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Physicochemical characteristics of weaning food formulated from different blends of cereal and soybean

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Abstract The physicochemical characteristics of porridges of adult and infant weaning food prepared from fermented blends of cereals and soybean are reported in this study. The pH of the formulated flour blends was less than 5.0 within 12 h of fermentation with F15B and F410B, attaining a pH of 3.4. Titratable acidity, which was not detected in unfermented samples, increased as the fermentation progressed. An increase in the gross energy content was noted with F25B, yielding a value of 439.0 kcal/100 g. All the fermented flour blends reconstituted well in boiling water and the water-holding capacity also increased. There was a slight difference in the bulk densities of the loose and packed flour. The index of gelatinization of unfermented formulated flour ranged from 82 (B. U.) in F15A to 334 (B. U.) in F310A. However, there was an increase in the values of the index of gelatinization of the blends at the end of the fermentation. All the blends had relatively low viscosities except F310B. Based on the parameters considered in this study, F15B is recommended as a potential infant and adult food.

Key words Weaning food · Fermented gruel · Cereal blends

Introduction

The majority of the people in sub-Saharan Africa depend mainly on cereal grains as their staple food, owing to the limited supply of animal foods. Maize, wheat and rice provide over one half of the total calories and protein for the aforementioned people [1]. Acid porridges prepared from cereal are still eaten in varying amounts in different parts of the world, particularly in developing countries where they represent the basic diet. Ogi (Nigeria), Uji (Kenya) and Koko (Ghana) are examples of these porridges prepared by the fermentation of maize, sorghum, millet or cassava [2, 3].

Fermented cereals are used as weaning and adult foods in West Africa; hence efforts have been geared towards improving their quality attributes. For instance, the dietary bulk of cereal products can be reduced by using flour from germinated cereals or by adding small amounts of ungerminated flour gruel. The use of flour from germinated cereal (power flour) for reducing dietary bulk problems has been successfully demonstrated in India [4], Tanzania [5] and Chile [6].

The technique of using power flour results in a breakdown of the starch network in the porridge prepared from ungerminated cereal flour. Thus the addition of germinated flour will allow the amount of flour of a porridge to be increased several times without thickening the consistency. This will invariably lead to more available nutrients, especially for weaning infants.

The potential of fermented foods for reducing or alleviating food-related factors of malnutrition, particularly among weaning age children, is important considering the beneficial properties inherent in these types of food [7]. There is therefore the need to replace the present uncontrolled fermentation processing existing in sub-Saharan Africa with a pure culture fermentation so as to obtain consistent product quality. Reports on the nutritional fortification of the cereal porridges, with vegetable proteins such as soybean in addition to germination and fermentation, are available [8].

In this paper, the physicochemical characteristics of formulated infant and adult food from composite blends of cereals and soybean are reported.

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Materials and methods

Sample preparation

Maize (*Zea mays*), sorghum (*Sorghum bicolor*) and wheat (*Triticum vulgare*) grains were obtained from a retail market in Ibadan, southwestern Nigeria. Broken and mouldy seeds were removed manually during and after screening. The grains were shelled and washed thoroughly in tap water, during which the floating seeds were discarded. Those remaining were divided into two equal batches. One batch was left ungerminated while the other batch was soaked in tap water for 18 h at ambient temperature (30–32 °C). The seeds were later germinated in a wooden tray with a screened bottom measuring 49.53 cm × 63.5 cm. The bottom was lined with wet paper towels and germinated in an air-circulating incubator at 30 °C for 4 days.

Germinated seeds were separated from non-germinated and mouldy seeds daily. The germinated seeds were washed and dried at 50 °C for 18–20 h. The dried, germinated and ungerminated seed samples were separately milled and stored at 5 °C. For the pretreatment of-soybean seeds, enough quantity of the seeds was soaked in tap water for 24 h. The seeds were dehulled, washed and dried at 55 °C for 36 h followed by milling before storage at 5 °C.

Formulation of cereal-soybean blends

About 150 g of different blends of cereal flour were separately weighed into 1 l fermenters and soybean flour was incorporated into the blends at 5% and 10% (w/w) concentration.

