Effect of soy flour addition and heat processing methods on nutritional quality and consumer acceptability of cassava complementary porridges

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Running title: Nutrition quality & consumer acceptability of extruded cassava-soy complementary porridges

ABSTRACT

BACKGROUND: Nutritional quality of cassava complementary porridge improved through extrusion cooking and compositing with either defatted or full fat soy flour (65:35) and product acceptability by mothers with children of the target population was evaluated.

RESULTS: Protein Digestibility Corrected Amino Acid Score (PDCAAS) of extruded and conventionally cooked composite porridges was within the recommendations for complementary foods. Kinetics of starch digestibility showed that all porridges had a rapid rate of starch digestibility, but the rates were lower when defatted soy flour was added and lowest when full fat soy flour was added. Formation of amylose-lipid complexes as shown by X-ray diffraction and differential scanning calorimetry can be attributed for the lower digestibility of extruded porridge with full fat soy flour. If fed thrice per day, extruded porridge with defatted soy flour and with full fat soy flour would meet the energy, protein and lysine (available) requirements of a child aged 6-8 months receiving low or average nutrients from breast milk. All the porridges were well received by Mozambican mothers who use cassava as staple food. The mean scores for sensory liking of all porridges were three and above on a 5-point hedonic scale.

CONCLUSION: Extruded cassava-soy flour porridges have a good potential for use as high energy and protein complementary foods; and have acceptable sensory properties.

Key words: Amylose-lipid complexes, Available lysine, Protein Digestibility Corrected Amino Acid Score (PDCAAS), starch digestion kinetics, X-ray diffraction

INTRODUCTION

Protein energy malnutrition (PEM) is a major health problem in Africa where complementary foods are based on starchy staple foods.[1] Any nutrient containing foods or liquids provided to young children along with breast milk are referred to as complementary foods.[2] PEM mainly starts when complementary feeding is initiated.[2] Nutritional improvement of staple foods is a suitable means to reduce PEM. In sub-Saharan Africa, cassava *(Manihot Esculenta* Crantz) is a staple crop. It is adaptable in marginal soils and grows in erratic rainfall conditions.[4] Except for histidine and leucine, cassava flour is deficient in essential amino acids compared to the recommended intakes for 1-2 year –old children.[4, 5]

Addition of soybean (*Gycine max*), whose cultivation and consumption is gaining popularity in sub-Saharan Africa, may enhance protein quality of cassava complementary porridges. Soybean is high in protein (~ 40%) and has a good balance of amino acids that would complement the limiting amino acids in cassava.[6]

Extrusion cooking is a well-known heat processing technology used to produce ready to eat (instant), high energy dense cereal complementary porridge with a viscosity that is palatable by children.[7, 8] Extrusion cooking may either positively or negatively affect the protein and energy nutrition of extruded foods. Extrusion cooking has been shown to reduce amino acid content of food and lysine is the most affected.[10, 11] The free ε-amino group of lysine can react with reducing sugars during Maillard reaction rendering lysine nutritionally unavailable.[12] Extrusion cooking also enhances protein digestibility of food through protein denaturation, unfolding of polypeptide bonds and reduction in antinutritional factors.[9]

The available literature on effect of extrusion cooking on starch, the main caloric source in food, is conflicting. Formation of resistant starch during extrusion of barley and corn has been

reported; [12,13] no formation of resistant starch was observed during extrusion cooking of barley and maize- lima bean flour blend, respectively.[14,15] Resistant starch refers to starch and starch degradation products not absorbed in the small intestine by normal individual [16] This information is of nutritional significance because infants have underdeveloped digestive system[17] and are not able to ferment starch in the colon for additional metabolic energy.[18]

Cassava porridge has a distinctive slimy texture, long cohesive consistency and bland taste, [19] which are lacking in commonly used cereal based complementary porridges. Further, extrusion cooking of cassava and soy flour is likely to cause Maillard reaction leading to development of colour and flavour.[9] Although various studies have demonstrated the use of soy and extrusion to improve the protein quality and energy density of cereal complementary porridges, no studies have focussed on cassava complementary porridges in terms of starch digestibility kinetics, available lysine, PDCAAS, and consumer sensory acceptability. Utilization of cassava-soy flour complementary porridges will not only depend on its nutritional quality but also consumer acceptability. Thus, this study aimed to determine the effect of soy flour addition and heat processing methods (conventional and extrusion cooking) on nutritional quality and consumer acceptability of cassava complementary porridges.

MATERIALS AND METHODS

Materials

Raw materials

The complementary porridges used in this study were prepared from cassava alone or composited with either full fat or defatted-toasted soy flour. To ensure that the raw material had similar configuration, soy oil was added to commercially available defatted-toasted soy flour instead of using full fat soy flour. Food grade soy oil and defatted-toasted soy flour were purchased from Nedan Oil Mills Ltd, South Africa. Trypsin inhibitor was 1.5 ± 0.3 trypsin inhibitor units in the defatted soy flour as determined using method 22-40.[20] Common method of preparing cassava flour was followed.[21] The total cyanide and acetone cyanohydrins content as determined according to method described by Bradbury[22] were 5.6 ± 0.2 ppm and 2.7 ± 0.7 ppm respectively, which is below safe levels of 10 ppm.[23]

Formulation of composites

Formulations were based on dry weight as follows: (1) 100% cassava flour (control) (2) 65% cassava flour and 35% defatted toasted soy flour (3) 65% cassava flour, 28% defatted toasted soy flour and 7% soy oil. Commercial ready to eat complementary porridge used as a reference was purchased from a retail supermarket in Pretoria, South Africa.

