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Acidification and Starch Behaviour during Co-Fermentation of Cassava and Soybean into Gari.

Acidification and starch behaviour during co-fermentation of cassava (*Manihot esculenta* Crantz) and soybean (*Glycine max* Merr) into *gari*, an African fermented food

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Abstract

Changes in acidification and starch behaviour were investigated during co-fermentation of cassava and soybean into *gari*, an African fermented product. Non-volatile acidity, pH and starch content were evaluated using standard analytical methods. Starch breakdown and pasting characteristics were also analysed using a Brabender viscoamylograph. Fermentation caused significant variations in the pH, non-volatile acidity and starch concentration. The pH decreased with concomitant increases in non-volatile acidity during co-fermentation of the cassava dough. Soy fortification up to 20% caused only minimal effects on the pH, titratable acidity and starch content during the fermentation period. Starch content decreased from 69.8% to 60.4% within the 48 h fermentation time in the unfortified sample, with similar trends noted at all levels of fortification. Starch pasting characteristics showed varied trends in pasting temperature, peak viscosity, viscosity at 95°C and at 50°C-hold with increasing fermentation time and soybean concentration. Cassava could be co-fermented with soybean up to 20% concentration during *gari* processing without significant effect on its process and product quality characteristics.

Keywords: *Souring, acidification, fermentation, starch, rheology, cassava, soybean, Fortification, gari*

Introduction

Cassava (*Manihot esculenta* Crantz) is an important vegetable crop that is grown throughout the tropics and sub-tropics, where it contributes a considerable proportion of the total caloric intake and ranks fourth after rice, wheat and corn on a food energy production basis as source of complex carbohydrates (Moorthy and Mathew 1998; Beleia et al. 2006). It is a staple food for more than one-half of the West African population (Anonymous 1992; Steinkraus 1983; Oduro et al. 2000), and can be processed into various products that are useful as human and animal foods, including *gari* (farina), *akyeke*, *agbelima*, *fufu*, *lafun* and many other West African traditional dishes (Beeching et al. 1994; Oboh and Akindahunsi 2003; Obilie et al. 2004).

Gari (fried, fermented cassava flour) is the most popular cassava product consumed in West Africa and the most important food product in the diet of millions of Ghanaians and Nigerians (Kordylas 1990; Oduro et al. 2000; Edem et al. 2001). It forms a significant part of the diet in many other countries such as Cameroon, Sierra Leone, Zaire and Brazil, where it is called *Farinhade moniaca* (Lancaster et al. 1992). Although cassava is high in linamarin (Steinkraus 1983; Vasconcelos et al. 1990), about 83% of the total cyanogenic glucosides (linamarin and lotaustralin) are detoxified during processing of the tuber into *gari* and 98% of the cyanide is lost when *gari* is cooked into *eba* (Mahungwu et al. 1987). However, cassava and its products are low in protein and deficient in essential amino acids, and therefore have poor protein quality, with a protein content of between 3.6 and 4.4% dry weight (Oboh and Akindahunsi 2003). Thus, continuous dependence on *gari* without supplementation with meat, fish and/or other protein-rich sources would result in protein deficiency. However, because of the high cost of animal proteins, the majority of the population cannot afford such fortification for *gari*, hence the need to search for cheaper but good quality protein sources that are readily available for the fortification of *gari*. Soybean, a protein-rich legume with a good essential amino acid profile, is potentially the most useful protein source for complementing and enhancing the nutritional value of *gari*.

