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The potential of bambara groundnut (*Vigna subterranea*) in vegetable milk production and basic protein functionality systems

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Bambara groundnut is an underutilized African legume which provides security for many farmers as it shows considerable drought resistance. The possibility of producing a vegetable milk for local use or an extracted protein with functional properties for use in food processing applications was studied. Milks were made by soaking bambara groundnut overnight, homogenizing and removing insoluble material to give a milky liquid. The beany taste could be removed by dry-frying the beans after soaking but before homogenization. Milks produced in this way were preferred by the taste panel (composed largely of Africans). A comparison of bambara groundnut milk and milks prepared from cowpea, pigeonpea and soybean was made using sensory and instrumental analysis. Sensory analysis showed all milks were acceptable with bambara groundnut ranked first in the preference trial. The lighter colour of bambara groundnut milk was more acceptable to the taste panel but there was no correlation between viscosity measured on a viscometer and viscosity perceived by the taste panel. A crude protein isolate (76% protein) from bambara groundnut was subjected to standard protein functionality tests but it was inferior to the standard used (egg albumen and soy isolate). It did not show any useful properties in emulsification, foam stabilization, or gelation or in a model cake system.

INTRODUCTION

Bambara groundnut (*Vigna subterranea*) is an indigenous African legume grown primarily by subsistence farmers. It is cultivated throughout Africa, from Senegal across to Kenya and from the Sahara to South Africa (National Research Council, 1979). In most traditional farming systems, the crop is grown by women as an intercrop in association with one or more species. Typically these include cereals such as sorghum, millet and maize; roots and tubers, e.g. cassava; other legumes, e.g. cowpea or groundnut; or even vegetables such as okra or pumpkin (Doku, 1967; Doku & Karikari, 1971; Ezueh, 1977; Haque, 1980; Linnemann, 1990). It is traditionally grown on poor soils in hot climates, generally in regions where the cultivation of other legumes such as groundnut (*Arachis hypogaea*) is too risky because of the threat of drought. The crop is grown for its edible seeds which may by eaten directly or stored as a dried pulse to be soaked and boiled before consumption. Dried seeds are also sometimes roasted and ground into flour.

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In many regions of Africa, bambara groundnut is the third most important legume after groundnut and cowpea (*Vigna unguiculata*) (Sellschop, 1962). Of the total annual production of around 300 000 tonnes, approximately half is produced in West Africa (Coudert, 1982). To date, bambara groundnut has not been characterized with regard to genotype. Most bambara groundnut is produced for local requirements and household consumption with little being available for the market. However, what little does reach the markets demands a price well above the world price of legumes indicating that the amounts made available for sale are insufficient to satisfy demand (Coudert, 1982)

In the drier parts of Africa, farmers perceive bambara groundnut as an important secondary food crop. However, because it is cultivated by women, usually as a subsistence crop, it has earned the reputation of being 'the groundnut of the women' and also 'a poor man's food'. One of the main attributes of bambara groundnut is its tolerance of drought and poor soils and its ability to yield in conditions when groundnut fails completely (Linnemann, 1990). It is also relatively pest and disease-free. The extremely tough seed coat of the harvested seeds confers resistance to weevil attack and allows the seed to be stored for long periods without loss.

Perhaps one of the most important reasons for producing bambara groundnut is that it is often preferred to groundnut in terms of taste and flavour.

Finally, bambara groundnut may be used as a source of additional income. Any excess production can easily be sold along the road as a snack to passers-by or in the local market. Many farmers do not want to completely oust groundnut by bambara groundnut because they consider the crops complementary in both cultivation and use (Linnemann, 1999).

The seeds of bambara groundnut are considered a complete food as they contain sufficient proportion of protein (25%) (albeit with low levels of the sulphur amino acids methionine and cysteine), carbohydrate (43%) and fat (Poulter & Caygill, 1980; Akyroyd & Doughty, 1982; Brough & Azam-Ali, 1992). Although the fat content of bambara groundnut seeds (6–8% of dry matter) is higher than that found in cereals, it is too low to be used as an oil source. Low levels of trypsin inhibitor and phenolic compounds have been identified in bambara groundnut seeds (Poulter & Caygill, 1980; Martino-Ferrer & Ferrer, 1983; Brough & Azam-Ali, 1992).

