As. J. Food Ag-Ind. **2010**, 3(03), 371-385

OPEN ACCESS

Asian Journal of Food and Agro-Industry
ISSN 1906-3040
Available online at www.ajofai.info

Research Article

Souring and starch behaviour during co-fermentation of cassava and soybean into *gari* 'farina'

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Abstract

Investigations were conducted to determine changes in souring/acidification and starch behaviour during co-fermentation of cassava and soybean into *gari*, 'farina' an African fermented product. A 3 x 4 factorial experiment was performed with fermentation time (0, 24 and 48 h) and soybean concentration (0, 10, 20 and 30%) as variables. Titratable acidity, pH and starch content were studied using standard analytical methods. Starch breakdown and pasting characteristics were also evaluated. The results revealed that pH decreased with concomitant increases in titratable acidity during co-fermentation of the cassava dough. Soy-fortification up to 30% caused significant ($p \leq 0.05$) effects on the pH, titratable acidity and starch content during the fermentation period with only minimal and insignificant ($p \leq 0.05$) effect noted at 20% soy level. Fermentation caused significant differences ($p \leq 0.05$) in the pH, titratable acidity and starch concentration. 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 that the pasting temperature significantly increased with increasing fermentation time and soybean concentration. Contrary to this, viscosity at 95°C and at 50°C HOLD decreased with increasing fermentation time and soybean concentration. Peak viscosity decreased from 1150 BU to 820 BU and 750 BU after 48 hours of fermentation, with 0% and 30% soybean levels respectively. 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: acidification, starch behaviour, cassava, soybean, fortification

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 food energy production basis as a source of complex carbohydrates [1, 2]. It is a staple food for more than half of the West African population [3, 4, 5], and can be processed into various products that are useful as human and animal food, including *gari* (farina), *akyeke*, *agbelima*, *fufu*, *lafun* and many other West African traditional dishes [6, 7, 8].

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 [5, 9, 10]. 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* [11]. Although cassava is high in linamarin [4, 12], 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* [13]. However, cassava and its products are low in protein, deficient in essential amino acids and therefore, have poor protein quality, with protein content of between 3.6-4.4% dry weight [7]. 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 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 to most other legumes, soybeans are much higher in protein (38 .9 – 41.8%) [14, 15, 16]. Soybean oil is 61% polyunsatyrated and 23.4% monounsaturated [17]. Interest in soybean and soy-based products has grown significantly in the last decade due to their reported nutritional and health-promoting benefits [18, 19]. Soybean contains high concentrations of components with health benefits, such as proteins, isoflavones, dietary fibre, protease inhibitors and phytic acid [20, 21]. Soy protein is reported to lower cholesterol levels in the blood [14, 22], and its amino acid content is considered key in its ability to control blood pressure, and this appears to be related to calcium conservation [18]. Soy isoflavones have been reported to play essential roles in preventing certain types of cancers and in reducing the risk of cardiovascular diseases [19, 23, 24]. 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 in concentrations higher than 1.5% [25]. The AP is highly branched because of its additional bonds (α-D-[$1 \rightarrow 6$]) and does not form gels [26, 27]. 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 cryst allinity disappears. As a result, the swollen granules (deformable particles) get imbedded in a

continuous matrix of cross-linked AM molecules [28, 29]. The polymeric complex exhibits viscoelastic behaviour and forms a gel or paste during the dispersion cooling when non-waxy starch concentration is $\geq$ 6% [30]. 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 [31, 32], and other processing techniques such as fermentation [7].

The process of fermentation has been reported to be applied to cereals [33, 34] and cassava-based products [8, 35, 36], to generate acids to effect souring or acid production to improve flavour development, cyanide elimination, colour and texture of food 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 starch gelatinization process remains unknown.

The objective of this 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 (*Manihot esculenta* Crantz) and soybeans (*Gycine max*, Merr) were obtained from the Crop Research Institute in Tafo in the Eastern Region of Ghana and used for this study. The chemicals used were of analytical grade and glass distilled water was also used.

Preparation of soy flour

The soybeans were cleaned by removing stones, sticks and damaged beans and 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 ^{o}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 1, Surrey, England) at 60 ^{o}C to constant weight. They were then ground in a mill (National Supergrinder MK 830N, Japan) into soy flour.

Preparation of gari

Fresh cassava (*Manihot 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, Ghana). The grated cassava was fermented for 48 h and the liquor squeezed using a hydraulic press (Blitz HPL 652, Germany). It was then sieved to remove fibre waste and fried in a hot metal dish with continuous stirring for 20 min into *gari*. 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 respectively and fermented for 48 h and fried in a hot metal dish to produce the soy-*gari*. Samples were taken after 0, 24 h and 48 h of fermentation for analysis.