Soybean (*Glycine max* Merr), an inexpensive high-quality protein source, is readily available in many countries where starchy tubers are consumed in large quantities. In comparison with most other legumes, soybeans are much higher in protein (38.9–41.8%; Nagata et al. 1998; Kumar et al. 2006; Redondo-Cuenca et al. 2006). Soybean oil is 61% polyunsaturated and 23.4% monounsaturated (Gunstone et al. 1986). Interest in soybean and soy-based products has grown significantly in the past decade due to their reported nutritional and health-promoting benefits (Dadson and Noureldin 2001; Rostagno et al. 2005). Soybean contains high concentrations of components with health benefits, such as proteins, isoflavones, dietary fibre, protease inhibitors and phytic acid (Wang and Wixon 1999; Ren et al. 2006). Soy protein is reported to lower cholesterol levels in the blood (Nagata et al. 1998; Henkel 2000), and its amino acid content is considered key in its ability to control blood pressure, and this appears to be related to calcium conservation (Dadson and Noureldin 2001). Soy isoflavones have been reported to play essential roles in preventing certain types of cancers and in reducing the risk of cardiovascular diseases (Lee et al. 2003; Jenkins et al. 2003; Rostagno et al. 2005). Supplementation of soy proteins to *gari* is therefore expected to enhance its protein quantity and quality as well as improve its health promoting benefits. However, acceptability of *gari* depends on the final texture and sensory attributes after processing, and these vary based on the extent of souring/acidification during fermentation and the starch behaviour during heat processing.

Starch consists of two polydispersed α-D-glucan components, amylase (AM) and amylopectin (AP). The AM is linear (α-D-[1$\rightarrow$4]) or slightly branched and dispersible in water, forming gels at concentrations higher than 1.5% (Miles et al. 1985). The AP is highly branched because of its additional bonds (α-D-[1$\rightarrow$6]) and does not form gels (Klucinec and Thompson 1999; Iturriaga et al. 2006). When starches are subjected to high temperatures (typically greater than 50°C in the presence of water), the granules irreversibly swell, AM-selective leaching occurs, starch loses its birefringence and crystallinity disappears. As a result, the swollen granules (deformable particles) get embedded in a continuous matrix of cross-linked AM molecules (Tester and Morrison 1990; Lii et al. 1995). The polymeric complex presents viscoelastic behaviour and

forms a gel or paste during the dispersion cooling when the non-waxy starch concentration is $\geq 6\%$ (Ring 1985). The formation of a gel or paste, which is a determinant of food texture, depends not only on the starch concentration but also on the structure of the swollen starch granules, the amount of AM and AP leached from the granules, the heating conditions such as temperature, time, heating velocity and shear stress (Morris 1990; Ong and Blanchard 1995), and other processing techniques such as fermentation (Oboh and Akindahunsi 2003).

The process of fermentation has been reported to be applied to cereals (Sefa-Dedeh et al. 2004; Afoakwa and Aidoo 2006) and cassava-based products (Amoa-Awua 1982; O'Hair 1995; Obilie et al. 2004) to generate acids to effect souring or acid production to improve flavour development, cyanide elimination, colour and texture of foods derived from them. However, the extent to which co-fermentation of soybean and cassava during fortification of *gari* would affect souring or acid production and the starch gelatinization process remains unknown.

The objective of the present study was therefore to investigate changes associated with souring or acid production and starch pasting characteristics during co-fermentation of cassava and soybean into *gari* 'farina'.

Materials and methods

Materials

Samples of cassava (*M. esculenta* Crantz) and soybeans (*G. max* Merr) were obtained from the Crop Research Institute in Tafo in the Eastern Region of Ghana and used for the study. The chemicals used were of analytical grade, and glass-distilled water was used.

Preparation of soy flour. The soybeans were cleaned by removing stones, sticks and damaged beans and were washed using plain tap water. The soy beans were dehulled by soaking in plain tap water (1:10 w/v seed to water ratio) at room temperature (28°C) for 5 h, followed by hand-rubbing (within two palms) to remove the testa. The floating testae on the soak water were removed by decanting until no testae were present. The soak water was decanted, before boiling. The dehulled seeds were boiled for 30 min with plain tap water (three times the weight of dry seeds) to inactivate the trypsin inhibitor. The boiled samples were then dried in a hot air-circulating oven (Stuart Scientific, HT Oven Size, Haslemere, Surrey, England) at 60°C to constant weight. They were then ground in a mill (National Supergrinder, Model MK 830N, Tokyo, Japan) into soy flour.

