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Production and Evaluation of an Instant Maize-Soy Flour Enriched With Refractance Window Dried Jackfruit (*Artocarpus heterophyllus L.*) Powder

Sophie Nansereko[a*], John Muyonga[a], and Yusuf Byaruhanga[a]

[a] Department of Food Technology and Nutrition, Makerere University, Uganda. P.O. Box 7062, Kampala, Uganda

*Corresponding author
snancy27@gmail.com
Tel: +256 776 382367

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Abstract

Porridge is a staple food in many developing countries and is usually used as a weaning or breakfast food. The increased preference for convenient and healthy meals has increased the desire for nutrient-enriched instant flours. Jackfruit is an underutilised fruit that is rich in vitamin C and other bioactive components. This study aimed to evaluate dried jackfruit powder as an ingredient for porridge flour. Formulations were made by substituting varying levels (0, 10, 20 and 30, 40 and 50%) of an extruded maize-soy blend (MSB) constituting 70% maize and 30% soy with refractance window dried jackfruit powder. The composite flours were used to make porridges which were analysed for their sensory acceptability by a 60-member semi-trained panel. The viscosity, water holding capacity, oil holding capacity, solubility index and bulk density of the flours were also assessed. Porridge acceptability, flour proximate composition, ascorbic acid and carotenoid content for the most preferred experimental formulation were compared to commercial maize-based instant flour and plain maize-soy instant flour. The most acceptable porridge was made from the 50% MSB and 50% jackfruit flour blend. The 50% jackfruit - MSB blend and control commercial instant flours attained drinking viscosity (2,500–3,000 cP) at 20% and 31% flour rates. The energy, protein, iron, calcium, β-carotene, and vitamin C densities of jackfruit - MSB porridge were 47.8 %, 48.9 %, 158.1 %, 226.5 %, 230.3 % and 125.9 % higher than those obtained from plain MSB porridge respectively. The results showed the potential of jackfruit as an ingredient for the nutritional enrichment of flours meant for making porridge.

Keywords: Refractance window drying technology; Jackfruit powder; Instant flours; Extrusion; Functional properties

1 Introduction

The jackfruit (*Artocarpus heterophyllus L.*) is a member of the Moraceae family. It is an underexploited tropical fruit crop (Williams & Haq, 2002). Jackfruit is widely cultivated in South and Southeast Asia, the Caribbean and Latin America and some parts of Africa, including Kenya and Uganda (Southampton Centre for Underutilised Crops, 2006). Jackfruit is the largest edible fruit and gives higher yields (150 to 180 fruits/tree) than any other fruit tree (Balamaze et al., 2019). Jackfruit provides an inexpensive, nutritious, edible bulb, rich in vitamins and minerals (Ranasinghe et al., 2019). Previous studies have revealed numerous health benefits of jackfruit including anticarcinogenic, antimicrobial, antifungal, anti-inflammatory, wound healing,

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Nomenclature

MSB	Maize-soy blend	RW	Refractance Window

and hypoglycaemic properties (Arora & Parle, 2016; Biworo et al., 2015; Ranasinghe et al., 2019). However, the fruit is highly perishable and considerable amounts, primarily obtained in the glut season, go to waste due to low market access and inappropriate post-harvest handling (Swami et al., 2016). Processing of jackfruit can extend shelf life, develop new food products, and contribute to income generation and employment (Swami et al., 2016). The use of jackfruit as an ingredient in widely consumed foods such as porridge flour would increase its consumption and consequently intake of vitamins and minerals. Drying specifically is an effective method for the production of shelf-stable food products or food ingredients. Refractance window (RW) drying is a simple, fast and inexpensive technology that gives products comparable in quality to freeze-dried products (Nindo & Tang, 2007). The production of jackfruit powder facilitates its use in different products such as instant soups, snacks, bakery, beverages, dairy, candy, ice cream, baby food, and pasta (Pua et al., 2007).