Experimental design

A 3 x 4 factorial experimental design was used. The principal factors investigated were:

- Fermentation time: 0, 24, and 48 hours.
- Soybean concentration: 0%, 10%, 20%, and 30%.

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

Analytical methods

Titratable acidity

Ten (10) grams of the oven-dried fermented cassava flour was weighed into a clean beaker and mixed with 100 ml distilled water. The mixture was then filtered using a Whatman no. 4 filter paper. Ten (10) ml of the filtrate was titrated against 0.1M NaOH using 1% phenolphthalein as an indicator. Acidity was calculated as grams lactic acid / 100g sample.

pH

Ten (10) 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 (Model HM 305, Tokyo, Japan).

Total starch content

Starch content of the fermented cassava flours was determined using acid hydrolysis method described by Association of Official Analytical Chemists' approved method 14.023 [37].

Pasting characteristics

The viscosities of the samples were determined using the American Association of Cereals Chemists Method 22–10 [38], with slight modifications. Six percent (6%) of starch slurry was prepared with 500 ml of 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 / min to 95°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 analyzed using Statgraphics statistical software (Graphics Software System, STCC, Inc. USA). Comparisons between sample treatments and the indices were done using analysis of variance (ANOVA) with a significance probability $p \leq 0.05$. Tukey's test of multiple comparisons was employed to compare mean values when the significant variance was found by ANOVA.

Results and Discussion

Titratable acidity

There were general increases in the titratable acidity of all the samples with increasing fermentation time (Table 1). 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/100g sample for the unfortified

sample, 0.0370 to 0.1784 g lactic acid/100g sample for the 10% fortified sample, 0.0343 to 0.1864 g lactic acid/100g sample for the 20% fortified sample and 0.0341 to 0. 2070 g lactic acid/100g sample for the 30% fortified sample (Table 1). 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 [39]. Sefa-Dedeh *et al.* [40] have reported that lactic acid fermentation exhibits antimicrobial effects on pathogenic microorganisms due to the presence of acid.

Table 1. Changes in titratable acidity, pH and total starch content during fermentation of soy - *gari*

Soy flour level (%)	Fermentation time (h)		
	0	24	48
Titratable acidity (gLactic acid/100g)			
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}

Values are means of triplicate analyses ± sta ndard deviation. Values followed by the same letter in the same column of a specified parameter are not significant ($P \leq 0.05$).

Analysis of variance showed that fermentation time and soybean level significantly affected ($P \leq 0.05$) the titratable acidity of the samples (Table 2). 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 upto 20% would produce souring similar to the unfortified product after 48 h of fermentation.

pH

The pH of all the cassava samples decreased wi th increasing fermentation time. The unfermented samples showed higher pH levels (weak acidic) prior to the fermentation, which reduced consistently with increasing fermentation time (Table 1). Generally, decreases in pH were observed at all soy fortification levels during the fermentation period, with values decreasing from 4.68 to 4.04, 5.01 to 3.99, 5.11 to 3.96, and 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 [41] 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 [33, 34, 42, 43].

Table 2. ANOVA Summary showing F-values of acidity, pH and starch.

Process variables	Titratable acidity	pH	Starch
Soy level	5.50*	5.04*	28.28*
Fermentation time	75.42*	42.22*	69.98*

* Significant at $P \leq 0.05$

The pH of the flour samples was also found to decrease with increasing fortification. Ampadu [44] 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*. [45] showed that co-fermentation of cereal products with cowpea was found to decrease the pH of the products and produce more acids compared to 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 2). 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 increased fermentation time (Table 1). It decreased from 69.8 to 60.4% for the unfortified sample after 48 hours of fermentation. Similar trends were observed for the 10%, 20% and 30% fortified samples, with decreases from 67.5 to 58.4% for the 10% fortified sample, 62.7 to 54.3% for the 20% fortified sample and 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 [46]. These sugars are then metabolised 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 increased 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 2). 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 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 [47]. 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. Pasting temperature, which is a reflection of the swelling of the starch granules, is affected by the starch concentration [48]. 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 [49]. The pasting temperature generally increased with increased fermentation time for all the samples (Tables 3 & 4). This is due to the decrease in starch concentration as fermentation proceeds. Diop [46] 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 soybean level is increased, the cassava content is decreased leading to decrease in starch content. Owusu-Ofosu [50], 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 3).

Peak viscosity

Peak viscosity is linked to the ease of cooking of sample being analyzed. It is measured as the highest value of viscosity attained by the paste during the heating cycle ($25^oC – 95^oC$). There was a general decrease in peak viscosity with increasing fermentation time and soy fortification level (Table 3). At 0% soybean level, the peak viscosity decreased consistently with increasing fermentation time. Similar trends were observed at 10%, 20% and 30% soybean levels (Figs. 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 [50], 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 soybean level and fermentation time significantly affected ($P<0.05$) the peak viscosity of the fermented flour samples. 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 similar degree of gelatinization as the unfortified samples when fermented for 48 h.