Preparation of gari. Fresh cassava (*M. esculenta* Crantz) tubers were washed using plain tap water and peeled using a kitchen knife. The peeled tubers were washed using plain tap water and grated in a cassava grater (Slawd Peters Engineering 436K; Kumasi, Ghana). The grated cassava was fermented for 48 h and the liquor squeezed using a hydraulic press (Blitz, Model HPL 652, Stuttgart, Germany). It was then sieved to remove fibre waste and fried into *gari* in a hot metal dish with continuous stirring for 20 min. The *gari* formed was cooled and packaged in air-tight plastic containers. The soy-fortified *gari* was prepared by adding soy flour to the grated cassava at 10%, 20% and 30% soy levels, and was fermented for 48 h and fried in a hot metal dish to produce the soy-*gari*. Samples were taken after 0 h, 24 h and 48 h of fermentation for analysis.

Experimental design. A 3 × 4 factorial experimental design was used. The principal factors investigated were: fermentation time (0 h, 24 h, and 48 h), and soybean concentration (0%, 10%, 20%, and 30%).

The samples were packaged in polypropylene bags and stored under tropical ambient conditions (26–31°C, relative humidity 85–100%) for analysis. All the samples were analysed in triplicate for non-volatile (titratable) acidity, pH, total starch content and starch pasting characteristics.

Analytical methods

Non-volatile (titratable) acidity. Ten grams of the oven-dried fermented cassava flour were weighed into a clean beaker and mixed with 100 ml distilled water. The mixture filtered using a Whatman No. 4 filter paper. Ten millilitres of the filtrate were titrated against 0.1 M NaOH using 1% phenolphthalein as indicator. Acidity was calculated as grams of lactic acid per 100 g sample.

pH profile. Ten grams of the oven-dried fermented cassava mash were mixed with 100 ml distilled water. The mixture was allowed to stand for 15 min, shaken at 5-min intervals and filtered using Whatman No. 4 filter paper. The pH of the filtrate was then measured using a pH meter (Taklon, Model HM 305, Tokyo, Japan).

Total starch content. The starch content of the fermented cassava flours was determined using the acid hydrolysis method described by the Association of Official Analytical Chemists' approved method 14.023 (AOAC 1990).

Pasting characteristics. The viscosities of the samples were determined using the American Association of Cereals Chemists Method 22-10 (AACC 1983) with slight modifications. Six per cent of starch slurry was prepared with 500 ml distilled water and used for the determination of the pasting characteristics. The pasting characteristics of the slurries were then measured using the Brabender viscoamylograph (Brabender, Duisburg, Germany), equipped with a 500 cmg sensitivity cartridge. The viscosity of the samples were continuously monitored as they were heated from 25°C at a rate of 1.5°C, held for 30 min, cooled to 50°C at 1.5°C/min and held at 50°C for 15 min.

Statistical analyses

The data obtained from the analyses were statistically analysed using Statgraphics statistical software (Graphics Software System, STCC, Inc., Rockville, MD, USA). Comparisons between sample treatments and the indices were done using analysis of variance (ANOVA) with a significance probability of $P \leq 0.05$. Tukey's test of multiple comparisons was employed to compare mean values when the significant variance was found by ANOVA.

Results and discussion

Non-volatile (titratable) acidity

There were general increases in the titratable acidity of all of the samples with increasing fermentation time (Table I). Similarly, titratable acidity of all the samples

increased with increasing level of soy fortification. Fermentation caused consistent increases in titratable acidity of the samples from 0.0476 to 0.1414 g lactic acid/100 g sample for the unfortified sample, from 0.0370 to 0.1784 g lactic acid/100 g sample for the 10% fortified sample, from 0.0343 to 0.1864 g lactic acid/100 g sample for the 20% fortified sample, and from 0.0341 to 0.2070 g lactic acid/100 g sample for the 30% fortified sample (Table I). These increases in titratable acidity could be attributed to the activity of the lactic acid bacteria during the fermentation process, which leads to the production of organic acids and other metabolites causing souring or acidification of the product. Souring of cassava dough during fermentation is an important and desirable quality attribute in *gari* production. Acid production has been reported to be responsible for product stability, flavour development, and cyanide elimination during cassava fermentation (Okigbo 1980). Sefa-Dedeh et al. (2004) have reported that lactic acid fermentation exhibits antimicrobial effects on pathogenic microorganisms due to the presence of acid.