Porridges, usually prepared from cereals, are widely consumed in developing countries and are a convenient food for weaning infants and feeding the elderly and convalescents (Šimurina et al., 2018). Conventional porridges, however, have a long preparation time and very low energy and nutrient densities (Ejigui et al., 2007). Extrusion can produce instant flours, which are convenient for use as they do not need long preparation (Gandhi & Singh, 2015). Acceptability and nutritional attributes of porridges are frequently enhanced by added ingredients (Gandhi & Singh, 2015). Jackfruit has attractive characteristics such as excellent digestive and nutritive value (Pavan et al., 2014; Zhu et al., 2019), pleasant flavour, high palatability, and abundant availability during glut seasons, at a moderate price (Balamaze et al., 2019). The utilization of jackfruit for the preparation of instant flour has, however, not been explored. Hence, the present investigation was undertaken to determine the most acceptable jackfruit formulation for instant flour and determine the effect of adding jackfruit powder on the consumer acceptance, nutritional value and physical properties of a maize-soy blend instant flour.

2 Materials and Methods

2.1 Jackfruit powder preparation

Mature yellow-fleshed jackfruits were procured from Kayunga district, Uganda, in March 2021. Maturity was determined when the last leaf on the fruit stalk turned yellow, and the fruit skin colour became pale (Asia-Pacific Association of Agricultural Research Institution, 2012). The fruits were left to ripen under ambient conditions. The fruits were washed using potable water to remove foreign matter from the surface. The cleaned fruits were sectioned, and the arils and seeds separated. The arils were crushed in a food blender (Phillips Blender Model HR 1727, Koninklijke Philips N.V., Netherlands) at the highest speed (2) to produce a pulp. Blending was done intermittently for a total of three minutes. Refractance window drying was done using a hybrid batch scale refractance window dryer (Utility Model reference number UG/U/2020/000012) on a Mylar sheet (k-mac plastics-Type D clear, thickness 0.010 inches). Electricity was used as a source of heat energy to power the drying system. Uniform thickness of jackfruit pulp was achieved using specially fabricated slates that spread the puree on the top surface of the Mylar float at a thickness of 2.56 mm. The drying water temperature was 93^{o}C, and drying was for 60 minutes. The drying conditions were based on optimisation experiments done previously. After drying, the jackfruit flakes were scraped from the mylar sheet, ground into a powder using a mill (Phillips Model HR 1727, Koninklijke Philips N.V., Netherlands) and stored in resealable Ziplock bags placed in an airtight container in subdued light until further use.

2.2 Formulation and preparation of blends

A 70% maize to 30% soy blend was purchased from a local commercial supplier. The 70:30 cereal to legume ratio is recommended based on the lysine content of the ingredients (Ejigui et al., 2007) Control porridge was made from maize and soy flour without the addition of fruit powder. Experimental samples consisted of 5 levels (10, 20, 30, 40, and 50% (w/w) of substitution of MSB with jackfruit powder (Gandhi & Singh, 2015). Ingredients used in the instant porridge formulation were mixed by blending in a mill (Phillips Model HR 1727, Koninklijke Philips N.V., Netherlands) and sieved using a 600-micron sieve (Endecotts, UK) before being stored at room temperature in airtight, opaque Ziplock bags until analysis.

2.3 Chemical analysis

AOAC (2000) methods 925.09, 923.03, 962.09, AOAC 4.5.01 and 979.09 were used to determine moisture, ash, fibre, crude fat and crude protein content. The carbohydrate content (g) was estimated by difference (AOAC, 1995).

Total energy

The total energy (TE) value in kcal/100g of the three formulations was determined according to the method of (Kanu et al., 2009) using the formula shown in equation 1:

$$TE = (CARB \times 4) + (PROT \times 4) + (FAT \times 9) \quad (1)$$

Where CARB, PROT and FAT are the carbohydrate, protein and fat content in percentage.

The percentage protein calories (PC) were determined as shown in equation 2:

$$PC = \frac{\%Protein \times 4}{TE} \quad (2)$$

(Kanu et al., 2009)

Mineral analysis

The Perkin-Elmer Corporation (1996) atomic absorption spectrometric (AAS) methods were employed to determine calcium, iron and zinc contents. The mineral concentrations were calculated using equation 3 below:

$$Ppm = \frac{\gamma \times V \times DF}{WT} \quad (3)$$

Where:
γ= the reading from the AAS at 422.7nm for Ca,213.9nm for Zn and 248.3nm for Fe
V= the volume to which the samples were brought,
DF= the dilution factor for those samples with concentrations beyond the calibration curve
WT= sample weight taken.

