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Improving nutritive value of fermented cereal porridge 'Ogi' by fortifying with Bambara nut

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ABSTRACT

Ogi, a fermented cereal porridge made from maize (*Zea mays*), sorghum (*Sorghum vulgare*) or millet (*Pennisetum typoideum*), experiences nutritional loss during traditional method of production. Hence, this study was undertaken to improve the nutritive value of 'Ogi' by fortifying with Bambara nut, a nutritious legume rich in carbohydrate, moderate protein and low fat. Fortification ratio of Bambara to the commonly known substrates (maize, millet and sorghum grains) was 2:3 while the control was constituted with equal quantity of substrate without Bambara. Traditional process including steeping, grinding, sieving and souring was used. Microbiological and physicochemical analysis were carried out on the resulting fortified and unfortified Ogi at 0, 24, 48 and 72 hours during primary fermentation and at 0, 24 and 48 hours during secondary fermentation. Bacteria isolated include *Lactobacillus fermentum, L. plantarum, Bacillus subtilis, Flavobacterium rigense, Proteus vulgaris, Flavobacterium aquantile* and *Bacillus alvei* and the fungi include *Geotrichum candidum, G. fermentum, Penicillium atrovene, Aspergillus niger, Rhizopus oryzae,* etc. Reduction in pH of the fermenting substrates was noticed as fermentation progressed and this was accompanied with increase in total titratable acid (TTA) in all cases. Temperature was constant at 30 ± 2 °C. Proximate analysis of the final products revealed that more than 100% nutrient improvement in protein composition in fortified Ogi from sorghum and maize and 53.82% nutrient improvement in fortified Ogi from millet. There is also increase in the fat content of the fortified Ogi from sorghum, maize and millet by 38%, 57% and 174% respectively. Fortifying these cereals with Bambara nut also improved the ash content of sorghum and maize 'ogi' by 23.89% and 15.33%. The organoleptic assessment designed to measure appearance, sourness, flavour, taste, aroma/smell, acceptability and comparability among 32 untrained panellists at overall acceptability at 5% confidence level revealed that fortified Ogi made from maize was the most acceptable.

Introduction

Bambara nut (*Vigna subterranea*) is a leguminous crop that belongs to the family *Fabaceae*. It originates from West Africa (Hepper, 1963) and the region of cultivation is sub-Saharan Africa's warm tropics (Nichterlein, 2011). It is the third most important member of the leguminous crops family after cowpea and groundnut (Ocran, 1998). It is rich in proteins, carbohydrates, minerals and fats and is very easy to cultivate as it does well in averagely fertile lands where other legumes would fail. Bambara nut is very good for land care as it fixes nitrogen in the soil (FAO, 2011). It requires less rainfall and this explains why it does well in most parts of Africa. It is known for its

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high nutritive value with 65% of carbohydrates, 18% of proteins and 6.5% of fat content (Doku, 1995).

Despite the aforementioned qualities of this crop, it has been relegated to the background over the years by stakeholders in agriculture and food science. This is partially due to little or no mechanisation breakthrough in its farming which discourages a lot of large scale farmers from planting it. Also, in some parts of Africa it is economically stigmatised as a poor-man's food so much that those who sell or buy it do so at night in their homes (Barimalaa, 1994). Most cultures in Africa also see it as a woman's crop and so make it suffer less priority during land allocation by the head of the family (Rassel, 1960). The extent of neglect that this crop has suffered has resulted in its classification by Food and Agricultural Organisation (FAO) as Nutritious Underutilised Species (NUS) (FAO, 2011).

'Ogi', on the other hand, is a food commonly taken in most parts of Africa. It is a staple cereal of most average Nigerian homes. It is prepared by soaking any of millet, sorghum and maize for 2-3 days followed by wet-milling and sieving through a screen mesh. The sieviate is allowed to sediment and the supernatant is decanted. The sieviate is what is now made into "Pap". As a result of the method of preparation, a lot of nutrients are lost during the process (Afolabi et al., 2015; Ajanaku et al., 2012). During the production of 'ogi', several bacteria, mould and yeast have been isolated over the years and they include *Corynebacterium, Lactobacillus, Aspergillus, Fusarium, Penicillium, Cephalosporium, Zygosaccharomyces, Saccharomyces*, etc.