Analysis of variance showed that the fermentation time and soybean level significantly affected ($P \leq 0.05$) the titratable acidity of the samples (Table II). Further analysis using multiple range tests revealed that the difference was due to the 30% soy level and that the unfortified dough had comparable acids as the 10% and 20% soy levels after 48 h of fermentation, suggesting that soy fortification up to 20% would produce similar souring as the unfortified product after 48 h of fermentation.

pH profile

The pH of all the cassava samples decreased with increasing fermentation time. The unfermented samples showed higher pH levels (weak acidic) prior to the fermentation, which reduced consistently with increasing fermentation time (Table I). Generally,

Table I. Changes in non-volatile (titratable) acidity, pH and total starch content during fermentation of soy-*gari*.

Soy flour level	Fermentation time		
	0 h	24 h	48 h
Non-volatile (titratable) acidity (g lactic acid/100 g)			
0%	0.0476 ± 0.003[A]	0.0659 ± 0.006[A]	0.1614 ± 0.005[A]
10%	0.0370 ± 0.005[B]	0.0662 ± 0.004[A]	0.1784 ± 0.002[AB]
20%	0.0343 ± 0.002[B]	0.0665 ± 0.003[AB]	0.1864 ± 0.008[AB]
30%	0.0341 ± 0.003[B]	0.0678 ± 0.002[B]	0.2070 ± 0.006[C]
PH			
0%	4.68 ± 0.08[A]	4.27 ± 0.04[A]	4.04 ± 0.03[A]
10%	5.01 ± 0.06[B]	4.18 ± 0.03[B]	3.99 ± 0.03[AB]
20%	5.11 ± 0.04[BC]	4.13 ± 0.06[BC]	3.96 ± 0.04[AB]
30%	5.13 ± 0.03[C]	4.08 ± 0.03[C]	3.78 ± 0.05[C]
Total starch content (%)			
0%	69.80 ± 0.16[A]	62.32 ± 1.53[A]	60.46 ± 1.82[A]
10%	67.54 ± 0.21[AB]	60.81 ± 0.72[AB]	58.43 ± 2.04[AB]
20%	62.78 ± 0.52[B]	59.04 ± 2.62[BC]	54.30 ± 0.80[BC]
30%	58.70 ± 0.19[BC]	55.21 ± 1.18[C]	52.56 ± 1.41[C]

Data presented as means of triplicate analyses ± standard deviation. Values followed by the same uppercase superscript letter in the same column of a specified parameter are not significant ($P \leq 0.05$).

decreases in pH were observed at all soy fortification levels during the fermentation period, with values decreasing from 4.68 to 4.04, from 5.01 to 3.99, from 5.11 to 3.96, and from 5.13 to 3.78, respectively, for the unfortified, 10%, 20% and 30% fortified samples after 48 h of fermentation. The decrease in pH during fermentation was due to the presence and activity of lactic acid bacteria during the spontaneous fermentation. Amoa-Awua and Jakobsen (1996) have reported the fermentation of cassava during *gari* and *agbelima* production in Ghana to be largely lactic acid fermentation. During the fermentation process, lactic acid bacteria hydrolyse carbohydrates (notably, starch) in the cassava into sugar, alcohols and organic acids. The production of the organic acids, which increases with fermentation time, leads to an increase in acidity of the samples and the resultant decrease in pH. Several studies have shown that acidity increases as pH falls during fermentation (Bressani et al. 1990; Mbugua 1988; Sefa-Dedeh et al. 2003; Afoakwa and Aidoo 2006).

The pH of the flour samples was also found to decrease with increasing fortification. Ampadu (1994) observed that, during maize fortification with legumes, the rate of decrease in pH increases as the ratio of legume added increases. The pH of all the fortified samples in which soybeans were added and co-fermented with the cassava were much lower than those samples fermented without any soybean. This could be due to the fact that the added soybeans were also undergoing fermentation and producing more acids. Work done by Afoakwa et al. (2004) showed that co-fermentation of cereal products with cowpea was found to decrease the pH of the products and produce more acids compared with fortifying the cereals after fermentation.