Cultivation of starter organisms

A stock culture of *Saccharomyces cerevisiae* was obtained from Dr. T. Ekunsanmi of the Department of Botany and Microbiology, University of Ibadan, while *Lactobacillus plantarum* ATCC 10776^T was from the culture collection of the Laboratory of Food Hygiene, Department of Food Technology, Chemical Centre, Lund, Sweden. *L. plantarum* was propagated in MRS broth (pH 5.5), while *S. cerevisiae* was grown in malt extract broth.

Fermentation studies

About 150 g of each formulated cereal blend (F15–F410) were weighed separately into 1 l fermenters and sterilized at 121 °C for 10 min. The soybean flour was separately sterilized and added aseptically to each cereal blend. The flour mixture was stirred with a glass rod and 500 ml of sterile distilled water added. Thorough mixing was achieved using a magnetic stirrer. The resulting mixture was inoculated with 1 ml each of *S. cerevisiae* and *L. plantarum.* The inocula contained 3×10^6 CFU/ml. Duplicate batches were carried out for each blend. Fermentation was carried out at 30 °C for 24 h with continuous pH monitoring using a combined glass-calomel electrode and a Pye Unicam pH metre (model 290).

Analyses

Estimation of titratable acidity. This was carried out by titrating a 10 g cereal-soybean blend sample mixed with 90 ml of distilled water and 0.1 M NaOH using phenolphthalein as indicator.

Determination of bulk density and gross energy density. The bulk density of loose fermented flour was determined by transferring 50 g flour into a 250 ml graduated cylinder and the volume read off the scale. For the packed flour, the volume was measured after tapping the cylinder until the powder stopped settling [9]. The energy density of each sample was obtained by measuring the dry matter content after freeze-drying, using food composition tables for energy values.

Measurement of reconstitution index and water-holding capacity. The reconstitution index was estimated by mixing 10 g of fermented flour blends with 100 ml of boiling water in a graduated cylinder for 90 s. Measurement of the volume of the sediment formed in the cylinder was read 10 min after the mixing [9]. Determination of the water-holding capacity of the samples was done according to the method of Quinn and Paton [10].

Viscosity measurement. An aqueous (200 ml) suspension of unfermented and fermented samples (10%, w/w dry basis) was prepared and transferred into the Brabender Amylograph (Visco/amylo/Graph, Brabender, Duisburg, Germany) using a 700 ml bowl. The rate of stirring was 75 rounds/min. The initial temperature was 25 °C and the viscosity of the slurry was monitored as the temperature was increased (1.5 °C/min) from 25 °C to 95 °C, during the holding period (30 min) at 95 °C and during the cooling period from 95 °C to 50 °C.

Results and discussion

In this study, different porridge samples were prepared from various blends of cereals and soybeans fermented with a mixed culture of *L. plantarum* and *S. cerevisiae.* The pH of the formulated gruels dropped below 5.0 within 12 h of fermentation. Samples F25B and F310B recorded a pH of 3.3 by the 18th hour while F15B and F410B attained a pH of 3.4 at the same hour (Table 1).

Fermented cereal gruel with a pH of less than 4.0 had earlier been produced within 12–24 h using microorganisms singly cultured or mixed [7, 11]. The relatively shorter fermentation period is desirable to obtain a product of good and consistent quality. In Nigeria, a locally produced "ogi" from maize, sorghum or millet would normally take 72 h (or more) of spontaneous and uncontrolled fermentation before attaining a pH of less than 5.0.

Titratable acidity, which was not detected at the zero hour, increased in all the samples during fermentation (Table 2). An increase in the gross energy content was noted in the fermented samples. F25B yielded a value

Table 1 Changes in pH of cereal-soybean blends during fermentation

Sample[a]	Fermentation period (h)				
	0	6	12	18	24
F15	5.2	4.9	4.0	3.4	3.4
F25	5.0	4.8	4.2	3.3	3.3
F310	5.0	4.8	4.0	3.3	3.3
F410	5.8	5.0	4.2	3.4	3.4

[a] F15 = germinated sorghum, ungerminated wheat; germinated maize, 5% soybean; F25 = ungerminated sorghum, germinated wheat, ungerminated maize, 5% soybean; F310 = ungerminated sorghum, germinated sorghum, ungerminated maize, germinated maize, 10% soybean; F410 = ungerminated wheat, germinated wheat, germinated maize, 10% soybean

Table 2 Changes in titratable acidity (%) of cereal-soybean blends during fermentation