Considering the agronomic advantages of bambara groundnut as a security crop, it is surprising that it is not more widely grown and utilized. Some of the problems are probably cultural in origin whilst others need some technical input. Novel forms of bambara groundnut utilization might encourage wide production. Poulter and Caygill (1980) explored the production of a vegetable milk based on bambara groundnut and locally available oils. In this paper we describe the production of a simple milk suitable for manufacture at the village level. In addition, since the oil content of bambara groundnut is too low to give it a cash crop status, the possibilities of using extracted bambara groundnut protein in food processes which currently utilize soy protein were explored. It is evident that these processes would not be carried out in rural Africa, but soy protein is used extensively in the food industry, and if bambara groundnut protein was found to possess similar functionality properties to soy, then this might be one means of increasing its production and elevating it cash crop status. Standard protein functionality tests were carried out to compare the performance of bambara groundnut protein against standard proteins.

MATERIALS AND METHODS

Preparation of bambara groundnut milk

Preparation of bambara groundnut milk was a modification of the method of Akinyele (1991) for the extraction of cowpea milk. Bambara groundnuts (500 g) were soaked overnight, dehulled and resoaked for 24 h. The soaked sample (wet weight 830 g) was divided into two, half being used to prepare raw milk directly and the other half dry-fried to prepare pre-treated milk. Raw milk was prepared by homogenizing soaked beans with hot water (1:2 w/v), initially in a food processor to reduce the size, followed by high speed mixing (Silverson food mixer) to ensure a fine suspension of beans and water. The pre-treated milk was produced by lightly dry-frying the beans prior to homogenization (about 5 min depending on temperature, seed size and volume) until the colour became slightly translucent. After homogenization, the milks were strained through muslin. The residue remaining after straining was reserved for incorporation into further products. The volume, viscosity and colour of milks were recorded prior to compositional analyses and further processing (heating to 100°C for 1 min). A taste panel was conducted to determine the optimum method of production and to compare the four milk types with a commercial sample of soy milk.

Procedure for taste panel

Because Europeans are not familiar with vegetable milks, it was thought that the assessment of milk quality would be more valid if performed by African volunteers. Hence the taste panel consisted mainly of Africans (12) with six non-African volunteers. The tasters were presented with the five milk samples (A to E) (four bambara groundnut milks plus commercially produced soy milk) and asked to assess the colour, viscosity and taste by placing the sample on a scale of 1 to 5, where 1 was the least acceptable, 5 the most acceptable (in the case of viscosity, 5 represented the most viscous). Additionally, subjects were asked to rank the five samples in order of preference. Scores from 5 to 1 were allocated to the samples according to their ranked position, the highest ranked sample gaining a score of 5 and the lowest a score of 1. The scores of the ranked samples were analysed using the Kruskal–Wallis test for distribution-free statistics (Neave & Worthington, 1988).

The production of bambara groundnut milk was compared with that of other legumes common to Africa (cowpea and pigeonpea) and with soy milk prepared by the same process. All samples were dry-fried prior to extraction with hot water (1:2, seed : water). The colour and viscosity of each sample were measured and organoleptic properties assessed by a taste panel. Scores from 4 to 1 were allocated to the samples according to their ranked position, the highest ranked sample gaining a score of 4 and the lowest a score of 1. The scores of the ranked samples were analysed using the Kruskal–Wallis test for distribution-free statistics (Neave & Worthington, 1988).

Colour measurements

Milk colour was determined using a Hunterlab system which defines colour as a three-dimensional series of co-ordinates (**L*,a*,b***). Samples of milk were placed in flat-sided glass cuvettes (5 ml capacity) and the reflectance measured. The hue and chroma of each sample were calculated from the **a*** and **b*** values. Hue is expressed as an angle where 0° represents red, 90°C yellow, 180° green and 270° blue. Chroma indicates the strength of the colour and is dimensionless.

Functionality of bambara groundnut protein

Bambara groundnut protein isolate, prepared according to the method of Sefa-Dedeh and Yiadom-Farkye (1988), was used in standard food processing functionality tests.

Preparation of protein isolate
Bambara groundnut flour was shaken for 30 min in 0·1M NaOH (flour : NaOH, 1 : 10 w/v) and then centrifuged (5000*g*; 20 min). The pH of the supernatant was adjusted to 4·5 with 0·1 M HCl and the protein curd was separated by centrifugation (5000*g*; 20 min). The precipitated protein was washed with distilled water and centrifuged (5000*g*; 10 min). A slurry containing 10% solids was prepared and the pH adjusted to 7·0 using 0·1M NaOH. The freeze-dried protein isolate was analysed for protein content (Kjeldahl procedure) and used for basic functionality tests.