Methods

Methods of heat processing

Conventional cooking

Complementary porridges (10% solids) were prepared following common practice in Africa[24] with some modification. Water was boiled in a stainless steel cooking pot. Cold water was added to flour to make a smooth slurry and added to the boiling water while stirring. Cooking

continued for 20 min, stirring every 5 min. Hot water was added to compensate for moisture lost during cooking. Freshly cooked porridges were used for analysis of *in vitro* starch digestibility. For the other analysis, the porridges were first freeze-dried. Fresh porridges (10% solids) were used for consumer sensory testing. After preparation, the porridges were kept warm (40-50°C) during the testing session (30 min to 1 h).

Extrusion cooking

Extrusion cooking was done using a Clextral BC 45 co-rotating twin screw extruder (Clextral Firminy, France). Freshly prepared composite formulations were conditioned overnight to a moisture content of 22%. Extruder conditions were: screw speed of 200 rpm, barrel temperature of 120 °C and retention time of 2 min. Extrudates were oven dried for 10 min at 100°C and then milled to a particle size of about 500 μm. Milling was done using a roller mill (Maximill Roller Mill cc, Kroonstad, South Africa) with the upper gap set at 2.1 mm and the lower gap at 0.5 mm. The milled extrudates were used for chemical analysis. To determine *in vitro* starch digestion, milled extrudates and reference were reconstituted using boiling water to a solid content of 10% and analysed immediately. For consumer acceptability study, porridges were reconstituted to 25% solids content. Porridges were kept at room temperature in covered cooking pots during testing session (30 min to 1 hour). Immediately before serving, porridges were re-heated for 3 min in a plastic bowl and then served warm (40- 50°C).

Analysis

Proximate analysis

AACC (2000) methods were used to determine moisture (method 44.15A), fat (method 30-25), ash (method 08-01) and protein content (N×6.25) by Dumas combustion (method 46-30). Total starch was determined using Megazyme International Ireland, total starch assay kit, α-

amylase/amyloglucosidase as described in AACC Method 76-13.[20] Gross energy was determined using a bomb calorimetric method.[24]

Protein quality

Amino acids content of milled extrudates, freeze-dried conventionally cooked porridges and reference commercial complementary porridge (powder) was determined as described by Bidlingmeyer et al.[26] The method described by Hurrell et al.[11] was followed to analyse available lysine. *In vitro* protein digestibility was determined as described by Hamaker et al.[27] The residual protein was determined by the Dumas combustion method. The equation suggested by WHO/FAO/UNU Expert Consultation[5] was used to calculate PDCAAS.

In vitro **kinetics of starch digestion**

In vitro starch digestion of freshly prepared porridges (reference, extruded and conventionally cooked) was determined according to the method proposed by Goni et al.[16] with modifications. The rate of starch digestion was expressed as % of total starch digested at different times (0, 5, 30, 60, 90, 120 and 180 min). A nonlinear model[16] was used to describe the kinetics of starch hydrolysis of the porridges to nutritionally classify the porridges.

X-ray diffraction

Samples were prepared for X-ray diffraction (XRD) analysis using back loading method. The samples were analysed with a PANalytical X'Pert Pro Powder Diffractometer (Ostfildern, Germany), with an X'Celerator detector. The diffractometer was equipped with variable divergence and receiving slits using Fe filtered Co-Kα radiation (1.78901 Å) and operated at 35

kV and 50 mA. Samples were scanned at 25 °C with 2θ in the range 2-90°. Diffractograms were interpreted using X'PertHigh score Plus software.

To calculate total % crystallinity, X-ray diffractograms were normalized using Origin-pro 7.5, (Originlab Corporation, Northampton, USA) software. Total % crystallinity was the difference between the area under the sample diffractogram and the area under the amorphous starch diffractogram divided by the area under the sample diffractogram multiplied by 100.[28]

Thermal properties

Thermal analyses were done using a differential scanning calorimeter (DSC) (HP DSC 827e, Mettler Toledo, Schwerzenbach, Switzerland). Sample (5 mg) was weighed into an aluminium sample pan (40μl) and 15μl of water was added. Samples were equilibrated overnight at room temperature. The measurements were done using a heating rate of 10 °C/min between 40°C and 125°C. The instrument was calibrated using indium; and an empty aluminium DSC pan was used as a reference.

colour determination

The colour of freshly prepared porridges was assessed using a Chroma Meter CR 400 (Konica, Minolta Sensing. Oska, Japan). The CIE-LAB system for colour values L* a* and b* were recorded. The L* value gives a measure of lightness of the product from 100 for perfect white and zero for black. The a* value accounted for redness (+) and greenness (-) while b*values accounted for yellowness (+) and blueness (-), respectively. A white tile (L= 96.76, a= 0.12 and b=1.80) was used to calibrate the colour meter before use. Hue angle was calculated as Tan[-1] (b*/a*).

Consumer sensory evaluation

Females (n = 122) aged >20 years with children aged below 2 years participated in the study. They were recruited from six peri-urban health centres in Nampula and Zambezia provinces, Mozambique. Ethical approval was obtained from the University of Pretoria, Ethics Committee and the provincial Directorate of Health, Nampula, Mozambique. The evaluation was done in meeting halls in Nampula and Zambezia. Porridge (± 50 g) was served at 40-50°C in 125 ml plastic cups. Plastic spoons were used to evaluate the porridges. Samples were blind-coded with three-digit random numbers. Order of serving was randomized per session; consumers (n=±25) within a session evaluated all six porridges. Consumers expressed their liking of colour, consistency, smell, taste and overall acceptability using a 5-point hedonic scale: 1=dislike to 5=like very much. Water was provided at room temperature to clean the mouth between samples.