Vitamin C determination

Vitamin C content of the dried fruit product was determined by 2, 6-dichloroindophenol titrimetric method (Ugbe et al., 2017). Vitamin C content was expressed on a dry weight basis as mg/100 g sample using equation 4.

$$VitC = \frac{NTitr \times DCPIP_{eqv} \times V_{tot}}{V_{titr} \times W_s} \times 100 \quad (4)$$

Where VitC is the concentration in mg/100 g, NTitr is the Net titre value in ml $DCPIP_{eqv}$ are the equivalents of the DCPIP tritrating solution, V_{tot} is the total volume of the solution in ml, V_{titr} is the total volume used in the pippete and W_s is the sample weight in g.

Determination of total carotenoids

Total carotenoids in the flours were determined according to the method of Rodriguez-Amaya and Kimura (2004). The total carotenoid content

(TC) in $\mu g/g$ was calculated using the formula in equation 5:

$$TC = \frac{A \times V(ml) \times 10^4}{A_{1cm}^{1\%} \times p(g)} \quad (5)$$

Where A = Absorbance at 450nm; V = Total extract volume; p = sample weight; $A_{1cm}^{1\%} = 2592$ (β-carotene Extinction Coefficient in petroleum ether).

2.4 Determination of porridge nutrient density

Porridges were prepared with different flour rates (20-35%), and their viscosities were measured using a Brookfield DV II viscometer (Brookfield Engineering Labs, U.S.A.) using spindle R.V. no. 5 at 55^oC. Flour rates that produced porridges of drinkable viscosities (2,500–3,000 cP) suitable for child feeding were recorded (Akande et al., 2017). Energy, protein, iron, zinc, calcium, β-carotene, and vitamin C densities (ND in $100ml^{-1}$) of the porridges with the desired viscosity (2,500–3,000 cP) were calculated using equation 6.

$$ND = \frac{Flourrate}{100ml} \times \frac{Nutrient}{100g} \quad (6)$$

2.5 Functional properties of composite flours

Water solubility index (WSI)

The WSI of the composite flour was determined using the method described by Kha et al. (2010) with some modifications. The WSI (%) was calculated as the percentage of dried supernatant with respect to the amount of the original 2.5 g jackfruit powder, as shown in equation 7.

$$WSI(\%) = \frac{Driedsupernatantweight}{Initialsampleweight} \times 100 \quad (7)$$

Water holding capacity

Water holding capacity (WHC) was determined according to Nguyen et al. (2015). Water holding capacity (g water/g of powder) was calculated as shown in equation 8.

$$WHC = \frac{Totalwatermass(g)}{Drymattermass(g)} \quad (8)$$

Oil holding capacity

Oil holding capacity (OHC) was calculated according to Nguyen et al. (2015). Oil holding capacity was calculated as shown in equation 9.

$$OHC = \frac{Massofsampleincludingheldoil(g)}{Massofdrymaterial(g)} \quad (9)$$

Bulk density

Bulk density was determined by the method of Chandra et al. (2015).

pH

The pH was determined according to the method by Amankwah et al. (2009).

2.6 Comparison of sensory properties of porridges made from different formulations of MSB-jackfruit powder

Five different porridge formulations (substitution with 10% - 50% jackfruit powder) were prepared by mixing 200 g of each composite flour in 800 ml of boiling water with constant stirring for about 4 minutes. Sensory acceptability was determined using the method by Akande et al. (2017) with slight modifications, using a semi-trained panel ($n = 60$) mainly comprised of students in the School of Food Technology, Nutrition, and Bioengineering, Makerere University. A 9-point hedonic scale was used with 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. The most acceptable MSB-jackfruit formulation was evaluated with a commercial instant porridge and the control porridge. Acceptability of the composite jackfruit porridge was compared with a commercial maize-based instant porridge commonly consumed in Kampala city, Uganda. Similarly, a 9-point hedonic scale was used with

1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely.

2.7 Statistical analysis

The results are reported as mean values±standard deviations of three independent determinations. Results obtained were subjected to statistical Analysis of Variance (ANOVA) using XLSTAT software version 2019 to determine variation between means. Tukey's HSD test was conducted to analyse differences between means at a 95% confidence interval.

3 Results and Discussion

3.1 Comparison of sensory properties of porridges made from different formulations of MSB-jackfruit powder

There were significant differences ($p<0.05$) in appearance, taste, mouthfeel and overall acceptability of the five formulations evaluated (Table 1). From the results, the superior overall acceptability of the 50% formulation could be associated with the sweet taste imparted by the jackfruit powder and the appearance of the porridge. The formulation with 50% jackfruit powder was selected for comparison with the control and a commercial sample.