—Foam capacity and stability
—Gelation
—Emulsion capacity
—Angel cake preparation

In addition, the pH, viscosity and solubility properties of a 10% w/v protein solution were measured. Egg albumen (76% protein; Fisons Chemicals, Loughborough, UK) and isolated soy protein (91·5% protein; Protein Technologies International, St Louis, MO) were used as a comparison in all functionality tests.

Foam capacity and stability
Protein solution (20 ml; 2% w/v in distilled water) was placed in a graduated 250 ml cylinder and stoppered. After shaking vigorously, the respective volumes of liquid and foam were recorded. Foam stability was measured at 5 min intervals over a 1 h period.

Gelation
Screw-capped Universal bottles containing 15 ml protein solution (10% w/v in distilled water) were placed in an 80°C water bath. After 30 min incubation the tubes were removed, cooled under running water and the gel hardness measured with a Stevens LFRA Texture Analyzer fitted with a plunger (diameter 12 mm; speed 2 mm s^{-1}; penetration depth 4 mm).

Emulsion capacity
Corn oil (20 g) was thoroughly mixed with protein solution (5 ml; 2% w/v is distilled water) using an Ultra Turrax mixer. After centrifugation of duplicate 10 g samples of the homogeneous mix (3000 rpm, 5 min), the volume of free oil was estimated and the emulsion capacity of the protein calculated. The emulsion capacity of each protein was calculated from the increase in volume of the oil fraction following homogenization and centrifugation, and was expressed as a percentage of the original oil volume.

Angel cake preparation
A blend of protein powder (to supply 8·68 g protein), monocalcium phosphate (1·15 g), sodium chloride (0·95 g) and sucrose (24·13 g) was added to 72·00 g distilled water. The contents were whipped in a Kenwood mixer (speed, 1, 5 min) for reconstitution and then for a further 9 min (speed 2) to produce a foam. A mixture of icing sugar (52·93 g), plain flour (23·40 g), wheat starch (6·25 g) and sodium bicarbonate (0·25 g) was added to the foam and the resulting batter baked at 190°C for 25 min. When cool, height of the baked cakes was measured at several points and the texture determined using a Stevens LFRA Texture Analyzer fitted with a plunger (diameter 12 mm; speed 0·5 mm s^{-1}; penetration depth 4 mm).

RESULTS AND DISCUSSION

The objectives of this study were to make a simple vegetable milk which could easily be produced at the village level, with the minimum of input and without the need for fortification with other ingredients. Although the seeds were homogenized with a food processor and high-speed mixer, there should be no problems achieving this with traditional African grinding and pounding tools.

Production of bambara groundnut milks

Experience of milk production from cowpea, which is closely related to bambara groundnut, has shown that, in order to remove the beany taste associated with the legume milk, it is necessary to heat-treat the beans prior to homogenization. Raw bambara groundnut seeds also possess this beany taste and odour, hence bambara groundnut milk was prepared from heat-treated seeds.

Boiling the cotyledons for 10 minutes before extraction had no benefit over dry-frying in terms of flavour removal, but produced a more viscous, grey-coloured milk. Gelatinization of the starch during boiling also caused problems with straining through muslin. Thus, the dry-frying method combined with hot water extraction was adopted for the production of bambara groundnut milk.

The three components of milk quality deemed to be most important in terms of consumer acceptability were the colour, taste and viscosity. Both colour and viscosity were measured physically whilst all three parameters were assessed by a taste panel of volunteers. In addition, tasters were asked to rank all milk samples in terms of overall acceptability. Although sensory assessments were made by a group consisting of Africans and non-Africans, there were no differences of opinion between the two groups of people. Hence the results relate to overall perception.

Table 1. Comparison of methods of bambara groundnut milk production

Treatment	Colour[a]			Viscosity (cps)	Milk yield (litres/kg seed)
	L*	Chroma	Hue (deg)		
Raw:					
Hot Water extraction	64·68 ± 0·07	3·72 ± 0·32	118·3 ± 3·04	2·5	3·6
Boiled	66·44 ± 0·04	3·04 ± 0·24	124·6 ± 3·09	50	
Dry fried:					
Hot water extraction	66·32 ± 0·02	3·71 ± 0·26	121·0 ± 3·21	300	3·2
Boiled	63·81 ± 0·13	2·80 ± 0·33	141·8 ± 3·91	700	
Soy milk	68·99 ± 0·45	9·67 ± 0·38	98·5 ± 0·90	2·5	

[a] Values represent the mean ± standard deviation of three replicates.

