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PRODUCTION AND EVALUATION OF A FUNCTIONAL BREAKFAST MEAL FROM ACHA (DIGITARIA EXILIS) AND BAOBAB (ADANSONIA DIGITATA) FRUIT PULP

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ABSTRACT

Breakfast is the meal most often skipped, yet it contributes substantially to dietary quality, concentration and academic performance. Conventional breakfast cereals rely on wheat, barley and sorghum, which are costly and difficult to cultivate in much of northern Nigeria. This study developed a low-cost functional breakfast meal from acha (*Digitaria exilis*), an underutilised gluten-free West African cereal, and baobab (*Adansonia digitata*) fruit pulp, a source of vitamin C, minerals and soluble fibre. Five blends were formulated: 100% acha (A) and acha:baobab ratios of 70:30 (B), 60:40 (C), 50:50 (D) and 40:60 (E). The blends were analysed for functional properties (bulk density, water absorption capacity, swelling index and gelatinisation temperature) and proximate composition using standard methods, and were evaluated by 12 panellists on a nine-point hedonic scale. Baobab inclusion raised ash from 3.95% to 5.54–5.99% and carbohydrate from 74.29% to 77.63–78.42%, and lowered moisture from 9.01% to 7.07–7.38%, fat from 2.07% to 1.20–1.40% and crude protein from 6.29% to 3.15–4.27%. Water absorption capacity rose from 1.21 to 1.42 g/g while swelling index fell from 1.81 to 1.43. Mean sensory scores lay between 7.42 and 8.17 ("like moderately" to "like very much") for all attributes, and two-way ANOVA showed no significant difference among the blends ($p > 0.05$). Acha and baobab fruit pulp can therefore be combined at up to 60% baobab to produce an acceptable, mineral-rich breakfast meal, although protein supplementation is advisable at higher baobab levels.

Keywords: Acha; Fonio; Baobab Fruit Pulp; Functional Food; Breakfast Meal; Proximate Composition; Sensory Evaluation

1 INTRODUCTION

Breakfast makes an important contribution to dietary quality and overall health, yet it is skipped more often than any other meal (Utter et al., 2007). Breakfast consumption has declined across all age groups over recent decades, most notably among adolescents aged 15–18 years and older adults (Australian Bureau of Statistics, 1995; Siega-Riz et al., 1998; Keski-Rahkonen et al., 2003). Among adolescents, skipping breakfast is associated with a higher body mass index (Vanelli et al., 2005). Those who eat breakfast make better food choices through the day, while those who skip it rarely

compensate at later meals (Nicklas et al., 2000). Breakfast quality therefore bears on nutrient intake, concentration and academic performance.

Foods that confer health benefits beyond basic nutrition are described as functional foods (Diplock et al., 1999; Saris et al., 2002). They are not medicines. Rather, they restore, reinforce or maintain normal body processes, or reduce factors linked to the risk of disease. Most commercial breakfast cereals are made from wheat, barley or sorghum, which are expensive and difficult to cultivate in parts of northern Nigeria. There is therefore a case for nutritious, affordable breakfast products made from locally available raw materials.

Acha (fonio, *Digitaria exilis*) is a West African cereal that is gluten-free and comparatively rich in the sulphur amino acids methionine and cystine (Jideani & Akingbala, 1993; National Research Council, 1996). Acha products are recommended as a carbohydrate source for people with diabetes (Chukwu & Abdul-kadir, 2008). Baobab (*Adansonia digitata*) fruit pulp is rich in vitamin C, minerals, soluble fibre and antioxidants, and is used traditionally to treat fevers, diarrhoea and malaria (Buchmann et al., 2010; Kamatou et al., 2011). Combining the two could yield a breakfast meal with functional value at low cost.

The aim of this study was to produce a nutritious and affordable breakfast meal for low-income consumers from acha and baobab fruit pulp. The specific objectives were to:

- Determine the proximate composition and functional properties of acha–baobab blends; and
- Assess the sensory acceptability of the resulting breakfast meals.