3.2 Proximate and mineral composition of commercial and jackfruit composite flours

The proximate chemical composition of the three formulations, the commercial flour, 50% jackfruit flour and plain maize-soy flour, are presented in Table 2 . The moisture content of the flours ranged from 6.3 % to 8.1%, which was within the range required for flours to be shelf-stable (Ntuli et al., 2013). Moisture content directly influences the stability of flours during storage, mainly because micro-organisms naturally occurring in the flour would readily thrive at high moisture content, causing deterioration during storage. The protein content for the commercial and formulated composite formulation was significantly different ($p<0.05$) from the plain MSB flour. The plain MSB flour had the highest protein content, which can be attributed to the higher proportion of soy flour in the formulation. The protein contents for all the flours were above 8% dry weight, indicating good quality flour (Ntuli et al., 2013). Carbohydrate content for the three formulations ranged from 75.7% to 81.32%, with the three formulations being significantly different ($p<0.05$) from each other. The commercial and formulated samples were within the range (70-96%) of results reported by Makame et al. (2020) for the nutritive value of common African indigenous/local complementary porridge samples. The high carbohydrate content of the formulations is attributable to the high carbohydrate content of maize which was the principal ingredient in the formulations, and the high carbohydrate content of the fruit powder added to the MSB. The high carbohydrate content of the jackfruit formulation in this study could be advantageous, especially to infants, as the fruit sugars impart more sweetness to the porridge, thereby enabling children to take more of the food per feeding and minimize the addition of table sugar during the preparation of the porridge.

The addition of jackfruit powder significantly ($p<0.05$) increased the fibre and ash contents of the porridge. Consumer interest in dietary fibre has grown significantly in recent years. Several studies link increased fibre intake to reduced risks of cancer and cardiovascular diseases, digestive health benefits, and weight management (Barber et al., 2020). The blend with 50% jackfruit powder showed higher amounts of dietary fibre (4.1%) than the plain maize and soya (2.7%) and the commercial flour samples (2.8%). Porridge flour supplemented with up to 50% jackfruit powder, with 4.1 g of fibre per 100 g of food, could be labelled as a 'source of fibre' according to Codex Alimentarius (1997), which has established that for solid food to be considered a 'source of fibre' it should present at least 3 g of fibre for each 100 g of food. This confirms that jackfruit maize-soy blends in a 50: 50 ratio would be potential sources of fibre in food preparations. The 50% jackfruit MSB formulation had the highest ash content, indicating an

Table 1: Consumer acceptability scores of porridges prepared from different formulations of jackfruit composite flours

Parameter	10%	20%	30%	40%	50%
Appearance	6.0±1.67^{ab}	5.9±1.46^{a}	6.0±1.40^{ab}	6.5±1.55^{b}	6.8±1.67^{bc}
Aroma	6.4±1.71^{a}	6.2±1.67^{a}	5.8±1.63^{a}	6.1±1.56^{a}	6.0±1.98^{a}
Taste	5.5±2.00^{a}	5.4±1.67^{a}	5.4±1.90^{a}	5.9±1.80^{ab}	6.2±1.89^{b}
Mouth feel	5.5±2.07^{ab}	5.6±1.65^{ab}	5.6±1.77^{a}	6.0±1.78^{ab}	6.3±1.86^{bc}
General acceptability	6.0±1.70^{ade}	5.9±1.30^{a}	5.7±1.42^{a}	6.4±1.62^{bde}	6.6±1.75^{bc}

Values show mean±SD (n = 60). Figures in the same row with the same superscript are not significantly (p > 0.05) different. A 9-point hedonic scale was used with 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely.

improvement in the total mineral contents due to substitution with jackfruit powder (Mandha et al., 2021). The addition of jackfruit powder increased the carotenoids content of the flour. The 50% jackfruit powder blend was highest in carotenoid content (346.5 μg/100 g), whereas the plain maize and soya bean blend was the lowest (142.1 μg/100 g). Similarly, the addition of jackfruit powder increased the ascorbic acid content, with the 50% jackfruit formulation containing 27.247 mg/100 g compared to the plain maize soya bean blend (17.814 mg/100 g).