Sample	Fermentation period (h)[a]				
	0	6	12	18	24
F15	n.d.	0.36	0.70	1.18	1.26
F25	n.d.	0.40	0.86	1.13	1.30
F310	n.d.	0.42	0.97	1.46	1.50
F410	n.d.	0.39	0.98	1.62	1.68

[a] n.d. = not detected

Table 3 Bulk density (BD) and gross energy content (GEC) of fermented cereal-soybean blends

Samples	BD (g/ml)		GEC (kcal/100 g)
	Packed fluor	Loose fluor	
F15	0.56	0.50	455.0
F25	1.25	1.00	439.0
F310	1.00	0.80	484.0
F410	0.76	0.66	485.5

of 439.0 kcal/100 g, while F410B recorded a value of 485.5 kcal/100 g. There was a slight difference in the bulk densities of the loose and packed flour blends (Table 3). The energy density of most typical weaning foods made from cereals is normally very small. Thus the addition of germinated flour may allow the amount of flour of the cereal porridge to be increased several times without thickening the consistency.

With a fermentation technique using a lactic acid starter and the addition of flour of germinated seeds, Lorri [7] reported the preparation of a liquid cereal gruel from maize, white sorghum, bulbrush millet and finger miller with a 30–35% flour concentration. The energy of such a lactic acid-fermented gruel was about 1.2 kcal/g compared to 0.4 kcal/g in a non-fermented gruel prepared to the same consistency. The gross energy content of the formulated blends of this study fall within the values recommended for infant and young children food [12].

All the fermented samples reconstituted very well in boiling water and their water-holding capacity also increased (Table 4).

Table 5 shows the visco-amylographic analysis of the unfermented and fermented formulated blends. The index of gelatinization for unfermented samples ranged from 82 (B. U.) in F15A to 334 (B. U.) in F310A. However, there was an increase in the values of the index of gelatinization for all the samples at the end of the fermentation period. With the exception of F310B, all the samples have relatively low viscosities.

Table 4 Water-holding capacity and reconstitution index of fermented cereal-soybean blends

Sample	WHC (ml/g)	RI (ml)
F15	0.80	80
F25	0.88	68
F310	1.02	60
F410	1.15	66

Fermentation has been reported to increase the swelling and thickening characteristics of starch components owing to the presence of certain ions, including acetate [13]. The acidic pH obtained during fermentation may also reduce the amylase activities of the grains, thus limiting the conversion of starch to fermentable sugars.

The gelling tendency and starch stability of Nigerian "ogi" made from maize are characteristics necessary for the preparation of "agidi" (stiff gel), which is consumed with vegetable soup or fried bean cake. In that regard, F310B with a high viscosity would be most suitable. However, for an infant weaning food, blends with relatively low viscosity (F15B and F25B) will be appropriate. This is because the amount of food a child eats depends on many factors, such as capacity of the stomach, ability to chew, appetite, consistency and palatability of the food, as well as the patience of the person doing the feeding.

Table 5 Viscosity measurements of cereal-soybean blends[a]

Sample		pH	T_g (°C)	Values in Brabender unit (B. U.)				
				V_m	V_r	V_e	V_m-V_r	V_e-V_r
F15	A	5.2	58.5	652	246	328	406	82
	B	3.6	56.2	686	314	494	372	180
F25	A	5.0	56.5	584	202	342	382	190
	B	4.0	58.0	604	318	516	286	198
F310	A	5.0	64.6	765	92	426	673	334
	B	3.0	70.2	844	162	755	682	589
F410	A	5.9	56.2	398	74	302	324	228
	B	4.0	62.5	412	108	386	304	278

[a] A = unfermented sample; B = fermented sample; T_g = gelatinization temperature; V_m = maximum viscosity; V_r = viscosity after heating at 95 °C; V_e = viscosity after cooking to 50 °C; V_m-V_r = starch stability; V_e-V_r = index of gelatinization

Conclusion

Fermented cereal-soybean gruel was produced using yeast and lactic acid bacteria with a pH of less than 5.0 within 24 h. Germination and fermentation techniques led to improved properties of the porridge produced from the blends when compared with the traditional processing of cereals for the same purpose. Based on the parameters considered in this study, F15B is recommended as a potential infant and adult food. Although an improved nutritional profile of the fermented blends is reported in another study [7], there is a need to provide information on the protein digestibility, iron availability, tannin content and shelf-life of the formulated flour blends.

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