Data analysis

Analysis of variance (ANOVA) was used to determine the effect of soy flour addition and heat processing methods on nutritional attributes, colour (L, a, b values) and parameters of kinetics of *in vitro* starch digestion using Statistica Version 9.0 (Statsoft, Tulsa, OK, USA). Cooking methods and type of composite were considered as independent variables and measured or calculated parameters as dependent variables. Experiments were repeated three times. Means of consumer ratings were analysed using one-way ANOVA. The means were separated using Fischer's Least Significant Difference (LSD) test.

RESULTS

Nutrient composition and protein quality

The nutrient composition of cassava-soy porridges is shown in Table 1. As dry weight basis, the energy content of all porridges ranged between 1404KJ g /100g in conventionally cooked cassava porridge and 1682 KJ g /100g in conventionally cooked porridge with full fat soy flour. Addition of full fat soy flour led to 20 and 26 fold increase in extractable fat content for extrusion and conventionally cooked porridges, respectively compared to cassava porridge.

Available lysine was lower than lysine content by 22% and 11% in extruded and conventionally cooked porridges containing defatted soy flour, respectively (Table 1). In porridges containing full fat soy flour; the decrease in available lysine compared to lysine content was 25% and 9% in extruded and conventional cooked porridges, respectively. The IVPD of extruded porridge with defatted soy flour and with full fat soy flour was 9% and 12% higher than in corresponding conventionally cooked porridges. The PDCAAS increased two fold in conventionally cooked composite porridges compared to cassava porridge. The PDCAAS in extruded porridges increased by 35% and 67% for porridges containing defatted soy flour and full fat soy flour, respectively compared to extruded porridge containing cassava only.

Kinetics of starch digestion

Cooking method and compositing significantly ($p < 0.05$) influenced starch digestion of porridges (Figure1). Preliminary analysis indicated a rapid digestion rate in all the porridges. This prompted sampling after 5 min of digestion. The starch digestion after 5 min was 77.6, 67.7 and 50.2% in extruded cassava porridges, porridge with defatted soy flour and with full fat soy flour, respectively. The corresponding values for conventionally cooked porridges were 66.0, 64.2 and

57.1% respectively. The hydrolysis time to reach the maximum starch digestion was within 60 min in all the porridges.

The total starch digested (TSD) was significantly ($p < 0.05$) reduced by addition of either defatted soy flour or full fat soy flour (Table 2). Extruded porridge with full fat soy flour showed the lowest TSD (62%). Extruded porridges containing full fat soy flour showed the lowest kinetic constant (k) value (0.061) indicating the highest resistance to digestion by α- amylase. Extruded cassava porridge showed the highest k -value (0.092). The k-value can be related to glycemic index (GI) [16]. The GI value ranged between 90 in extruded porridge with full fat soy flour and 119 in conventionally cooked porridge with defatted soy flour.

X-ray diffractogram and thermal properties

The X-Ray diffractograms of raw formulations had peaks at 2θ = 20.4, 22.6, 23.9 and 29.9° (Figure 2). These peaks are a mixture of A and B polymorph starches.[29] Conventionally cooked porridge seemed mainly amorphous; with no clear peaks. Extruded cassava porridge and porridge with defatted soy flour had peaks at 2θ = 15.1 and 23.2°. Extruded porridge with full fat soy flour had peaks at 2θ = 7.9, 13.0, 15.3, 20.4 and 23.3°. Peaks at 2θ = 7.9 and 13° have been associated with presence of amylose-lipid complexes.[30; 31.] The total crystallinity of uncooked formulations was 30%. For extruded cassava porridge, porridge with defatted soy flour and porridge with full fat soy flour, the total crystallinity was 16, 17 and 19%, respectively. Total crystallinity of conventionally cooked porridges was not determined because they were mainly amorphous.

Figure 3 shows the DSC thermograms of milled extrudates and freeze-dried conventionally cooked porridges heated from 40°C to 125 °C. A transition endotherm occurred in extruded porridge with full fat soy flour only. The onset temperature and end set temperature were 106.5

°C and 108.5 °C respectively. This endotherm peak has been associated with melting of crystalline amylose-lipid complex.[32]

Colour (L, a, b values)

Extrusion cooked porridges had higher L, + a* and + b* values compared to the corresponding conventionally cooked porridges (Table 4). Extrusion cooked porridges with full fat soy flour were more red and yellow (higher +a* and +b* values, respectively) than the other extrusion cooked porridges. Porridges with full fat soy flour (both extrusion cooked and conventionally cooked) were significantly lighter ($p < 0.05$) as indicated by higher L* values, compared to the corresponding cassava porridges and porridges with defatted soy flour. Extrusion cooked cassava porridge had significantly lower hue angle compared to extrusion cooked porridge with defatted soy flour and with full fat soy flour.

Porridge acceptability by mothers

The mean consumer sensory acceptability scores were three and above on a 5-point hedonic scale for all sensory attributes. Figure 4 (a-e). Conventionally cooked composite porridges were liked significantly more ($p < 0.05$) than cassava porridges. The average ratings for conventionally cooked porridge with defatted soy flour and with full fat soy flour were not significantly different for all attributes.