The energy density of the porridges was in the range of 379 to 397 kcal/100g, with a significant difference (p<0.05) among the values. According to the Codex standard for processed cereal-based foods for infants and young children (CODEX STAN 074-1981, 2006), the energy density of a cereal-based complementary food should be $\geq$ 80 kcal/100g. The formulated porridge considerably surpassed the minimum stipulated daily energy requirement for infants up to 12 months.

The 0% and 50% formulations were rich in calcium, followed by iron, with the 0% having the highest (p<0.05) amount of the two minerals. The high amount of calcium and iron observed for the 0% formulation could be attributed to its higher content of soya (Tenagashaw et al., 2017).

3.3 Functional properties of jackfruit blends

The functional properties of jackfruit composite flours (Table 3) showed that the substitution of the maize-soy flour with jackfruit powder in the blends led to decreased water holding capacity (from 3.76 to 2.75 g water/ g sample), oil holding capacity (1.96 to 1.62 g water/ g sample), bulk density and pH (6.717 to 5.467).

WSI values for the formulations ranged between 26.91% and 46.12%. The highest WSI was observed in the 50% jackfruit formulation. The high WSI of the jackfruit formulations in this study can be explained by the quantity of soluble molecules (e.g. sugars and possibly soluble fibre). The relatively high WSI of formulations with higher jackfruit powder substitution ratios may suggest easier digestibility of the porridges, which is desired for infant feeding (Amagloh et al., 2013; Awuchi et al., 2019). The lower solubility of the commercial flour and 0% formulations could be due to the slightly higher starch content Amagloh et al. (2013). These findings are consistent with the findings of Gandhi and Singh (2015), who established that an increase in the level of fruit pulp in instant porridge formulations showed an increasing trend of water solubility index with a significant increase observed beyond 10% guava pulp. Higher values for water solubility index were recorded at 40–50% fruit pulp.

Table 2: Proximate and mineral composition of commercial and jackfruit composite flours

	Commercial sample	**0%**	**50%**
Moisture (%)	8.14±0.05^{b}	6.66±0.10^{a}	6.31±0.29^{a}
Fibre (%)	2.85±0.37^{a}	2.67±0.37^{a}	4.09±0.27^{b}
Ash (%)	1.41±0.04^{a}	1.99±0.04^{b}	2.59±0.08^{c}
Fat (%)	2.99±0.13^{b}	2.45±0.44^{ab}	1.24±0.12^{a}
Protein (%)	11.43±0.30^{a}	17.18±0.69^{b}	10.99±1.32^{a}
Carbohydrate (%)	81.33±0.71^{b}	75.70±1.48^{a}	81.09±1.61^{c}
Energy (kcal/100 g)	397.91±0.92^{b}	393.64±1.66^{b}	379.22±1.68^{a}
% protein calories	12.51±0.38^{a}	18.71±0.84^{b}	12.36±1.63^{a}
Carotenoids (µg/100 g)	162.4±0.16^{a}	142.1±0.21^{a}	346.5±0.18^{b}
Ascorbic acid (mg/100 g)	18.69±0.28^{b}	17.81±0.10^{a}	27.25±0.20^{c}
Fe (mg/100g)	13.61±0.09^{a}	36.59±0.09^{c}	22.64±0.08^{b}
Zn (mg/100g)	1.09±0.08^{b}	0.86±0.00^{ab}	0.57±0.01^{a}
Ca (mg/100g)	25.69±0.06^{a}	67.08±0.08^{c}	54.12±0.02^{b}

Values show mean±SD. Figures in the same row with the same superscript were not significantly (p >0 .05) different.

Table 3: Water holding capacity, oil holding capacity, bulk density, solubility index and pH of commercial and jackfruit composite flours

	WHC(g/ml)	**OHC (g oil/g)**	**BD (g/cc)**	**SI (%)**	**pH**
Com	3.84±0.03^{b}	1.23±0.08^{a}	0.41±0.01^{a}	11.50±1.04^{a}	6.437^{e}
0%	3.76±0.04^{b}	1.96±0.02^{b}	0.49±0.01^{ab}	26.91±0.20^{b}	6.717^{f}
10%	3.72±0.10^{b}	1.98±0.01^{b}	0.49±0.01^{ab}	28.61±0.71^{b}	6.393^{d}
20%	3.61±0.09^{b}	1.95±0.02^{b}	0.51±0.03^{b}	36.24±0.82^{c}	6.080^{c}
30%	3.42±0.09^{b}	1.87±0.06^{b}	0.51±0.01^{b}	42.09±0.90^{d}	5.930^{b}
40%	3.17±0.28^{ab}	1.86±0.04^{b}	0.51±0.01^{b}	42.09±0.88^{d}	6.137^{c}
50%	2.75±0.07^{a}	1.62±0.06^{ab}	0.49±0.02^{ab}	46.12±0.19^{d}	5.467^{a}