Table 3. Pasting characteristics of soy-fortified cassava dough during fermentation.

Soy level (%)	Ferm. Time (h)	Pasting Temp. (°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

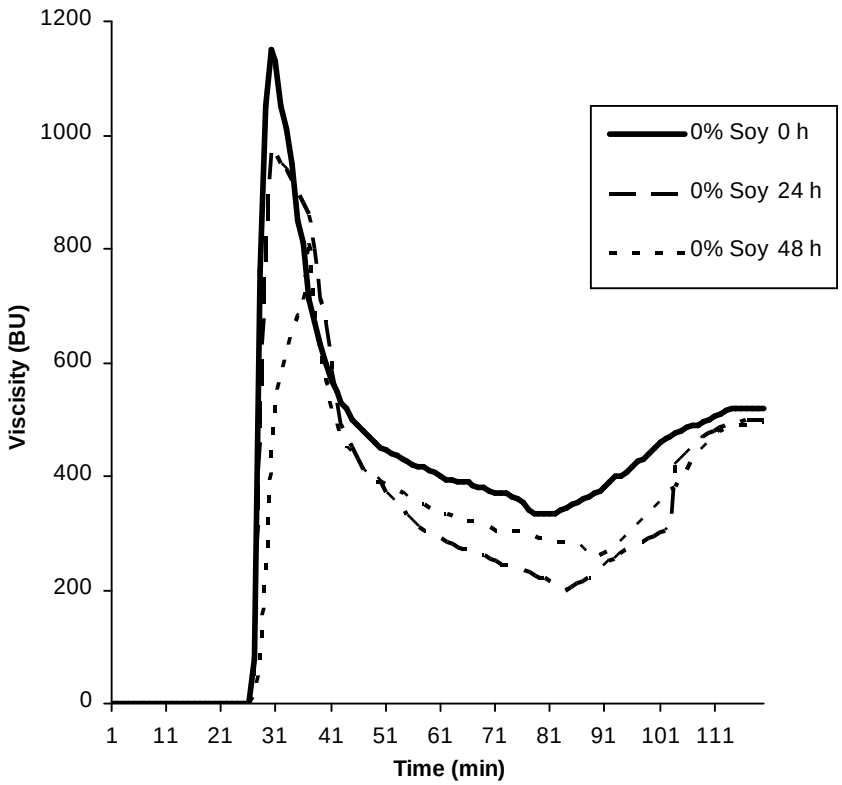

Figure 1. Effect of fermentation on pasting characteristics of unfortified cassava dough.

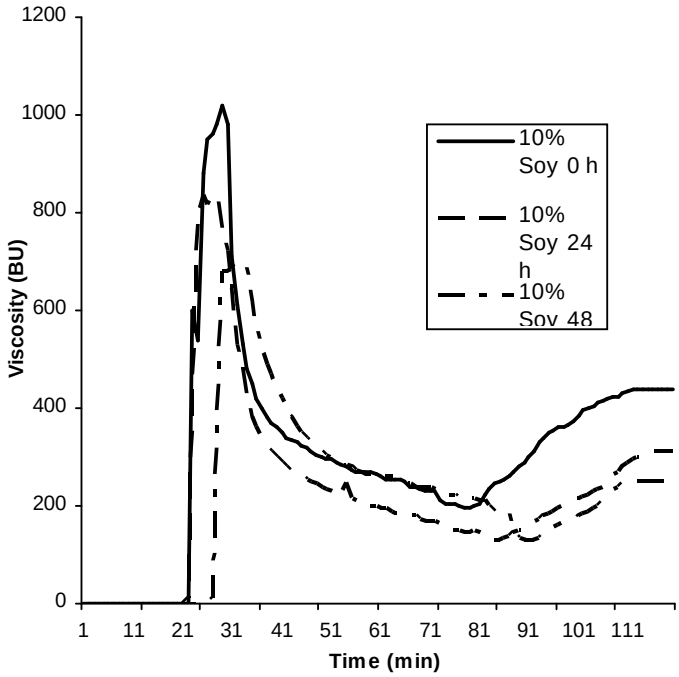

Figure 2. Effect of co-fermentation on the pasting characteristics of 10% soy -fortified cassava dough.