The most important use of 'ogi' in Africa is for weaning (Omemu, 2011). However, 'ogi' is so poor in essential nutrients that children weaned entirely on 'ogi' are known to suffer from protein-energy malnutrition-PEM (Mbata, 2009). Hence, there is need to consider the fact that a child's development and growth is directly related to access to appropriate diet especially during the first two years of his life (Mbata, 2009). 'Ogi' has also been a food of choice for people recuperating from ailments in Nigeria and Africa (Afolabi et al., 2015).

Several efforts have been made over the years to improve the nutritive content of 'ogi' mostly in form of fortification and process modification with the use of soya bean, okra seed, amino acids, pawpaw, groundnut, pigeon pea, crayfish, sesame seed to mention but a few (Banigo and Muller, 1972; Banigo et al., 1974; Adeniji and Potter, 1978; Aminigo and Ossai, 1999; Aminigo and Akingbala, 2004; Adelekan and Oyewole, 2010; Ajanaku et al., 2012; Ajanaku et al., 2013; Akinrinola et al., 2014). However, despite the fact that most of these efforts resulted in 'ogi' with good protein, mineral and fat contents, they ended up with unpleasant rheological and organoleptic properties which adversely affected their acceptance (Osungbaro, 2009).

One of the reasons believed to be responsible for the problems above is the use of crops that are not indigenous to the people such as soya bean. Others include the nature of the fortifier (slimy nature of Okra) aroma and flavour of some (sesame seed) inadequate or lack of carbohydrate in the fortifier (pigeon pea). Consequently, scientists continue to look for better ways, crops and approaches to solve the above-mentioned problems.

Therefore, this study was undertaken to improve the nutritive value of 'ogi' by fortification with Bambara nut, a nutritious legume rich in carbohydrates, moderate in proteins and low in fats.

Materials and methods

The collection of samples

Six kilograms of each, Bambara nut (*Vigna subterranean*), maize (*Zea mays L.*), millet (*Pennisetum typoideum*) and sorghum (*Sorghum vulgare*), were purchased from Ajoke Market in Oka-Akoko, Ondo State, Nigeria. They were all transported to the laboratory in clean, well-tied polythene bags for later use.

The preparation of samples

All the substrates were meticulously checked and cleaned by removing impurities such as stone, pieces of wood, infested seeds and other particles. They were then washed with clean water.

The preparation of ogi samples

Fortification level with Bambara nut was 40% for each of the grains based on a modified method of Mbata et al. (2009). The grains were steeped separately and also in five different combinations, i.e. 40% Bambara + 60% of millet, sorghum and maize, 100% Bambara and the control which is equal quantity of maize, millet and sorghum. They were steeped for 72 hours. These were done in triplicate. The steeped grains were recovered by decanting the steeping water and then wet-milled using a mill that had been sterilized with hot water and ethanol. The sterilisation was also done after grinding each of the substrates. They were then sieved using the common traditional sieve. This was concluded with the souring stage of 48 hours.

Microbiological analysis

One gram of the fermenting substrates was taken at 24 h intervals (0, 24, 48 and 72 h). These were then homogenized in 9 ml of sterile distilled water for 30 s. The mixture was serially diluted in sterile distilled water as described by Olutiola et al. (1991) and from the 10-fold dilution, colony-forming units (CFU) were determined using the spread plate method. Spread plate counts were carried out using nutrient agar **(**Lab M Limited, Lancashire, UK**)** at 37 °C for 48 hours, potato dextrose agar (Lab M Limited, Lancashire, UK) at 28 °C for 72 hours and MacConkey agar (Oxoid, UK) at 37 °C for 48 hours.

The isolation and characterization of bacteria

Based on the previously mentioned time interval, i.e. 24 h, colonies were randomly picked from nutrient agar (NA) and MacConkey Agar (MA) plates earlier used for the total counts. The isolates were purified by repeated sub-culturing before being tested for Gram reaction (Claus, 1992), morphology and motility.