Values show mean±S.D. Figures in the same row with the same superscript were not significantly (p > 0.05) different. Com: Commercial sample, W.H.C.: Water holding capacity, O.H.C.: Oil holding capacity, BD: Bulk density, SI: Solubility index

Bulk density

Bulk density measures the heaviness of a flour sample and can be used to determine its packaging requirements (Kraithong et al., 2018). There were no significant differences in the bulk densities ($p>0.05$) amongst the composite flours with jackfruit powder added. However, the bulk density of the commercial flour was significantly lower than that of the composite flours with jackfruit powder. Bulk density ranged from 0.41 to 0.51 g/ml. The results obtained for the bulk density were slightly higher than the value reported by Yusufu et al. (2013) for complementary food consisting of sorghum, African yam bean and mango (0.42 g/cm^3). A higher bulk density is undesirable in the packaging of foods because it results in a large oxygen reservoir (Otegbayo et al., 2013).

Oil holding capacity

Oil holding capacity is an important functional property as it plays a vital role in enhancing the mouthfeel and retaining the flavour of foods. According to Grigelmo-Miguel et al. (1999), ingredients with a high OHC allow the stabilisation of high-fat food products and emulsions. The oil holding capacity of the composite flours ranged from 1.62-1.96 g oil /g of sample. While there were no significant differences in the oil holding capacities ($p>0.05$) amongst the composite flours with jackfruit powder added, there was a significant difference between the commercial flour sample and the composite flour samples. This property is mainly affected by protein content in the sample, where the side chains of non-polar amino acids can form hydrophobic interactions with hydrocarbon chains of lipid (Jitngarmkusol et al., 2008). According to Keskin et al. (2022), fibre composition also affects the oil holding capacity of food products.

Water holding capacity

Water holding capacity decreased considerably as the percentage of fruit powder increased. This may be attributed to the relative decrease in starch content with the addition of fruit powder and competition of absorption of water between the fruit powder and available starch. This result is in agreement with those of Gandhi and Singh (2015). They reported a decrease in the water holding capacity when the ratio of fibre/maize starch increased in the extrusion of maize fibre and maize starch blend. According to Ajanaku et al. (2012), a low water holding capacity aids digestibility of the food in the alimentary canal of children suggesting the potential use of the 50% jackfruit composite porridge as a weaning food to improve the nutritional and health status of growing infants.

pH levels

The addition of jackfruit powder significantly affected the pH in the composite porridges. A significant decrease in pH was observed in composite porridges due to blend formulation (Table 3). The control porridge (100% maize-soy blend) had a higher pH (6.717) than the MSB-jackfruit composite porridges, with pH values of 6.3 to 5.4. Similarly, Ngadze et al. (2019) observed a drop in pH with the addition of monkey orange to a staple maize porridge.

3.4 Viscosity analysis of the jackfruit and commercial instant porridges

Viscosity influences nutrient intake because it contributes to an increase or decrease in the bulk of a product (Mburu et al., 2011). The high viscosity and low energy density of food make it difficult for an individual to consume enough of that food to meet the nutritional requirements. Porridge with a high flour rate is usually more energy and nutrient-dense than those with lower flour content. However, the high viscosity of porridges with high flour content make consumption difficult, especially for young children. Nout (1993) recommends that weaning porridges should have approximately 20% dry matter content. The jackfruit and control commercial instant porridges attained the drinking viscosity (2,500–3,000 cP) at 20% (20 g/100 ml) and 31% (31 g/100 ml) flour rates, respectively (Fig. 1 and Fig. 2). Porridge viscosity of 1000—3000 cps is soup-like and easily spoonable, making it