Bambara groundnut milk samples were slightly lighter in colour than the cowpea milks (63·81 < **L*** < 66·44), with a hint of green (−2·19 < **a*** < −1·72) and yellow (1·74 < **b*** < 3·28). Commercial soy milk, however, was more yellow than both bambara groundnut and cowpea milks (**b*** = 9·56). Dry-frying the seeds prior to extraction had no deleterious effect on milk colour.

The viscosity of milk produced from dry-fried beans was greater than that produced from raw seed. Similarly, heat treatment of the extracted milk resulted in a more viscous solution (Table 1). It is highly likely that the thickening effect was due to gelatinization of starch present in the extract.

Taste panellists found the colour of the raw milk sample most acceptable, closely followed by the dry-fried milk (Table 2). The yellower colour of soy milk was less acceptable to these observers. The perceived viscosity of the bambara groundnut milk samples (Table 2) correlated with the recorded values in terms of order of ranking. The ranked viscosity of soy milk, however, was not in accord with the measured value (Tables 1 and 2). Candidates remarked that this sample was more creamy than the bambara groundnut milks. Presumably the increased oil content of the milk imparted a smoother mouthfeel texture which was incorrectly interpreted as increased viscosity.

Table 2. Ranked positions and organoleptic properties of the four milks prepared from bambara groundnut plus commercial soy milk. Values obtained from 15 panellists

Position	Ranking	Acceptability		
	Sample[a] (score)	Colour[b]	Viscosity[c]	Taste[b]
1	C(54)	A	B	C
2	D(53)	E	E	E
3	E(53)	D	C	D
4	B(37)	B	D	B
5	A(28)	C	A	A

[a] Raw; B Dry-fried, boiled; C soya; D Raw, boiled; E dry-fried.
[b] In terms of colour and taste, a position of 1 indicates the most acceptable product and 5 the least acceptable.
[c] In terms of viscosity, a position of 1 indicates the most viscous milk and 5 the least viscous.

In terms of taste, panellists found the soy milk sample (C) most acceptable, closely followed by the dry-fried (E) and boiled raw (D) bambara groundnut milks (Table 2). The beany flavour of the raw bambara groundnut sample (A) greatly reduced its acceptability. Application of the Kruskal–Wallis test of distribution-free statistics to the ranked results indicated that there were significant differences in acceptability of the five samples (Table 2).

Comparison of bambara groundnut milk with cowpea, pigeonpea and soybean milks

To evaluate bambara groundnut milks, a comparison with other vegetable milks was made. Samples of cowpea, pigeonpea and soybean milk were prepared under the same conditions used for bambara groundnut milk.

All milk samples were pale in colour (58·24 < **L*** < 70·48), soy milk being the lightest of the four. Both soy milk and pigeonpea milk were more yellow (**b*** = 9·19 and 9·48 respectively) than cowpea and bambara groundnut milks (Table 3). Taste panellists found the white colour of bambara groundnut milk and cowpea milk more acceptable than that of the yellow soybean and pigeonpea milks (Table 4).

The viscosity of the samples was assessed by the taste panel who ranked the samples in order of perceived viscosity (Table 4) and by viscometry (Table 3). There is no correlation between the sensory and instrumental data. Again it is possible that the creaminess of soy milk, due to the higher oil content, was wrongly interpreted as increased viscosity. Of the four samples, panellists found the bambara groundnut milk to be the least viscous, but not necessarily the least acceptable.

Table 3. Comparison of legume milks prepared from bambara groundnut, cowpea, pigeonpea and soybean

Treatment	Colour[a]			Viscosity (cps)	Milk yield (litres/kg seed)
	L*	Chroma	Hue (deg)		
Bambara:					
Dry-fried	63·95 ± 0·17	1·67 ± 0·02	168·3 ± 0·85	1 000	3·2
Cowpea:					
Dry-fried	62·66 ± 0·09	2·50 ± 0·03	135·5 ± 0·93	2 000	3·6
Pigeonpea:					
Dry-fried	58·24 ± 0·19	10·16 ± 0·49	111·0 ± 2·21	6 000	3·6
Soybean:					
Dry-fried	70·48 ± 0·36	9·40 ± 0·13	103·6 ± 1·40	0	3·2

[a] Values represent the mean ± standard deviation of three replicates.