2 LITERATURE REVIEW

2.1 Breakfast and its definition

The meaning of breakfast has varied across cultures and generations, which makes it difficult to study as a single meal. Researchers have defined it as any solid food eaten before school or before 11 a.m. at weekends, or, in a summer sports camp, any food or drink taken between 6 and 8 a.m. (Vanelli et al., 2005). Others treat breakfast as whatever respondents themselves consider breakfast (Cho et al., 2003). Whatever the definition, regular breakfast eaters show better nutrient intakes and healthier body weights than skippers (Nicklas et al., 2000; Utter et al., 2007).

2.2 Functional foods

The systematic study of food functionality began in Japan in the 1980s, leading in 1991 to the legal category "Foods for Specified Health Use". In Europe, the Functional Food Science in Europe (FUFOSE) concerted action defined a functional food as one shown to benefit one or more target functions in the body beyond adequate nutrition, in a way relevant to improved health or reduced disease risk (Diplock et al., 1999). Target functions include early growth and development, energy balance and body weight, cardiovascular function, defence against oxidative stress, gut function, mental performance and physical fitness (Saris et al., 2002). A functional food may be a natural unmodified food, or one in which a component has been added, removed, enhanced, replaced or made more bioavailable.

2.3 Acha (fonio)

Acha is probably one of the oldest African cereals, cultivated for thousands of years across the dry savannahs of West Africa (Chukwu & Abdul-kadir, 2008). It is grown in Nigeria, Sierra Leone, Ghana, Guinea-Bissau, Senegal, Togo, Mali, Benin and Côte d'Ivoire. White acha (*D. exilis*) is the more widely grown variety in Nigeria, while black acha (*D. iburua*) is rarely cultivated. The crop is so neglected that it has been called a "lost crop of Africa" (National Research Council, 1996). It is hardy, grows on poor soils and matures early, which has earned it the name "hungry rice" (Ibrahim, 2001).

The grains are tiny, with 1,000 grains weighing 0.6–0.7 g, and the husk makes up about 24% of grain weight (National Research Council, 1996). Acha contains about 7–9% crude protein and 75% carbohydrate. Its protein is high in leucine (9.8%), methionine (5.6%) and valine (5.5%), and contains almost twice as much methionine as egg protein (Jideani & Akingbala, 1993). Table 1 summarises its mineral composition. Acha's fibre aids digestion and satiety (Anderson et al., 2009), and its low glycaemic response underlies its use as a food for people with diabetes (Chukwu & Abdul-kadir, 2008).

Table 1: Mineral composition of acha grain (mg/100 g)

Mineral	Content
Potassium	215.82
Phosphorus	131.00
Magnesium	46.02
Sulphur	32.40
Calcium	28.17
Iron (ppm)	22.82
Manganese (ppm)	21.73
Sodium	11.30

Source: Chukwu and Abdul-kadir (2008).

2.3.1 Baobab fruit pulp

Baobab is a large, culturally important tree native to sub-Saharan Africa (Wickens, 1982). The genus name honours Michel Adanson, who described the tree after visiting Senegal in 1754, and *digitata* refers to its hand-shaped leaves (Kamatou et al., 2011). More than 300 traditional uses of its leaves, bark, seeds and pulp have been recorded across Africa (Buchmann et al., 2010). In northern Nigeria, the leaves are used in soups such as *miyan kuka*, and Fulani and Hausa herders mix the pulp with milk as a drink. The European Commission authorised baobab pulp as a novel food in 2008, and the United States approved it as a food ingredient in 2009 (Addy, 2009).

