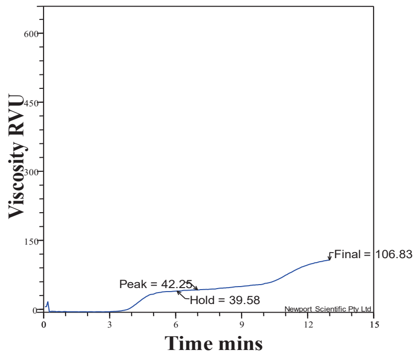

Figure 4g. Pasting property of 10:90 Cassava: Breadfruit *pupuru* flour

4 Conclusions

The study concluded that the functional and pasting characteristics of *pupuru* and *pupuru* analogues from cassava and cassava substituted with breadfruit improved with increase in the proportion of breadfruit. This study has shown another avenue to increase the utilization of breadfruit.

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