Consumers rated extruded cassava porridge higher than the composite porridges for all sensory attributes. Extruded porridge with full fat soy flour was, on the contrary, rated significantly lower ($p < 0.05$) for all sensory attributes except overall acceptability. The overall liking of extruded porridge with defatted soy flour had the highest variability as indicated by wide distribution of scores.

DISCUSSION

The decrease in available lysine compared to lysine content was higher (~10%) in extrusion cooked composite porridges compared to the corresponding conventionally cooked porridges. Reduction in available lysine (0-32 %) in sweet potato-soy flour extrudates has been reported.[10] The decrease could be due to occurrence of Maillard reaction between ε-amino group of lysine and carbonyl group of reducing sugar.[33] Low moisture content during extrusion may have favoured occurrence of higher Maillard reaction than in conventional cooking.[9] The PDCAAS of cassava composite porridges (extruded and conventionally cooked) were >70%; the recommended minimum level for complementary foods.[34] The fat content of extruded and conventionally cooked porridges was lower than in the uncooked formulations. Formation of amylose-lipid complexes as indicated by Figure 2 and 3 could have contributed to the reduced fat recovery.

Starch digestion follows first order kinetics[16] whereby catalytic rate increase with additional substrate until a maximum value is reached. The rate of starch digestion reached a plateau in all porridges within 60 min (Figure 1). Addition of defatted soy flour reduced the TSD in extruded and conventionally cooked porridges compared to the corresponding cassava porridges. Reduction in *in vitro* starch digestibility has been reported in extruded durum semolina and gluten blends.[35] Increased physical barrier by protein that reduced accessibility of starch by α-amylase has been suggested. All porridges had high GI.[36] This can be attributed to high rate of starch digestibility due to disruption of starch granule during extrusion and conventional cooking. Further, cassava has low amylose/amylopectin ratio[20], which is associated with high digestibility and consequently high GI. These GI ranges are consistent with the literature for complementary foods.[36]

The TSD was lowest in extruded porridge containing full fat soy flour. Formation of amylose–lipid complexes as shown to have occurred during extrusion of porridge with full fat soy flour (Figure 2 and 3) may contribute to the relatively low digestibility. A V-polymorph pattern of amylose-lipid complexes in extruded wheat- almond flour has been reported.[37] Amylose-lipid complexes tend to reduce access of α-amylase to amylose for digestion.[38] The limited access could be due to the compact nature of the V- crystalline pattern of amylose–lipid complexes[39] Extruded porridge with full fat soy flour had relatively higher total crystallinity (19%), which may further explain the low TSD. A positive correlation between total crystallinity of starch and *in vitro* starch digestion has also been observed. [40]

The extruded porridge containing full fat soy flour had a lower total digestible starch compared to conventionally cooked porridge containing full fat soy flour. This can also be related to absence of amylose-lipid complexes in the conventionally cooked porridges as determined by DSC and X-ray. It is possible that the high energy input (high temperature and high shear) during extrusion compared to conventional cooking may be responsible for this difference. In extrusion, the high temperature and high shear may allow more interaction between amylose and available lipids to produce amylose-lipid complexes. In conventional cooking (less than 20 minutes), starch granules have not been severely solubilised compared to extrusion cooking for interaction of starch and lipid to produce amylose lipid complexes. A second pasting peak associated with amylose-lipid complexes was only observed after 34 min pasting of maize starch using the RVA[41], suggesting limited complexation occurs between amylose and lipids occurred before h;af an hour of pasting.

The mean TSD in extruded porridges was lower than the corresponding conventionally cooked porridges (Figure 1). This could in part be due to presence of more crystalline structure in

extruded porridges compared to the conventionally cooked porridges (Figure 2). All extruded porridges had peaks characteristic of A-type polymorph.[28] Similar findings were reported during extrusion of maize starch.[31] Recrystallization of starch at low water and/or high temperature as is the case during extrusion forms type A-polymorph.[31, 42] The A-type polymorph has close-packed arrangement of double helices, and is relatively resistant to digestive enzyme.[28]

Table 3 shows a simulation of the amount of energy, protein and lysine (calculated based on available lysine) that can be provided by cassava-soy porridges to a child aged 6-8 months, receiving low or average quantity of nutrients from breast milk. Low or average intake of nutrients from breast milk is common in Africa.[2] To calculate the nutritional adequacy of cassava-soy flour porridges, extruded porridges were assumed to contain 25% solid and the conventionally cooked porridges to contain 10%. Preliminary analysis with a rotational viscometer also suggest that extrusion cooked porridges at 25% solid had a viscous flow similar to 10 % solid for conventionally cooked porridges and commercial reference (at 25% according to manufacturer's guidelines). More studies on the viscosity and visco-elastic properties are currently being carried out. These solid contents were therefore also used to prepare porridges for consumer sensory evaluation.