Table 4. Ranked positions and organoleptic properties of vegetable milks produced from bambara groundnut, cowpea, pigeonpea and soybean. Values obtained from 12 panellists

Position	Ranking	Acceptability		
	Sample[a] (score)	Colour[b]	Viscosity[c]	Taste[b]
1	D(30)	D	B	D
2	A(29)	A	A	A
3	B(29)	B	C	B
4	C(22)	C	D	C

[a] A cowpea; B soybean; C pigeonpea; D bambara.
[b] In terms of colour and taste, a position of 1 indicates the most acceptable product and 4 the least acceptable.
[c] In terms of viscosity, a position of 1 indicates the most viscous milk and 4 the least viscous.

In terms of taste, milk prepared from bambara groundnut (D) was the most acceptable, followed by cowpea (A), soybean (B) and pigeonpea (C) (Table 4). This is in close agreement with the ranked results for the order of preference (Table 4). Application of the Kruskal–Wallis test to the ranked results indicated that there were no significant differences in acceptability of the four samples.

There was little difference in the total solids, protein content and efficiency of protein extraction for the two methods of milk production (Table 5). The recovery of protein in the extracted milk, however, averaged only 23%; thus the bean residue remains a valuable source of protein and should not be discarded. The possibility of incorporating the residue into other food and feed products should be considered.

Protein functionality tests

A crude protein extract was prepared as described in Materials and Methods. The yield of extract was 17·6% (dry solids basis) with a protein content of 76%.

The ability of extracted bambara groundnut protein to form and maintain a foam was rather poor in comparison to egg albumen and slightly inferior to soy isolate (Fig. 1). However, observations made during the high speed homogenization of raw bambara groundnut

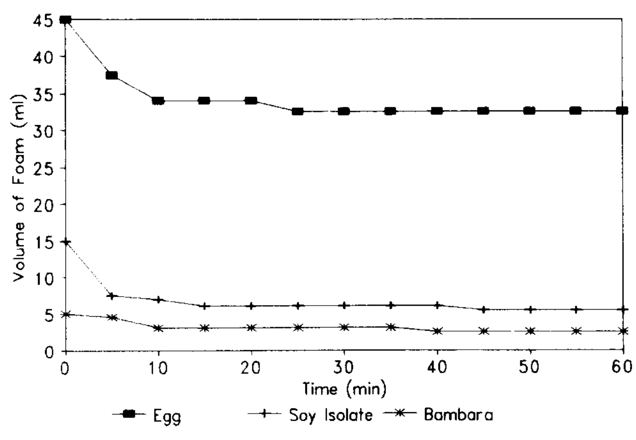

Fig. 1. The volume of foam (ml) maintained by egg albumen, soy isolate and bambara groundnut protein over a 1 h period.

Table 5. The total solids (% DM), protein (% DM) and % protein recovery of raw and cooked bambara groundnut milks

Sample	Total solids (% DM)	Protein (% DM)	% Protein recovery
Raw milk	10·37	19·8	23·9
Cooked milk (dry-fried)	9·37	23·1	22·5

Table 6. Viscosity, pH, solubility properties, gelation and emulsion capacity of egg albumen, soy isolate and bambara groundnut protein

	Egg albumen	Soy isolate	Bambara
Viscosity[a] (cps)	200	5 500	50
pH[a]	7·13	7·28	6·54
Solubility[a] (%)	81·6	14·6	41·4
Gel puncture test[a] (g)	261	10	4
Emulsion capacity[b] (%)	6·25	10·0	5·0

[a] 10% (w/v) solution.
[b] 2% (w/v) solution.

Table 7. Properties of angel cakes prepared from egg albumen, soy isolate and bambara groundnut protein

	Egg albumin	Soy isolate	Bambara
Centre height (cm)	3·87	2·87	3·07
Edge height (cm)	2·87	2·07	2·17
Cake puncture test: top (g)	56·7	209·7	165·7
Cake puncture test: bottom (g)	61·7	152·0	120·7

milk indicated that the whole seed flour was capable of forming a fairly stable foam. This suggests that the harshness of the protein extraction procedure was deleterious to the functionality. Similarly, bambara groundnut protein was inferior to both soy isolate and egg albumen as a gelling agent and an emulsifier (Table 6).

The cake puncture test gives an indication of the texture and 'lightness' of the cake while the cake height measurements show the extent to which the batter has risen. These are both functions of the ability of the protein to trap air and maintain a structure (Table 7). Bambara groundnut protein produced an angel cake with a more dense texture than egg albumen, but lighter than the soy isolate. The centre and edge heights of the bambara groundnut cake were also intermediate to the egg albumen and soy isolate, egg albumen again being superior. Bambara groundnut produced a darker cake than the other two flours. This is a consequence of including red seed coats in the flour and can be removed if the seeds are de-hulled prior to grinding or if white seeds coat varieties are used.