Baobab pulp is notable for its vitamin C content, reported at almost ten times that of orange, and for its potassium and calcium (Table 2). About half of its dietary fibre is soluble and has prebiotic effects on lactobacilli and bifidobacteria (Leatherhead Food Research, 2009). Its vitamin C enhances iron absorption, and the pulp has been reported to slow starch digestion and blood glucose rise, increase satiety, and protect the liver and heart in animal studies (Leatherhead Food Research, 2009; Kamatou et al., 2011).

Table 2: Mineral and vitamin composition of baobab fruit pulp (mg/100 g)

Nutrient	Content
Potassium	2,390
Calcium	370
Magnesium	179
Vitamin C	163
Phosphorus	73.3
Sodium	31.1
Iron	9.13
Manganese	1.30
Zinc	1.02
Copper	0.75
Thiamin	0.09
Riboflavin	0.03

Source: Leatherhead Food Research (2009).

2.4 Research gap

Acha has been studied mainly as a staple and baobab pulp mainly as a beverage or drink ingredient. Little work has examined their combination as a ready-to-eat breakfast meal, or how baobab inclusion affects the composition, functional behaviour and acceptability of acha-based products. This study addresses that gap.

3 MATERIALS AND METHODS

3.1 Materials

Baobab fruits were purchased from Kaura Namoda market and acha grains from Kaduna market, Nigeria. Equipment and utensils were obtained from the food processing laboratory of the Department of Food Science and Technology, Federal Polytechnic, Kaura Namoda.

3.2 Sample preparation

Baobab pods were broken open with a knife and the pulp-coated seeds collected in a tray. These were pounded in a mortar, the fibrous threads and seeds removed by hand, and the powder sieved through a 40-mesh sieve. Acha grains were sorted and washed thoroughly to remove dirt and foreign materials. The two components were mixed in the proportions in Table 3, milled, sieved through muslin cloth, packaged and labelled (Figure 1).