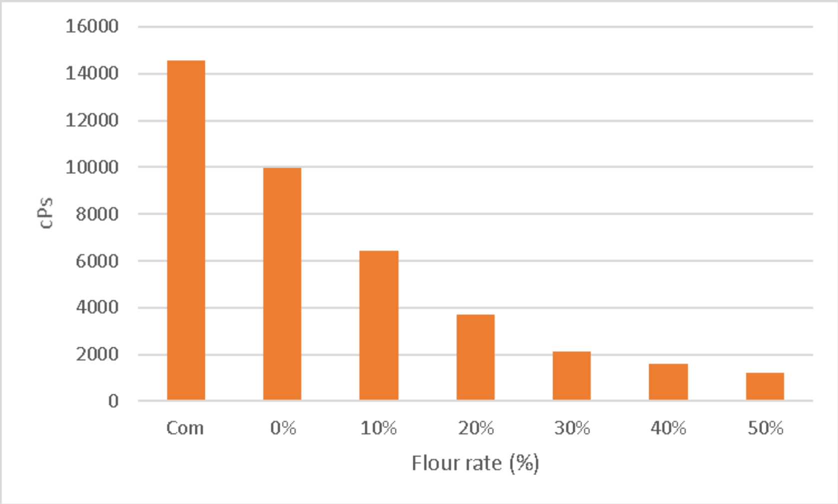

Figure 1: Viscosity of different jackfruit porridge formulations at 25% flour rate; Com: Commercial composite flour

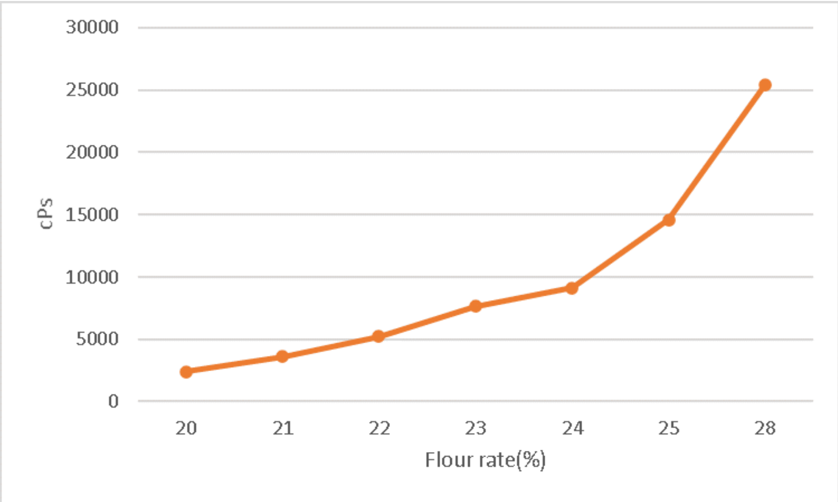

Figure 2: Viscosity of commercial porridge at different flour rates

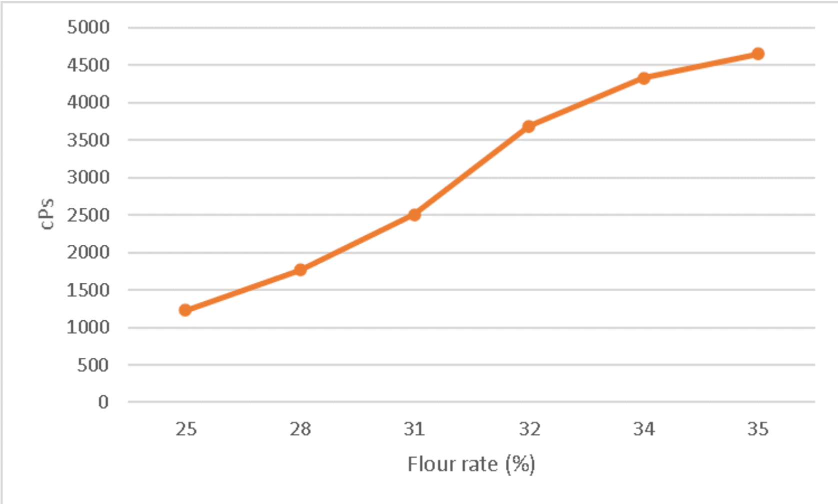

Figure 3: Viscosity of 50% jackfruit porridge at different flour rates

especially appropriate for infant feeding (Oladiran & Emmambux, 2022). The viscosity of the porridges was significantly reduced by the addition of jackfruit powder (Fig. 3). This is because, at higher concentrations of maize-soy blend flour, there are more starch granules to interfere with the flow properties of the porridge, hence increasing the viscosity. These findings were consistent with Mandha et al. (2021) who found that the addition of mango flour decreased the viscosity of the porridge. Benefits of the reduced viscosity are increased total energy and nutrient intakes, greater ease of feeding, the consequent reduction in feeding times, and increased digestibility of the foods (World Health Organization, 1998).