CONCLUSIONS

The simple vegetable milk produced from bambara groundnut was as acceptable as milks from other common legumes, notably cowpea and soybean, and was slightly preferable to pigeonpea milk, although this difference was not significant.

One of the main assets of milk produced from this particular landrace of bambara groundnut is that the white seeds give a highly acceptable pale coloured milk. Care would have to be taken when using other landraces as there may be variation in seed colour. It is evident from the taste panel sensory analysis that white milks were preferable to the yellow milks of soybean and pigeonpea.

The taste panellists also preferred the taste of bambara groundnut milk to the other legume milks tested but they did not specify which aspect of the taste they found appealing. It must be noted that it was always necessary to heat-treat the soaked seeds prior to homogenization to remove the beany taste. Boiling the beans prior to extraction was unacceptable as it led to the gelatinization of starch which greatly hampered straining through the muslin cloth and consequently reduced the total volume of milk. However, dry-frying the beans proved effective.

It is encouraging that an acceptable vegetable milk can be produced from bambara groundnut seeds as one potential use of this process is in the production of low cost weaning foods. A combination of poverty, food shortage and parental ignorance regarding the nutritional requirements of the infant means that weaning infants are particularly prone to malnutrition. Vegetable milk production is a simple, non-time-consuming process which could benefit weaning children in developing communities. An added advantage of producing weaning foods from bambara groundnut is that it is a local seed; hence costs will be low and mothers are already familiar with the seed.

Vegetable milks from soybean are now an acceptable product. However, soybeans are not widely grown in Africa, making these products extremely expensive and unavailable to the poorer sections of the community. It would seem more logical to promote vegetable milk production from native species, especially one with such agronomic advantages as bambara groundnut, than to import expensive infant feed formulae. There is no need to wait until there is a drought to cultivate bambara groundnut. Instead we can exploit the evidence that this hardy crop tolerates a range of soils and water conditions, is relatively free of pests and diseases, in optimal growing conditions yields as much as groundnut and, above all, is indigenous to Africa.

If farmers can be assured that there is a market for bambara groundnut, they might be encouraged to increase production. However, they usually prefer to gamble that groundnut, for which they have a market for the oil, will produce good yields. Therefore, they only produce enough bambara groundnut for the family requirements. Perhaps the promotion of bambara groundnut milk as a suitable infant food is one means of providing a market for the seeds.

Unfortunately, the energy value and composition of the milks, nitrogen excepted, was not measured in this study and it was not possible to perform any digestibility measurements. Clearly this latter parameter is highly important in the production of weaning milks, and further work in this area should be considered.

Regarding the protein content, this extraction procedure recovered only 23% of the initial protein. Hence, there is a need to improve the extraction method if this idea is to be adopted on a larger scale.

Another area of concern in the suitability of bambara groundnut milk for infant feeding is the presence of anti-nutritional factors. Previous reports mention that bambara groundnuts contain only tannins and low levels of trypsin inhibitor (Poulter & Caygill, 1980; Martino-Ferrer & Ferrer, 1983; Brough & Azam-Ali, 1992), but it is possible that the levels of these components will vary with different landraces. Most tannins are contained within the seed coat; hence this problem is largely removed when milk is produced. If the vegetable milk is pasteurized after production, it is possible that the heat-labile trypsin inhibitors will be denatured.

To increase the energy content of the milk and improve its nutritional value as a weaning food, it is possible to add oil to the final product (Poulter & Caygill, 1980), but this practice will increase the overall cost.

With respect to oligosaccharides, the main causes of flatulence and diarrhoea associated with the consumption of legumes, there has been no work carried out in this laboratory to identify the oligosaccharides, but other reports suggest that the concentration in bambara groundnut is low (Dixon-Phillips & Abbey, 1989).

In terms of protein functionality, the extracted protein from bambara groundnut was inferior to both egg albumen (the standard reference protein) and soy isolate in most of the basic tests. Hence it would not be recommended that bambara groundnut protein be marketed commercially as a functional protein. It is possible that the extraction procedure was too harsh and resulted in some loss of functionality of the bambara groundnut protein.

To develop the status of bambara groundnut, improved milk production seems to offer the best hope in developing countries. An improved extraction of protein may assist in developing a weaning food based on bambara groundnut.

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