The determination of proximate composition

Crude protein, ash, ether extract, moisture and fibre were all evaluated using the procedure of AOAC (2000). Moisture content was determined by transferring known weights of samples into the crucibles and drying at a temperature between 103-105 °C. The dried samples were cooled in desiccators and the weights noted. They were later returned to the oven and the process continued until constant weights were obtained. Protein was estimated by multiplying total nitrogen content evaluated by standard micro Kjeldahl method 6.26. Ash content was calculated by transferring of already ignited samples by placing them over a low flame to char the organic matter with lid removed to crucible, which was then placed in muffle furnace at 600 °C for 6 hours until it ashed completely. The ash percentage was calculated by using the first and the last weights. Crude fat was determined by Soxhlet extraction method. Crude fibre was determined by loss in ignition. Carbohydrate was calculated by differences: % CHO = 100 - (sum of the percentages of moisture, ash, fat, protein and crude fibre).

Sensory evaluation

Sensory evaluation of the fermented cereal gruels was carried out by the use of 32 untrained panellists. They were instructed to taste the prepared 'ogi' samples and to rinse their mouths after each tasting. They were requested to express their feelings about the samples by scoring the following attributes: appearance, sourness, taste, aroma/smell, overall acceptability, flavour and comparability. Questionnaires were distributed to each of the panellists and sensory scores were based on a 6-point hedonic scale, where 0 meant extremely dislike and 6 extremely like (Watt et al., 1989).

Statistical analysis

Data were presented as mean ± standard error of mean (SEM). The mean values were analysed with analysis of variance (ANOVA) and the difference between the mean were determined by Bonferroni Multiple Range Test at $p < 0.05$ using Primer of Biostatistics version 3.01 (1992).

Results and discussion

Consciously or otherwise, especially in Nigeria, people tend to eat cereals along with legumes or vice versa. People eat popcorn along with groundnut, rice with cowpea, even bean cake (Akara) with 'ogi' (Osundahunsi et al., 2003) so this work is in line with that tendency. Some may argue that the problem of inadequacy of nutrients in the grains may have been solved by these combinations. It must, however, be borne in mind that the groups of people that depend mostly on 'ogi', i.e. infants and convalescence are not usually able to eat solid food.

As seen in the study, the water used is of acceptable quality and was not found to affect the processes either positively or negatively. The biochemical characterisation of the bacteria isolated during the steeping and souring stage of the fermentation of the five different substrates combination shows that organisms such as *Bacillus alvei, Pseudomonas cepacia, Flavobacterium rigense, Aeromonas hydrophilia, Lactobacillus fermentum* and *Lactobacillus plantarum* etc., were present at different stages of fermentation (Table 1). However, only members of the genus *Lactobacillus* were isolated during the souring stage.

On the other hand, some fungi were also isolated, both during steeping and souring stage, and they include *Aspergillus niger, Rhizopus stolonifer, Candida tropicalis, Penicillium claviforme* and *Saccharomyces cerevisiae*. Mucoraceae fungi have been reported to have roles in the initial phase of fermentation, mostly in saccharification of the substrates (Thapa and Tamang, 2004). Only *S. cerevisiae*, *Candida tropicalis* and *Geotrichum fermentum* were isolated during the souring stage of the fermentation (Table 2). The composition of the microorganisms isolated during the process showed a

succession of gram-negative enteric bacteria and a mixed fungal population with lactic acid bacteria and yeasts, respectively.

The symbiotic relationship between yeast and lactic acid bacteria in traditional African fermented foods have been investigated by several researchers (Omemu et al., 2007; Jespersen et al., 1994). They have been found to be associated with the development of the flavour typical of these fermented foods. Some of the yeasts have also been reported to demonstrate amylolytic, proteolytic and phytate- breaking activities. This enzymatic ability may contribute to the breaking down of maize, sorghum and millet starch and also allow better access to nutritionally essential minerals (Amoa-Awua et al., 2007; Omemu et al., 2007).