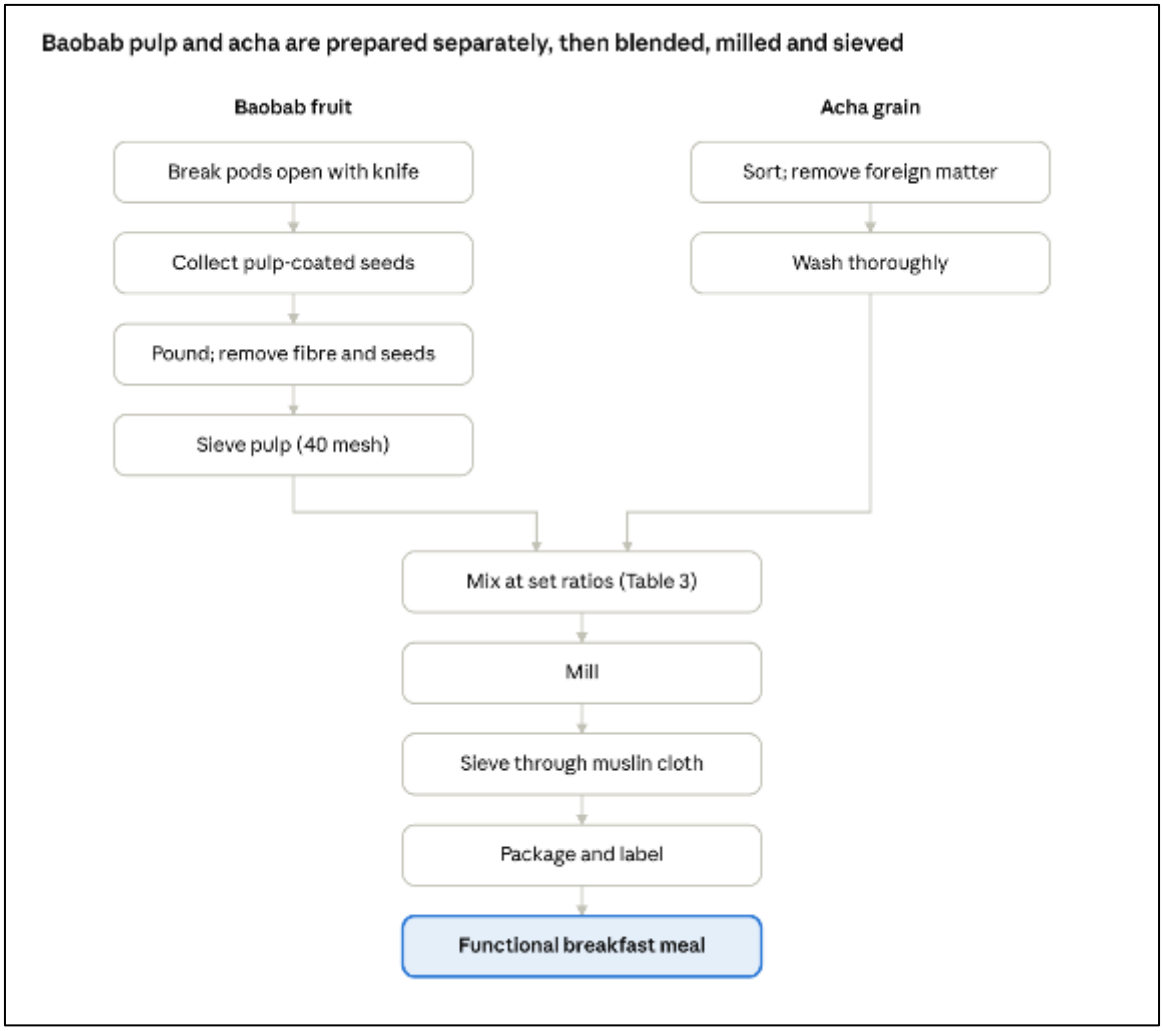

Figure 1: Flow chart for the production of acha–baobab breakfast meal

Table 3: Formulation of acha–baobab breakfast blends

Sample	Acha (%)	Baobab pulp (%)
A (control)	100	0
B	70	30
C	60	40
D	50	50
E	40	60

3.3 Functional properties

- **Bulk density** was determined by weighing 5 g of sample into a 100 mL graduated cylinder, tapping it ten times, and dividing the mass by the settled volume (g/mL) (Akinjayeju, 2002).
- **Water absorption capacity** was determined by mixing 1 g of sample with 10 mL distilled water for 30 s, standing it for 30 min at room temperature, and centrifuging at 5,000 × g for 30 min. The volume of free water was read from the graduated tube (Onwuka, 2005).
- **Swelling index** was determined by placing 5 g of sample in a 100 mL graduated cylinder, adding water to 100 mL, stirring, and standing for 30 min (Onwuka, 2005). The swelling index was calculated from the initial (V_1) and final (V_2) volumes: \text{Swelling index} = \frac{V_2 - V_1}{V_1}
- **Gelatinisation temperature** was taken as the temperature at which a heated aqueous suspension of the sample formed a gel (Onwuka, 2005).

3.4 Proximate analysis

Moisture was determined by oven drying 5 g of sample at 105 °C to constant weight (AOAC, 1990). Ash was determined by incinerating 5 g of sample in a muffle furnace at 500 °C until a light grey ash was obtained (AOAC, 1990). Crude fat was extracted from 2 g of sample with petroleum ether (40–60 °C) in a Soxhlet apparatus for 6 h (Onwuka, 2005). Crude protein was determined by the micro-Kjeldahl method (N × 6.25) (Onwuka, 2005). Crude fibre was determined by successive digestion with boiling dilute sulphuric acid and sodium hydroxide, followed by drying and ashing of the residue (AOAC, 1990). Carbohydrate was calculated by difference:

$$\text{CHO}\,(\%) = 100 - (\text{moisture} + \text{protein} + \text{fat} + \text{ash} + \text{crude fibre})$$

3.5 Sensory evaluation

The five breakfast meals were presented in coded cups to a panel of 12 untrained panellists. Each panellist rated taste, colour, texture, aroma, flavour and overall acceptability on a nine-point hedonic scale, where 1 = dislike extremely, 5 = neither like nor dislike and 9 = like extremely (Larmond, 1977).