Analysis of variance showed that fermentation time and soybean level significantly affected ($P < 0.001$) the pH of the samples (Table II). Further analysis using multiple range tests revealed that a significant decrease in pH occurred only after 24 h of fermentation and at 30% soy level. After 48 h of fermentation, no significant differences were noted in pH in the unfortified, 10% and 20% soy-fortified samples, suggesting the potential to generate similar acids as the unfortified samples with 48 h of fermentation when cassava is fortified up to 20% soy concentration. Increasing the soy concentration to 30% significantly ($P < 0.001$) increases the acid production after 48 h of fermentation, and would thus have negative effects on the flavour, colour and texture of the product.

Starch content

The starch content of the entire fermented samples was observed to decrease with increase fermentation time (Table I). It decreased from 69.8 to 60.4% for the unfortified sample after 48 h of fermentation. Similar trends were observed for the

Table II. ANOVA summary showing *F*-values of non-volatile (titratable) acidity, pH and starch contents.

Process variable	Non-volatile (titratable) acidity	pH	Starch
Soy level	5.50★	5.04★	28.28★
Fermentation time	75.42★	42.22★	69.98★

★Significant at $P \leq 0.05$.

10%, 20% and 30% fortified samples, with decreases from 67.5 to 58.4% for the 10% fortified sample, from 62.7 to 54.3% for the 20% fortified sample, and from 58.7 to 52.5% for the 30% fortified sample. These decreases in the starch content with increased fermentation time are due to the breakdown of starch molecules into sugars by microorganisms during the fermentation process. Earlier research revealed that, during the first stage of the spontaneous fermentation process, the starch in the cassava is hydrolysed by corynebacterium to give sugars (Diop 1998). These sugars are then metabolized by microorganisms to organic acids, which hydrolyse the cyanogenic glucosides in the cassava and releases HCN.

The starch content of the flour samples was also observed to decrease with increasing level of fortification. The decrease in the starch content with increase level of fortification is due to the decrease in the starch content as fortification is increased. The soybean level and fermentation time significantly affected ($P < 0.001$) the starch content of the co-fermented samples (Table II). Multiple range tests conducted on the results indicated that the significant effect of soybean level on the starch content of the samples was observed at the 30% level of fortification.

Pasting characteristics

The ability of starch to swell and give a viscous paste when an aqueous suspension of the starch granules are heated above the gelatinization temperature is one of the most important functional properties of starch (Afoakwa and Sefa-Dedeh 2002). Prolonged heating of the starch granules leads to disintegration of the granules, which brings about significant change in the viscosity and other rheological properties of the paste. They also reported that the transition of starch granules in suspension to a paste when heated, is accompanied by changes in viscosity.

Pasting temperature. The pasting temperature is the temperature at which the first detectable viscosity is measured by the amylograph. It is characterized by an initial change in the viscosity due to the swelling properties of the starch granules. The pasting temperature, which is a reflection of the swelling of the starch granules, is affected by the starch concentration (Rasper 1980). Generally, a high starch concentration leads to a low pasting temperature and the presence of monosaccharides and oligosaccharides have been reported to lead to an upward shift of pasting temperature (Colonna et al. 1992). The pasting temperature generally increased with increased fermentation time for all samples (Table III). This is due to the decrease in starch concentration as fermentation proceeds. Diop (1998) reported that, during the initial stage of fermentation, starch is hydrolysed by corynebacteria to give sugars. This process results in a decrease in the starch content of the samples. As the starch granule content decreases in the sample, high temperature is thus required to bring about the first detectable change in viscosity. The pasting temperature also increased for all the samples with increasing level of soy fortification. This is due to the decrease in the starch content of the flour as fortification is increased. As the soybean level is increased, the cassava content is decreased leading to a decrease in starch content. Owusu-Ofosu (1999) reported an increase in the pasting temperature of cowpea-fortified cassava dough with increasing level of cowpea addition. Analysis of variance showed that soybean level and fermentation time significantly affected ($P<0.02$) the pasting temperature of the fermented samples (Table III).

Table III. Pasting characteristics of soy-fortified cassava dough during fermentation.