The high nutrient content of Bambara nut makes it ideal for this fortification trial (Table 2). The sizeable carbohydrate content (which is uncommon for a legume) also prevented rheological problems that have been encountered in previous efforts. The proximate composition of the unfortified 'ogi' samples made from the three grains, i.e. maize, millet and sorghum used in this study, revealed how much nutrient is lost during traditional 'ogi' manufacture. Except for carbohydrate, all other nutrients are far below their recommended dietary allowances (RDA).

Table 1. Bacteria isolated during fermentation

ORGANISMS	PRIMARY FERMENTATION	SECONDARY FERMENTATION
Pseudomonas chlororaphis	+	-
Bacillus alvei	+	-
Aeromonas hydrophilia	+	-
Lactobacillus fermentum	+	+
Lactobacillus plantarum	+	+
Proteus vulgaris	+	-
Flavobacterium rigense	+	-
Bacillus pulmillus	+	-
Bacillus subtillis	+	-
Pseudomonas flourescens	+	-
Flavobaterium aquantile	+	-
Proteus mirabilis	+	-

ISOLATED +; NOT ISOLATED -

Table 2. Fungi isolated during fermentation

ORGANISMS	PRIMARY FERMENTATION	SECONDARY FERMENTATION
Aspergillus niger	-	-
Rhizopus oryzae	-	-
Geotrichum candidum	-	-
Penicillium claviforme	-	-
Saccharomyces cerevisiae	-	+
Candida tropicalis	-	+
Rhizopus stolonifer	-	-
Aspergillus flavus	-	-
Geotrichum fermentum	-	+
Penicillium foniculosum	-	-
Penicillium putida	-	-
Penicillium atrovene	-	-

ISOLATED +; NOT ISOLATED -

Table 3. Proximate composition of final products (fortified)

Nutrients (%)	A	B	C	D	E
Moisture	54.23±0.09	$52.30\pm0.09^{\beta}$	53.33±1.08	55.43±0.09	53.70±0.12
Protein	$6.10\pm0.06\beta^{\pi\Omega}$	$9.93\pm0.03^{\Omega\beta}$	$6.70\pm0.06^{\Omega£}$	6.93±0.03	$6.10\pm0.06^{\beta}$
Ether extract	$1.27\pm0.03^{\pi}$	3.03±0.03	$1.47\pm0.03^{£\pi}$	$1.37\pm0.03^{\beta}$	$1.50\pm0.06^{£}$
Ash	$1.77\pm0.03^{\pi}$	2.03±0.03	$1.73\pm0.03^{£}$	$1.33\pm0.03^{\beta\pi}$	$1.67\pm0.03^{\Omega£}$
Crude fibre	$0.57\pm0.03^{\pi}$	0.90±0.06	0.73±0.03	$0.57\pm0.03^{\beta}$	$0.63\pm0.03^{\Omega}$
Carbohydrate	36.07±0.07	$31.80\pm0.15^{£\pi\Omega}$	37.03±0.09	$34.37\pm0.19^{\beta}$	35.73±0.59

Values are presented as mean ± standard error of mean (SEM). Different superscript across the row indicate significant difference at $p < 0.05$; ***Key:*** β - comparison of D with other samples, A sorghum + Bambara nut; π - comparison of A with other samples, B Bambara nut only; Ω - comparison of E with other samples, C maize + Bambara nut; £ - comparison of B with other samples, D millet + Bambara nut, E sorghum + maize + millet

The use of Bambara nut in this study resulted in more than 100% increase in the protein contents of the unfortified sorghum and maize 'ogi' when compared with their fortified counterparts (Table 4). In the case of millet, the fortification resulted in 86% increase in the protein content. In all three cases, the fat contents of the fortified 'ogi' samples improved hugely with fortified maize and millet scoring more than 100% while fortified sorghum scored 59% increment (Table 5). The fat content of the fortified 'ogi' ranges from 1.30-1.47% which falls conveniently within the sufficient range for human for any food providing its caloric energy as fat (Anita et al., 2006).

In the earlier work by Okonkwo and Opara (2010), it was established that the free fatty acid in Bambara nut is low i.e. 1.11% and this is an indication that it is stable and that its oxidative rancidity will not be easily attained. They also found that it contains high amount of linolenic, oleic and palmitic acids which are all unsaturated fatty acids vital in the production of hormone-like substances that regulate wide range of functions. Decrease in the carbohydrate content of the fortified 'ogi' agrees with the findings of Sefa-Dedeh et al. (2000) that the addition of legumes causes such reductions in fortified maize gruel.