The energy content of extruded porridges (25% solids), was between 0.9 kcal/g in cassava porridge and 1kcal/g in porridge with full fat soy flour, which is within the recommendation of complementary foods of ≥ 0.8 kcal/g.[2] If fed thrice per day, all extruded porridges can meet the energy needs of children receiving average and low energy from breast milk. At this feeding frequency, conventionally cooked porridges can supply less than 50% of the energy required by a child receiving either low or average energy from breast milk. Furthermore, the low energy content (0.3-0.4 kcal/g) of conventionally cooked cassava-soy porridges would require large

amounts of porridge to be consumed in order to meet energy needs. This is not possible due to low gastric capacity of children (30 g / kg body weight).[2]

In as would be eaten basis, extruded and conventionally cooked composite porridges can exceed by 0.85 to 7 times the protein requirements of 6-8 month old children receiving low or average quantity of protein from breast milk. Further, extruded porridge with defatted soy flour and with full fat soy flour would meet the lysine requirements (based on available lysine) of 6-8 months old children receiving average or low quantities of lysine from breast milk.

The colour lightness (L* values) ranged from 48-58 in the six porridges. These values were within the ranges reported for sorghum porridges; which is one of the commonly eaten porridge in Africa[43] Presence of brown colour due to Maillard browning during soy flour manufacture could have contributed to the higher (+) a*, (+) b* and hue angle values in composite porridges during convention and extrusion cooking. . The higher (+) *a and + *b values in extrusion cooked porridges as compared to the corresponding conventionally cooked porridges could be due to additional Maillard browning during extrusion of the cassava-soy composite flours. Millard browning is a chemical reaction involving free amino groups of protein and carbonyl groups of reducing sugars [44]. The reaction is dependent on presence of amino acids and sugars, processing conditions (time, temperature and moisture).[15] Maillard reaction is favoured at a high temperature and higher shear conditions (>100rev/min) [45.] Extrusion cooking was done within similar conditions, as the temperature was 120°C and the shear rate was 200 rpm.

In terms of consumer liking of the cassava-soy flour porridges, all sensory attributes of conventionally cooked composite porridges were more liked than cassava porridge. Soy flour contains limited starch; physical reduction of starch available in the continuous phase of porridge may have reduced the resulting viscosity. Limited reassociation of amylose, which accounts for

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retrogradation and increased viscosity in the short term during cooling of starch paste[19], may have also reduced viscosity. Tuber starches are devoid of lipids and therefore have a bland taste.[19] Addition of soy flour could have introduced flavours associated with caramelization and Maillard reaction because it was toasted during manufacturing.

It was expected that extruded composite porridges would be more liked than extruded cassava porridge due to increased flavour and aroma volatile compounds formed during extrusion. Dimethyl disulphide and dimethyl trisulphide volatiles were categorised in extruded vegetable protein and wheat starch.[46] Further, extrusion of starch in the presence of linoleic fatty acid has been shown to form benzaldehyde and hezanal volatile compounds.[46] Probably the relatively lower liking could be because the volatile compounds formed during extrusion were not familiar to the consumers. There were large variations in liking of extruded composite porridges, indicating that some consumers liked the porridges while others disliked them. Sensory profiling of these porridges is under study to further inform on the drivers of consumer liking and dislike.

CONCLUSION

Extruded cassava-soy flour complementary porridges are energy dense and high in protein quality, with acceptable sensory properties. They therefore have good potential for use in reducing PEM in sub-Saharan Africa, where cassava is a staple food. Extrusion cooking and compositing cassava and soy flour, either defatted or full fat greatly improves the protein quality of cassava complementary porridges in terms of protein content, available lysine and PDCAAS. At 35% soy flour inclusion, extruded porridges if fed thrice per day meet the protein, lysine (available) and energy requirements of a child aged 6-8 months receiving low or average quantities of protein from breast milk. Cassava-soy flour porridges contain rapidly digested starch, which is desirable in young children whose digestive system is underdeveloped.