Soy level	Fermentation time (h)	Pasting temperature (°C)	Viscosity (BU)				
			Peak	95°C	95°C-hold	50°C	50°C-hold
0%	0	54.2	1150	570	370	470	520
	24	56.6	980	420	240	440	500
	48	62.3	820	400	290	460	495
10%	0	61.2	950	310	230	350	440
	24	64.8	835	290	175	205	235
	48	65.3	700	260	215	240	250
20%	0	64.6	820	290	220	340	420
	24	65.6	750	270	160	215	230
	48	66.9	645	250	215	225	245
30%	0	70.0	750	280	205	335	380
	24	74.4	650	260	155	195	225
	48	76.7	570	240	200	210	240

Peak viscosity. Peak viscosity is linked to the ease of cooking of the samples being analysed. It is measured as the highest value of viscosity attained by the paste during the heating cycle (25–95°C). There was a general decrease in peak viscosity with increasing fermentation time and soy fortification level (Table III). At the 0% soybean level, the peak viscosity decreased consistently with increasing fermentation time. Similar trends were observed at 10%, 20% and 30% soybean levels (Figures 1–4). The decrease in peak viscosity with fermentation time is due to the breakdown of starch molecules into smaller molecular weight sugars by microorganisms during the fermentation process. Owusu-Ofosu (1999) also observed a general decrease in the peak viscosity of cowpea-fortified cassava dough with increasing levels of cowpea fortification. Analysis of variance revealed that the soybean level and fermentation time significantly affected ($P < 0.05$) the peak viscosity of the fermented flour sample (Table IV). Further analysis using multiple range tests revealed that the difference in peak viscosity occurred only after 24 h of fermentation and at 30% soy level. At 48 h of fermentation, no significant differences were noted in peak viscosity in the unfortified, 10% and 20% soy-fortified samples—indicating that cassava could be fortified up to 20% soy concentration with a similar degree of gelatinization as the unfortified samples when fermented for 48 h.

Table IV. ANOVA summary showing *F*-values of pasting characteristics.

Process variable	Soy level	Fermentation time
Pasting temperature	764.07★	94.69★
Peak viscosity	55.46★	33.32★
Viscosity at 95°C	20.16★	3.32
Viscosity at 95°C-hold	17.82★	7.54
Viscosity at 50°C	16.28★	5.49
Viscosity at 50°C-hold	16.47★	5.52

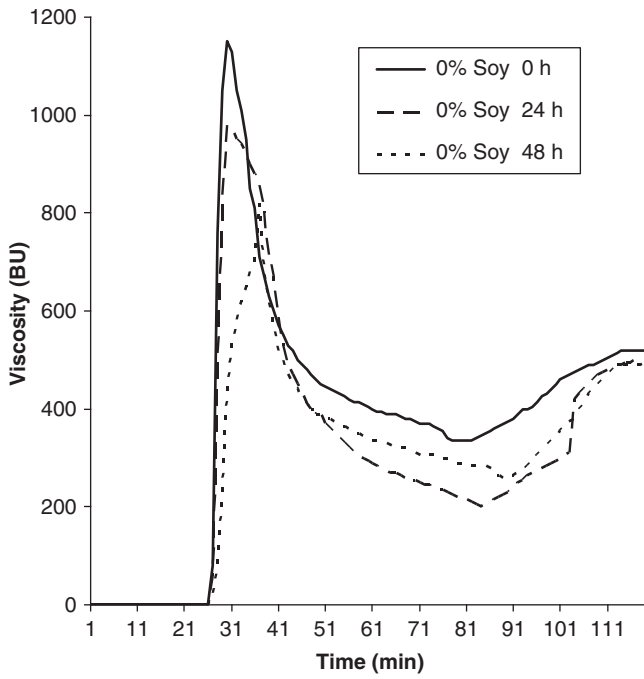★Significant at $P \leq 0.05$.