Nutrient density of the jackfruit porridge

Table 4 shows the nutrient densities of the jackfruit and commercial porridges at 31% and 20% flour rates, respectively. The energy, protein, iron, calcium, β-carotene and vitamin C densities of the jackfruit composite instant flours were higher than that of the maize-soy instant porridge. However, the zinc density of the jackfruit composite instant porridge was lower than that of the commercial maize-soy instant porridge. The percentage of soya bean flour in the commercial maize-soy instant porridge could have accounted for its higher zinc density. The high nutrient densities of the jackfruit composite instant porridge indicated its suitability for infant and young child feeding and could help reduce protein-energy malnutrition and micronutrient deficiencies.

Sensory evaluation

The mean acceptability scores for all attributes ranged from 5.8 to 6.6 for the commercial porridge, 5.3-6.7 for the 0% jackfruit porridge and 6.2–7.0 for the jackfruit composite porridge (Table 5). There were no significant differences among the three porridges in sensory attributes except for taste, mouthfeel, consistency and overall acceptability. The flavour of the porridge prepared with 50% jackfruit powder was most preferred ($p<0.05$). The mean overall acceptability score for 50% jackfruit porridge was significantly ($p<0.05$) higher than that for the plain MSB (0% jackfruit powder) porridge. The inclusion of jackfruit powder in instant porridge resulted in a product with a sweeter taste and smoother consistency which was most likely responsible for higher taste and consistency scores.

Table 4: Calculated nutrient density (per 100 ml) of the porridges

Nutrient	Jackfruit instant porridge (31 g/100 ml)	Maize and soy instant porridge (20 g/100 ml)
Energy (kcal)	117.64	79.58
Protein (g)	3.41	2.29
Iron (mg)	7.02	2.72
Zinc (mg)	0.18	0.22
Calcium(mg)	16.78	5.14
B-carotene (μg)	8.95	2.71
Vitamin C (mg)	8.45	3.74

Table 5: Comparison of sensory acceptability scores for plain porridge, jackfruit composite porridge and a commercial instant soy porridge

	Sample code		
Attribute	Commercial	0%	50%
Appearance	6.6 ± 1.43^{a}	6.2 ± 1.68^{a}	6.7 ± 2.02^{a}
Aroma	6.4 ± 1.51^{a}	6.7 ± 1.69^{a}	6.2 ± 2.07^{a}
Taste	5.8 ± 1.87^{a}	5.3 ± 1.87^{a}	6.9 ± 1.76^{b}
Mouthfeel	6.2 ± 1.87^{ab}	5.7 ± 2.11^{a}	6.9 ± 1.50^{b}
Consistency	6.3 ± 1.86^{b}	5.4 ± 1.86^{a}	6.5 ± 1.78^{b}
General acceptability	6.4 ± 1.61^{ab}	5.9 ± 1.63^{a}	7.0 ± 1.55^{b}

Values show mean ± SD (n = 62). Figures in the same row with the same superscript were not significantly ($p > 0.05$) different. A 9-point hedonic scale was used with 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely.

4 Conclusions

The study demonstrated that refractance window dried jackfruit powder could be used as an ingredient for maize-soy flour blends to improve their nutritional and sensory attributes. Addition of jackfruit powder increased the fibre, ash, carbohydrate, carotenoids and ascorbic acid contents of the flour. The jackfruit enriched the energy content of the flour, and protein, iron and calcium densities were higher than that of the plain maize-soy flour, the latter being more acceptable in terms of its sensory characteristics. Furthermore, replacing 50% of maize-soy flour with jackfruit powder resulted in a significant reduction in the viscosity, thus making it appropriate as a weaning food. A porridge with low viscosity but with high energy density is desirable for infants and young children for easy mastication and swallowing. The porridge also met the nutritional requirements of infants and preschool children. Therefore, it can be recommended as a sustainable supplementary food source to improve vulnerable populations' nutritional status and health.

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