ACKNOWLEDGEMENTS

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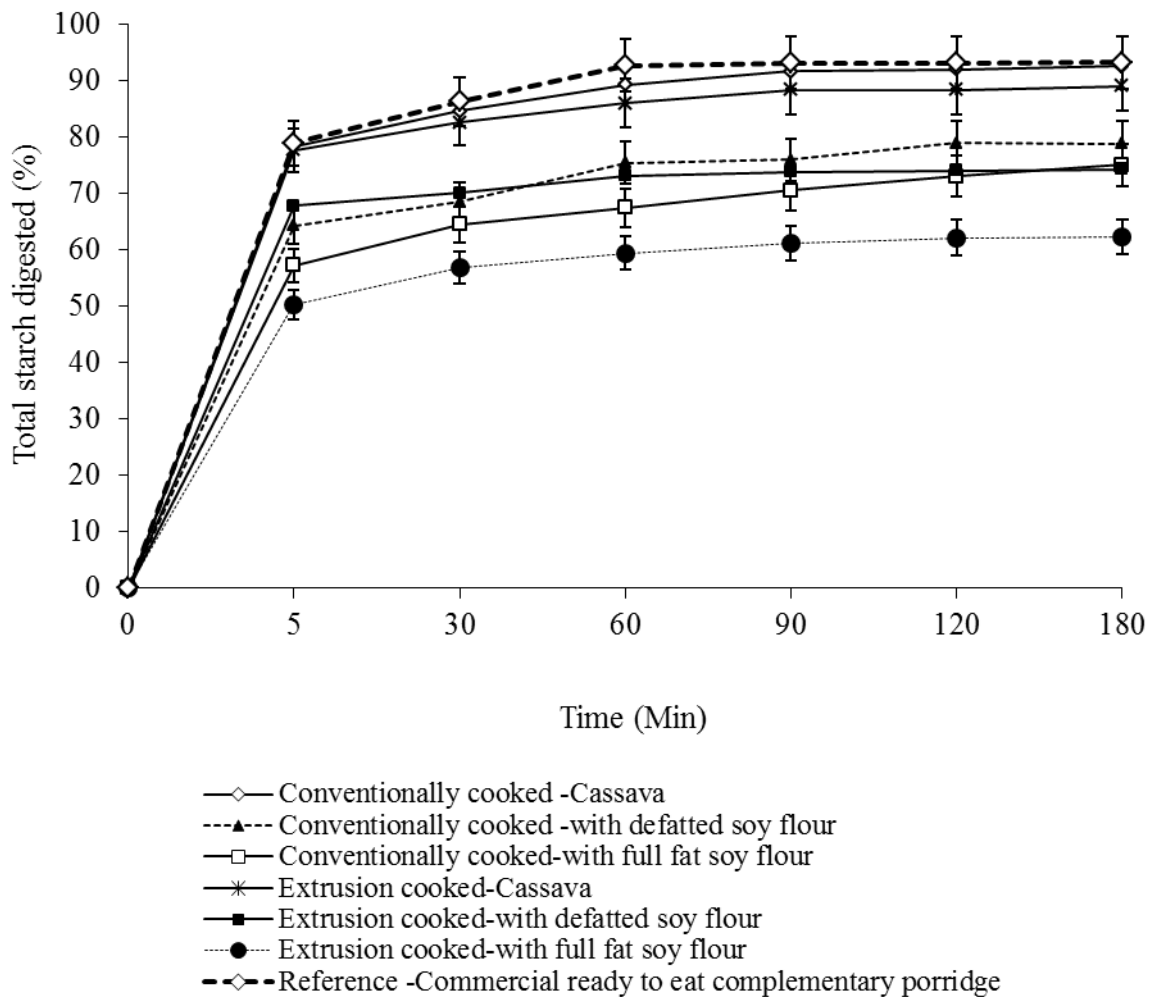
Figure 1: Effect of soy flour addition and heat processing methods on kinetics of starch digestion of cassava complementary porridges. Bars are standard deviation of 3 independent experiments.
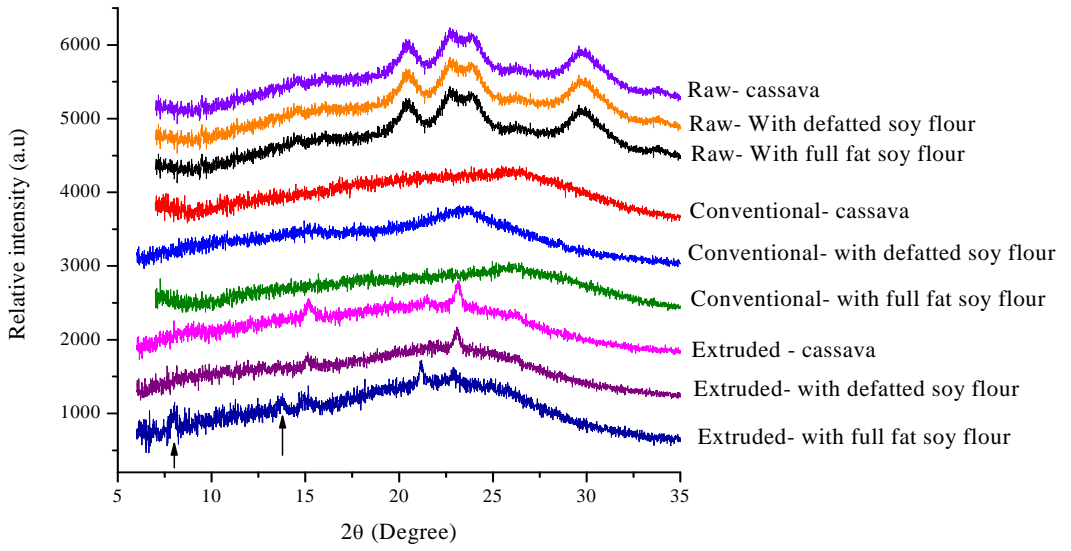
Figure 2: Effect of soy flour addition and heat processing methods on X-ray diffraction pattern of cassava complementary porridges.
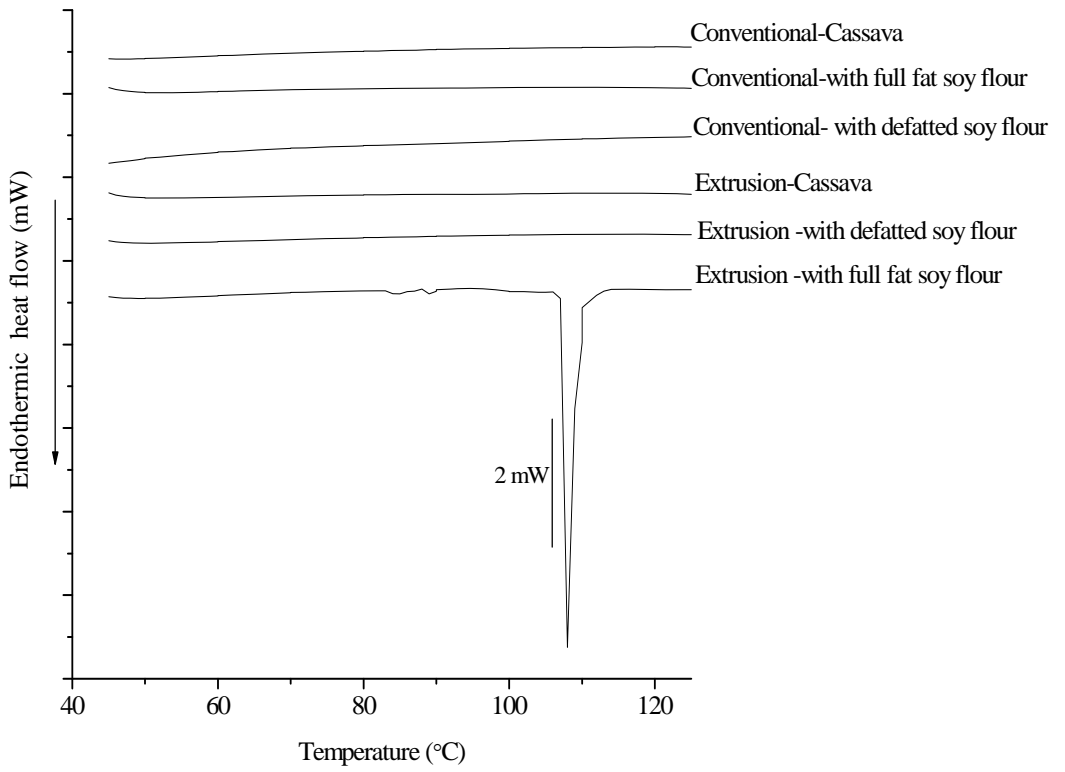Arrows show peaks related to amylose-lipid complexes [30, 31]