Figure 1. Effect of fermentation on pasting characteristics of unfortified cassava dough.
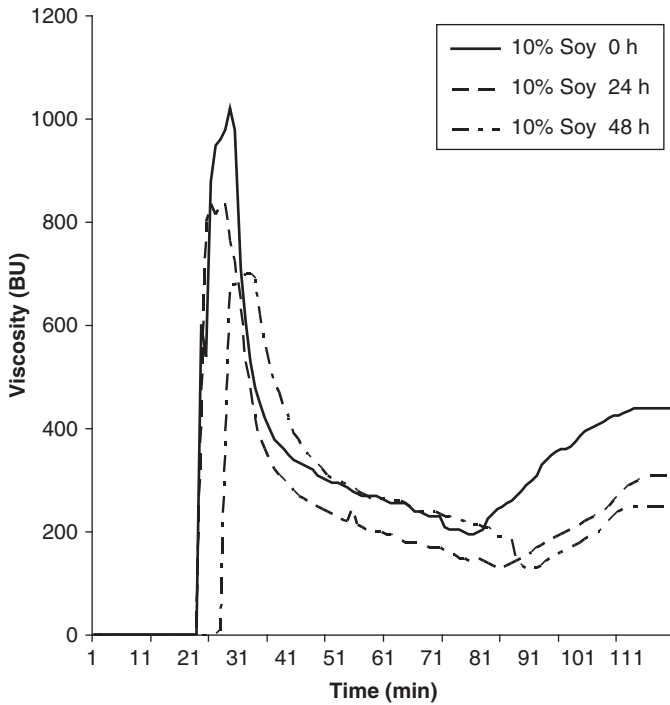

Figure 2. Effect of co-fermentation on the pasting characteristics of 10% soy-fortified cassava dough.

Heating cycle (viscosity at 95°C and viscosity at 95°C-hold). The viscosity at 95°C measures the ease of cooking of the sample by the amylograph. A low viscosity at 95°C means the sample will be difficult to cook. The viscosity at 95°C showed a similar trend with fermentation time as in the peak viscosity, increasing with increasing fermentation time (Table III). The high sugar content of the samples with increasing fermentation time as a result of the breakdown of starch molecules into sugars influences the viscosity at 95°C of the samples fermented for 24 and 48 h. The soybean level significantly affected ($P < 0.02$) the viscosity at 95°C of the fermented samples but the fermentation time had no significant effect ($P \leq 0.05$) on the viscosity at 95°C of the flour samples (Table IV). The viscosity attained by the sample after holding the temperature constant at 95°C for 30 min indicates the ease of breakdown of the cooked paste. This illustrates the stability of the paste during cooking (Figures 1–4). At 95°C-hold there was a general reduction in the viscosities of all the samples, indicating lower resistance to shear at high temperatures in the entire samples. The soybean level and fermentation time significantly affected ($P \leq 0.05$) the viscosity at 95°C-hold of the fermented sample. Multiple range tests revealed that the differences in viscosities during the heating cycle (95°C and 95°C-hold) occurred only following 24 h of fermentation and with the 30% soy level. No significant differences were noted between the unfortified, 10% and 20% soy-fortified samples—suggesting that to enhance the nutritional quality of *gari*, cassava could be fortified with 20% soybean with 48 h fermentation without any significant effect on their cooking properties.
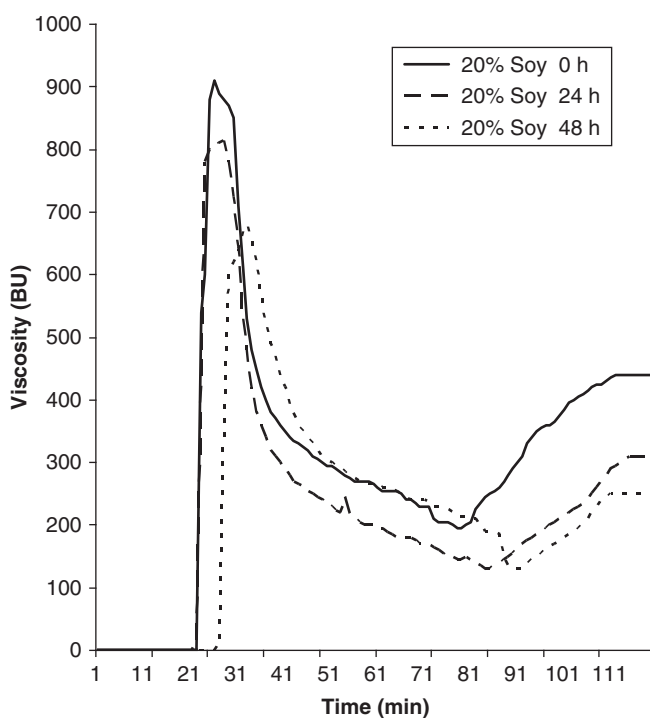