3.6 Statistical analysis

Proximate analyses were carried out in duplicate and reported as mean ± standard deviation; means were separated at $p < 0.05$. Sensory scores were analysed by two-way analysis of variance (ANOVA) with samples and panellists as factors. Each F ratio was compared against the critical value $F(4, 44) = 2.58$ at the 5% level of significance.

4 RESULTS

4.1 Functional properties

Baobab inclusion increased water absorption capacity and lowered swelling index and gelatinisation temperature (Table 4). Bulk density ranged from 0.51 to 0.83 g/mL, with the 50:50 blend (D) highest.

Table 4: Functional properties of acha–baobab breakfast blends

Sample (acha:baobab)	Bulk density (g/mL)	Water absorption capacity (g/g)	Swelling index	Gelatinisation temperature (°C)
A (100:0)	0.62	1.21	1.81	60
B (70:30)	0.60	1.26	1.78	59
C (60:40)	0.51	1.30	1.62	59
D (50:50)	0.83	1.42	1.52	58
E (40:60)	0.63	1.41	1.43	58

4.2 Proximate composition

Adding baobab pulp raised ash and carbohydrate and lowered moisture, fat and crude protein relative to the 100% acha control (Table 5). Crude protein fell by half, from 6.29% in A to 3.15% in E. Ash rose by up to 52%, from 3.95% to 5.99% in C. Crude fibre (4.00–4.38%) and carbohydrate (74.29–78.42%) did not differ significantly among samples.

Table 5: Proximate composition of acha–baobab breakfast blends (%)

Sample (acha:baobab)	Moisture	Ash	Crude fibre	Crude fat	Crude protein	Carbohydrate
A (100:0)	9.01 ± 0.63^{b}	3.95 ± 0.77^{a}	4.38 ± 0.66^{a}	2.07 ± 0.25^{b}	6.29 ± 0.71^{c}	74.29 ± 3.04^{a}
B (70:30)	7.07 ± 0.77^{a}	5.54 ± 0.92^{ab}	4.27 ± 0.60^{a}	1.20 ± 0.14^{a}	4.27 ± 0.17^{b}	77.63 ± 2.62^{a}
C (60:40)	7.19 ± 0.43^{a}	5.99 ± 0.57^{b}	4.25 ± 0.07^{a}	1.23 ± 0.12^{a}	3.41 ± 0.09^{ab}	78.30 ± 0.73^{a}
D (50:50)	7.19 ± 0.26^{a}	5.93 ± 0.52^{b}	4.20 ± 0.31^{a}	1.38 ± 0.02^{a}	3.20 ± 0.44^{a}	78.09 ± 1.52^{a}
E (40:60)	7.38 ± 0.60^{a}	5.65 ± 0.63^{ab}	4.00 ± 0.28^{a}	1.40 ± 0.07^{a}	3.15 ± 0.07^{a}	78.42 ± 1.66^{a}

Values are mean ± SD. Within a column, values with different superscripts differ significantly ($p < 0.05$).

4.3 Sensory evaluation

All five meals were well liked, with mean scores between 7.42 and 8.17 on every attribute (Figure 2). The 40:60 blend (E) scored highest for overall acceptability (8.00) and texture (8.17), and the 70:30 blend (B) lowest for overall acceptability (7.42).