Figure 3: Effect of soy flour addition and heat processing methods on DSC thermogram of cassava complementary porridges

Table 1: Effect of soy flour addition and heat processing methods on total starch, fat, energy content and protein quality (protein content, lysine and available lysine content, lysine score, *in vitro* protein digestibility (IVPD), and Protein Digestibility Corrected Amino Acid Score (PDCAAS), of cassava complementary porridges (dry weight basis)

	Type of Porridge	Total Starch g kg^{-1}	Fat g kg^{-1}	Energy (j) g kg^{-1}	Protein (N×6.25) g kg^{-1}	[φ]Lysine (g kg^{-1} protein)	Available lysine (g kg^{-1} protein)	% IVPD	Lysine score	[*]PDCAAS
Conventional cooking	Cassava	870.0e ± 10.7	2.0a ± 0.5	14.0a ± 0.14	25.7a ± 0.7	28a ± 0.1	nd	59.9a ± 8.3	0.53	0.31
	With defatted soy flour	591.9c ± 23.6	2.2a ± 0.6	15.4c ± 0.0	164.0d ± 2.3	54c ± 2.0	48b ± 0.3	83.8b ± 5.4	0.99	0.76
	With full fat soy flour	551.3b ± 8.4	52.3d ± 1.8	16.8d ± 0.2	137.3b ± 2.7	53c ± 2.0	48b ± 2.0	78.5b ± 7.1	1.00	0.80
Extrusion cooking	Cassava	877.6e ± 5.0	1.9a ± 0.7	14.5b ± 0.2	22.3a ± 0.7	33b ± 0.2	nd	86.5b ± 1.4	0.64	0.56
	With defatted soy flour	609.0c ± 14.2	2.1a ± 0.2	15.3c ± 0.9	160.2d ± 5.9	54c ± 5.0	42a ± 5.0	92.8c ± 4.3	0.83	0.83
	With full fat soy flour	563.2b ± 13.7	39.6b ± 0.5	16.6d ± 0. 2	130.1b ± 7.3	53c ± 4.0	40a ± 2.0	90.7c ± 2.5	1.00	0.94
	Reference	376.8a ± 30.4	45.7c ± 1.8	17.0b ± 0.1	149.8c ± 5.0	68d ± 3.0	64c ± 0.2	93.3c ± 2.2	1.20	1.00

Values are means ±standard deviation of 3 independent experiments. Values within the same column followed by different letters are significantly different (p ≤ 0.05)
Cassava - 100% cassava flour
With defatted soy flour - 65% cassava flour and 35% defatted soy flour
With full fat soy flour - 65% cassava flour, 28% defatted soy flour and 7% soy oil
Reference - Commercial ready to eat complementary porridge
nd- Not determined because amino acids Histidine and Arginine were not detected[11]
[φ]Lysine score = mg lysine in 1 g protein of test sample /52 mg lysine requirement for a 1-2 year old child[7]
[*]PDCAAS = Lysine score × IVPD/10

Table 2: Effect of soy flour addition and heat processing methods on kinetic parameters of *in vitro* starch digestion of cassava complementary porridges

	Type of porridge	C∞ (%)	k (Min^{-1})	HI (%)	GI
	Cassava	92.5d ± 2.0	0.091ab ± 0.00	128.4c ± 2.3	110.4de ± 0.5
Conventional cooking	With defatted soy flour	78.8bc ± 0.9	0.069ab ± 0.00	114.0b ± 0.9	102.7bcd ± 1.6
	With full fat soy flour	75.0b ± 0.9	0.061a ± 0.00	106.0b ± 1.1	103.3bc ± 2.1
	Cassava	89.3d ± 2.8	0.092b ± 0.01	144.9d ± 0.7	119.2e±0.5
Extrusion cooking	With defatted soy flour	73.6b ± 1.4	0.085ab ± 0.01	115.6b ± 0.9	104.1cd ± 0.5
	With full fat soy flour	62.3a ± 2.5	0.072ab ± 0.00	98.8a ± 1.1	90.1a ± 0.5
	Reference	93.1d ± 3.0	0.065ab ± 0.01	142.8d ± 1.0	118.3e ± 0.5
	White bread	62.9a ± 2.5	0.069ab ± 0.01	97.7a ± 0.3	94.6ab ± 1.9