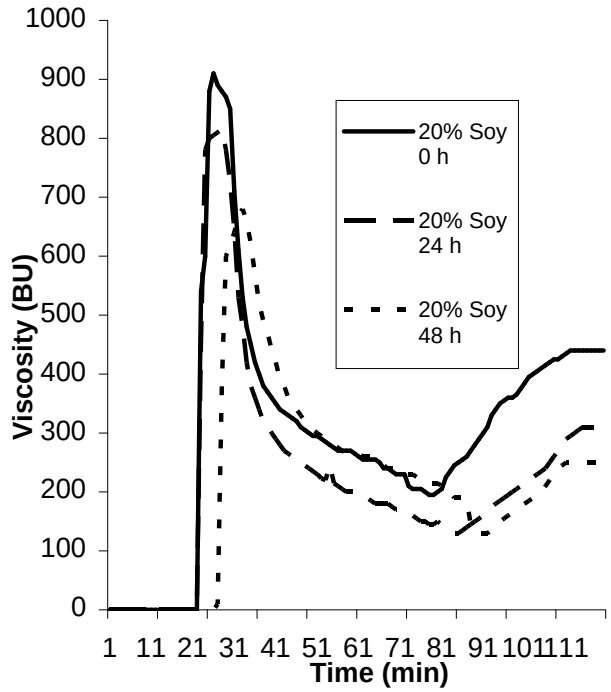

Figure 3. Effect of co-fermentation on the pasting characteristics of 20% soy -fortified cassava dough.

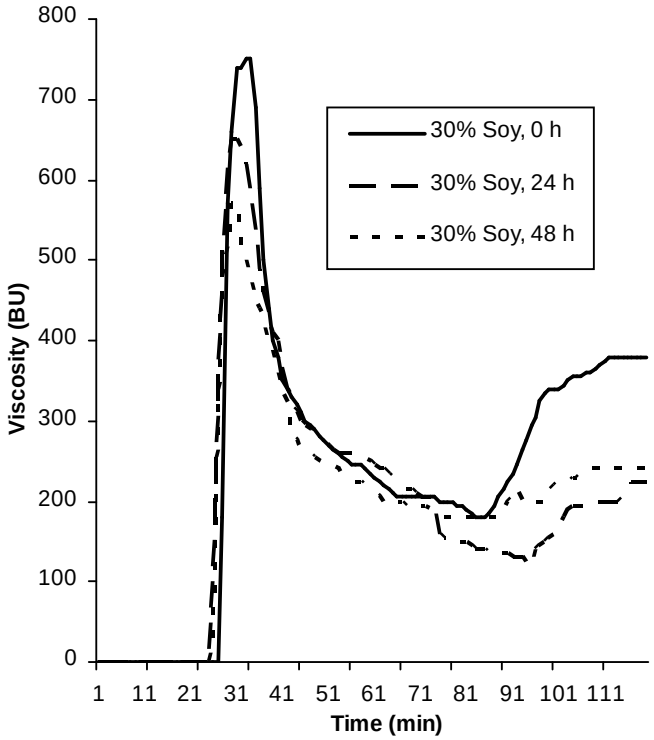

Figure 4. Effect of co-fermentation on the pasting characteristics of 30% soy -fortified cassava dough.

Table 4. ANOVA summary showing F-values of pasting characteristics.

Process variables	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 $p \leq 0.05$

Heating cycle (Viscosity at 95^{o}C and Viscosity at 95^{o}C – Hold)

The viscosity at 95^{o}C measures the ease of cooking of the sample by the amylograph. A low viscosity at 95^{o}C means the sample will be difficult to cook. The viscosity at 95^{o}C showed a similar trend with fermentation time as in the peak viscosity, increasing with increasing fermentation time (Table 3). The high sugar content of the samples with increasing fermentation time as a result of the breakdown of starch molecules into sugars influence the viscosity at 95^{o}C of the samples fermented for 24 and 48 h. Soybean level significantly affected ($P<0.02$) the viscosity at 95^{o}C of the fermented samples but the fermentation time had no significant effect ($P \leq 0.05$) on the viscosity at 95^{o}C of the flour samples. The viscosity attained by the sample after holding the temperature constant at 95 ^{o}C for 30 minutes indicates the ease of breakdown of the cooked paste. This illustrates the stability of the paste during

cooking (Figs. 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. 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.

Cooling cycle (viscosity at 50°C and viscosity at 50°C-Hold)

Viscosity at 50°C reflects the retrogradation tendency of the cooked paste. Increased retrogradation properties of the paste can be attributed to the association of the starch molecules caused by strong tendency for hydrogen bond formation between hydroxyl groups on adjacent molecules [47]. There was a general increase of the viscosity at 50 °C for all the samples (Figs. 1-4). The viscosity at 50°C was high for samples fermented for 48 h than 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 fermentation time had no significant effect ($P \leq 0.05$) on the viscosity at 50°C for the samples.

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 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 upto 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 negative effects on the flavour, colour and texture of the product. Starch pasting characteristics were also affected by the soy fortification but the effect was insignificant at 20% soy fortification level. This suggests that cassava dough could be effectively co-fermented for 48 h with soybean upto 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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