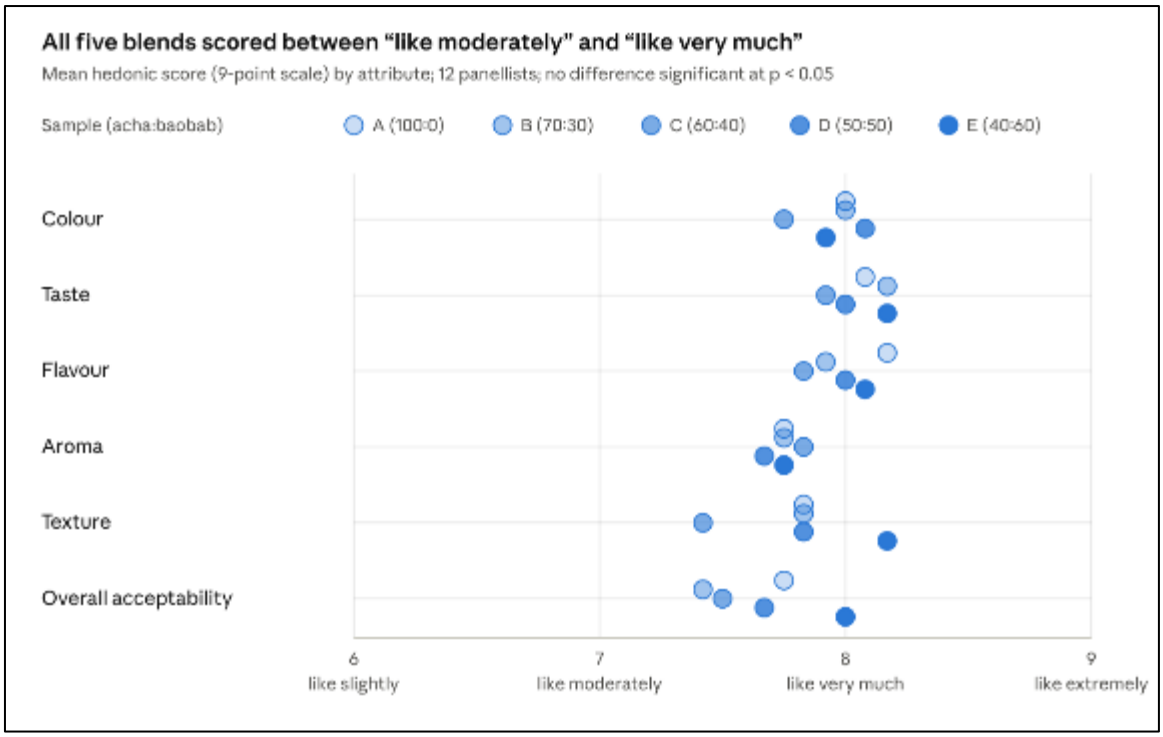

Figure 2: Mean sensory scores of acha–baobab breakfast meals (n = 12 panellists)

Two-way ANOVA found no significant effect of blend on any attribute (Table 6). Every F ratio for samples (0.04–0.63) fell well below the critical value of 2.58.

Table 6: Two-way ANOVA of sensory scores (df: samples = 4, panellists = 11, error = 44)

Attribute	SS samples	SS panellists	SS error	F (samples)	p
Colour	0.77	6.45	25.63	0.33	0.857
Taste	0.57	5.73	31.43	0.20	0.938
Texture	3.40	16.58	59.00	0.63	0.641
Aroma	0.17	8.45	42.63	0.04	0.996
Flavour	0.83	5.60	29.57	0.31	0.870
Overall acceptability	2.50	4.53	64.30	0.43	0.788

F critical (4, 44; $\alpha = 0.05$) = 2.58. No attribute differed significantly among samples.

5 DISCUSSION

5.1 Functional properties

Bulk density (0.51–0.83 g/mL) showed no consistent trend with baobab level, with the 50:50 blend (D) markedly denser than the others. Bulk density governs packaging volume and the amount of powder per serving. The higher value for D suggests that more product can be packed into a given volume, which favours packaging and transport economy (Onwuka, 2005). The irregular pattern may reflect differences in particle size after milling and sieving rather than an effect of formulation.