Values are means ± standard deviation of 3 independent experiments. Values within the same column followed by different letters are significantly different (p≤0.05).
Cassava-100% cassava flour
With defatted soy flour -65% cassava flour and 35% defatted soy flour
With full fat soy flour - 65% cassava flour, 28% defatted soy flour and 7% soy oil
Reference- Commercial ready to eat complementary porridge
C∞ = % starch digested after 180 minutes
HI, k and GI were calculated from the equation proposed by Goni et al.[16]
White bread was used as the reference for calculating GI

Table 3: Tabulation of contribution of cassava-soy flour complementary porridges to energy, protein and lysine requirements of a well-nourished 6-8 months old child if fed thrice per day *(249 g per feeding)

Recommended requirement	[9]Level &quantity of nutrient intake from breast milk		[9]Required nutrient from complementary food	[§]Conventionally cooked (10% solid)			[§]Extrusion cooked (25% solid)			Reference (25% solid)
				Cassava	With defatted soy	With full fat soy	Cassava	With defatted soy	With full fat soy	
[9]Energy 769 (kcal/ day)	Low	217	552	269.2	289.5	317.9	689.2	722.9	784.7	807.5
	Average	413	356	269.2	289.5	317.9	689.2	722.9	784.7	807.5
[9]Protein 9.6 (g/ day)	Low	2.3	7.3	1.7	12.2	10.2	5.0	30.0	24.3	27.8
	Average	4.5	5.1	1.7	12.2	10.2	5.0	30.0	24.3	27.8
*Lysine 355 (mg/ day)	Low	176	179	[φ]nd	58.5	48.8	nd	125.4	97.0	178.0
	Average	335	20	nd	58.5	48.8	nd	125.4	97.0	178.0

Cassava - 100% cassava flour

With defatted soy flour - 65% Cassava flour and 35% defatted soy flour

With full fat soy flour - 65% Cassava flour, 28% defatted soy flour and 7% soy oil

Reference-Commercial ready to eat complementary porridge

[φ] nd- Not determined because available lysine was not determined (Table 2)

[9] Calculations of energy and protein are based on requirements of 6-8 months-old children ; receiving maximum recommended feeding frequency (3 times per day)[2]

* Calculations were done using available lysine content of study porridges (Table 2) based on amino acid requirement of a child aged < 2 years.[6]Median weight of 6 months-old boy child (7.9 kg) was used to calculate lysine requirements (WHO child growth standards)

[§]Calculations were based on conventionally cooked porridges containing 10% solids and extruded porridges containing 25% to mimic traditional African complementary porridges and commercial ready to eat complementary porridge, respectively

Table 4: Effect of compositing on colour and consumer sensory ratings of cassava-soy flour porridges

Type of porridge		Colour (L, a b values)					Consumer ratings			
		L*	a*	b*	Hue angle	Visual Colour	Consistency	Smell	Taste	Aftertaste
Conventi-onally cooked	Cassava	48.8a ± 1.2	-0.1a ± 0.3	0.2a ± 0.5	63.4a ± 0.6	3.3a ± 1.0	3.2a ± 0.9	3.3a ± 1.0	63.4a ± 0.6	3.3a ± 1.0
	With defatted soy	48.9a ± 0.1	0.7b ± 0.0	2.0b ± 0.0	70.7a ± 2.6	4.3b ± 0.9	4.4b ± 0.8	4.0b ± 1.0	70.7a ± 2.6	4.1b ± 1.1
	With full fat soy	53.1b ± 0.3	0.5b ± 0.1	3.7c ± 0.3	82.3 b± 2.8	4.4b ± 1.0	4.4b ± 0.8	4.2b ± 1.0	82.3 b± 2.8	4.1 b ± 1.1
Extrusion cooked	Cassava	56.6b ± 0.4	-1.4a ± 0.0	2.6a ± 0.2	61.6a ± 2.8	4.0b ± 1.4	3.9b ± 1.4	3.6b ± 1.4	61.6a ± 2.8	3.8b ± 1.5
	With defatted soy	52.1a ± 0.2	0.9b ± 0.3	5.0b ± 0.5	79.8b ± 2.6	4.2b ±1.2	3.7b ± 1.5	3.9a ± 1.4	79.8b ± 2.6	3.1b ± 1.6
	With full fat soy	58.3c ± 0.1	1.9c ± 0.1	8.8c ± 0.1	77.8b ± 1.9	3.3a ±1.1	3.0a ± 1.1	3.2a ±1.2	77.8 b± 1.9	3.4b ± 1.2

Values are means of three independent analyses ± standard deviation. Values in the same column and similar cooking method followed by the same letter are not significantly different ($p < 0.05$)

Cassava -100% cassava flour

With defatted soy flour -65% cassava flour and 35% defatted soy flour

With full fat soy flour-65% Cassava flour, 28% defatted soy flour and 7% soy oil

[1]L^*, Lightness (0- Black, 100 - white); $+a*$, red, $-a^*$ green; $+b^*$ yellow; $-b^*$, blue, Hue angle = Tan^{-1} (b*/a*)

Consumer sensory ratings were 1-5 point hedonic scales where 1=dislike very much, 3=neither like nor dislike and 5= like very much