Figure 3. Effect of co-fermentation on the pasting characteristics of 20% soy-fortified cassava dough.
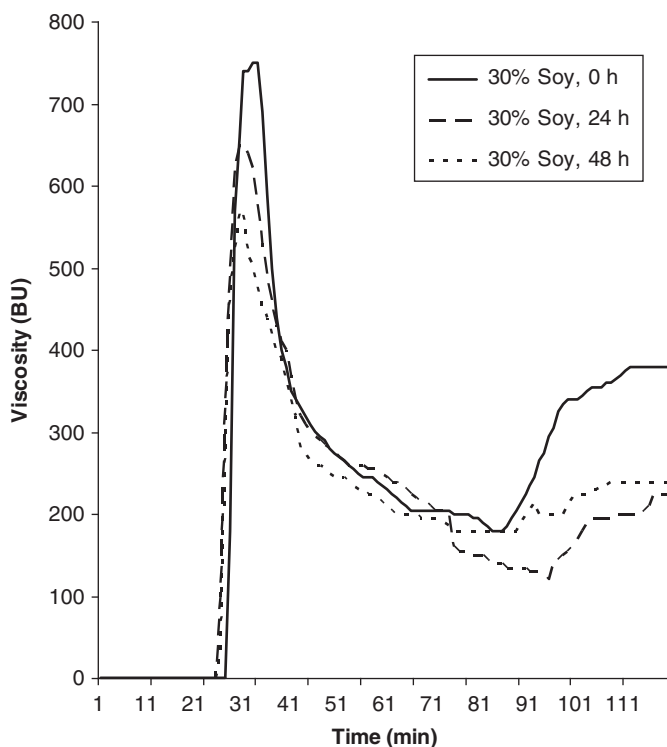
Figure 4. Effect of co-fermentation on the pasting characteristics of 30% soy-fortified cassava dough.

Cooling cycle (viscosity at 50°C and viscosity at 50°C-hold). Viscosity at 50°C reflects the retrogradation tendency of the cooked paste. An increased retrogradation property of the paste can be attributed to the association of the starch molecules caused by the strong tendency for hydrogen bond formation between hydroxyl groups on adjacent molecules (Afoakwa and Sefa-Dedeh 2002). There was a general increase of the viscosity at 50°C for all samples (Figures 1–4). The viscosity at 50°C was higher for samples fermented for 48 h than for those fermented for 24 h irrespective of the level of fortification. Analysis of variance revealed that soybean level significantly affected ($P \leq 0.05$) the viscosity at 50°C of the fermented sample, but the fermentation time had no significant effect ($P \leq 0.05$) on the viscosity at 50°C for the samples (Table IV).

The viscosity at 50°C-hold measures the stability of the paste as it might be used in products. It was observed that the viscosity of the samples at 50°C-hold was higher after 24 h of fermentation than after 48 h. Analysis of variance revealed that soybean level significantly affected ($P \leq 0.05$) the viscosity at 50°C-hold of the fermented sample but the fermentation time had no significant effect ($P \leq 0.05$) on the viscosity at 50°C-hold. Multiple range tests revealed that the differences in viscosities with soy fortification occurred as a result of the 30% soy addition. No significant differences were noted between the unfortified, 10% and 20% soy-fortified samples, suggesting that cassava could be fortified up to 20% soybean without any significant effect on their retrogradation or paste stability after 48 h of fermentation.

Conclusions

Souring or acid production generally increased with increasing fermentation time with both single-component (cassava only) and multiple-component (cassava and soybean) fermentation systems. However, fortification of the cassava dough with 20% soy caused only minimal and insignificant variation in the acid generation relative to the unfortified sample after 48 h of fermentation. Increasing the soy concentration to 30% caused significant increases in acid production, with consequential significant reductions in starch content, which would have negatively affect the flavour, colour and texture of the product. Starch pasting characteristics were also affected by the soy fortification but the effect was insignificant at the 20% soy fortification level. These suggest that cassava dough could be effectively co-fermented for 48 h with soybean up to 20% concentration without significant effect on acid production and starch pasting characteristics of the resulting product. This would improve the nutritional quality of the product without affecting the process development and/or product quality characteristics.

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