Water absorption capacity rose steadily from 1.21 g/g in the acha control to 1.41–1.42 g/g in the high-baobab blends (D and E). Baobab pulp is rich in soluble fibre and pectin, which bind water (Leatherhead Food Research, 2009). Higher water absorption is desirable in a reconstituted breakfast meal because it promotes a thick, porridge-like consistency. Swelling index, by contrast, fell from 1.81 to 1.43 as acha was replaced. Swelling is driven mainly by starch granules imbibing water, so diluting acha starch with baobab pulp reduced it. Gelatinisation temperature also dropped slightly, from 60 °C to 58 °C, indicating that the high-baobab blends would thicken at marginally lower cooking temperatures.

5.2 Proximate composition

Moisture fell from 9.01% in the control to 7.07–7.38% in the blends, reflecting the low moisture of dried baobab pulp. All values were below 10%, the level generally regarded as safe for shelf-stable flours. They are comparable to the 8.89–10.60% reported for stored acha powder by Sarkar et al. (2014). Low moisture limits microbial growth and extends shelf life.

Ash content rose from 3.95% to 5.54–5.99% with baobab inclusion. This is consistent with the high potassium, calcium and magnesium content of baobab pulp (Table 2) and indicates a richer mineral profile in the blended products. Since ash reflects total minerals, the blends are likely to contribute more calcium and potassium per serving than acha alone.

Crude protein fell from 6.29% to 3.15% as the proportion of acha decreased, because baobab pulp is low in protein. The 100% acha value agrees with the 6.5–9.0% range reported for acha grain (Jideani & Akingbala, 1993; National Research Council, 1996). Fat fell from 2.07% to 1.20–1.40%, again reflecting dilution of the cereal. Crude fibre was statistically similar across samples (4.00–4.38%), and carbohydrate was high in all blends (74.29–78.42%), confirming the meals as energy foods. The fall in protein is the main nutritional trade-off of higher baobab levels and should be offset by a protein-rich complement such as legumes or milk.

5.3 Sensory acceptability

All five meals were rated between "like moderately" and "like very much" on every attribute, and no attribute differed significantly among blends. Baobab pulp therefore did not impair colour, taste, aroma, flavour or texture, even at 60% inclusion. The 40:60 blend (E) scored highest for texture and overall acceptability. This suggests that the tart flavour of baobab was welcomed rather than rejected. Because acceptability was maintained across the range, formulators can choose a blend on nutritional or cost grounds without loss of consumer appeal.

Taken together, the 50:50 to 40:60 blends offer the best balance of higher minerals, better water absorption and unchanged acceptability. Their lower protein, however, means that they should be eaten with a protein source or fortified.

6 CONCLUSION

A functional breakfast meal was successfully produced from acha and baobab fruit pulp. Replacing up to 60% of acha with baobab pulp increased ash (mineral) content and water absorption capacity and lowered moisture, which favours shelf stability. It also reduced crude protein and fat. All blends were well accepted, with mean scores of 7.42–8.17 on a nine-point scale and no significant sensory difference among them. Acha and baobab fruit pulp are therefore suitable, locally available ingredients for an affordable functional breakfast meal, and they add variety to diets otherwise based on imported or costly cereals.

Recommendations

- The 50:50 and 40:60 acha–baobab blends are recommended for further development, as they combine the highest mineral content and water absorption with full sensory acceptability.
- To offset the lower protein of high-baobab blends, the meal should be fortified with a protein-rich ingredient such as soybean, groundnut or milk powder, or served with milk.
- Further studies should determine the antioxidant activity, vitamin C retention, specific minerals and antinutrient content (e.g. phytate, tannin and oxalate) of the product.
- Shelf-life and packaging studies should be carried out to establish storage stability under ambient tropical conditions.
- Larger consumer acceptability trials, including children and low-income households, are needed before commercial production.

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