There was also a significant increase in the ash content of the fortified 'ogi' samples with respect to sorghum and maize but not for millet. In all t three cases, there was no significant increase in the fibre composition of the 'ogi' samples. This, however, contrasts with the report of Mbata et al. (2009) who recorded improvement in fibre content after fortification with 30% Bambara nut. This may be due to the fact that the Bambara nut used in the study was pre-treated by one hour of steeping, boiled at 100 ˚C for 20 min, deshelled and sundried before use. Also, the fermented mixture was not sieved at the end of the fermentation. It may also be due to differences in species of Bambara nut used or soil type. Also Olanipekun et al. (2010) reported a gradual decrease in the fibre content of Bambara nut (as sole substrate) fermented with a combination of *Rhizopus oligosporus* and *Rhizopus nigricans*.

The mean values of the qualities measured during the organoleptic assessment of the 'ogi' samples show that the values for samples C and E are the highest out of all the samples (Table 6). The values for samples A, B and D were all found to be significantly lower than samples C and E and so were the least acceptable. Sample B was the least preferred and this may not be unconnected with the fact that about 50% of the respondents confirmed not to have taken any product from Bambara nut before. Also, most people who do not like Bambara nut always cite its flavour for their dislike and this was the case too in the organoleptic assessment carried out; as the 'ogi' sample made entirely from Bambara had the least rating in flavour when compared with the rest. Except for appearance where it fared better than sample D, sample B ('ogi' made entirely from Bambara nut) recorded the lowest values in all the other qualities measured.

Table 4. Proximate composition of unfortified 'ogi'

Nutrients (%)	**Maize 'ogi'**	**Millet 'ogi'**	**Sorghum 'ogi'**
Moisture	$55.47\pm0.32^{£}$	57.73±0.12	$54.20\pm0.09^{£,\pi}$
Protein	$2.57\pm0.07^{£\pi}$	3.73±0.03	$2.97\pm0.03^{£}$
Ether extract	$0.63\pm0.03^{\pi}$	$0.57\pm0.03^{\pi}$	0.8±0.06
Ash	1.53±0.03	$1.23\pm0.03^{\beta,\pi}$	$1.37\pm0.03^{\beta}$
Crude fibre	0.67±0.03	$0.53\pm0.03^{\beta}$	0.63±0.03
Carbohydrate	$38.60\pm0.27^{\pi}$	$36.10\pm0.10^{\pi\beta}$	39.90±0.21

Values are presented as mean ± standard error of mean (SEM). Different superscript across the row indicate significant difference at $P < 0.05$; ***Key***: £ - comparison of millet 'ogi' with the rest; β - comparison of maize 'ogi' with the rest; π - comparison of sorghum 'ogi' with the rest.

Table 5. Comparison of fortified and unfortified 'ogi' samples

'Ogi' Samples	**Comparison**	**Protein (%)**	**Ether Extract (%)**	**Ash (%)**	**Fibre (%)**
Sorghum 'ogi'	Fortified	6.10 ± 0.06^{b}	1.30 ± 0.00^{b}	1.80 ± 0.00^{a}	0.57 ± 0.03^{a}
	Unfortified	2.97 ± 0.03^{a}	0.80 ± 0.06^{a}	1.37 ± 0.03^{b}	0.63 ± 0.03^{a}
Maize 'ogi'	Fortified	6.70 ± 0.06^{b}	1.47 ± 0.03^{b}	1.75 ± 0.03^{b}	0.73 ± 0.03^{a}
	Unfortified	2.57 ± 0.07^{a}	0.63 ± 0.03^{a}	1.53 ± 0.03^{a}	0.67 ± 0.03^{a}
Millet 'ogi'	Fortified	6.93 ± 0.03^{b}	1.37 ± 0.03^{b}	1.33 ± 0.03^{b}	0.57 ± 0.03^{a}
	Unfortified	3.73 ± 0.03^{a}	0.57 ± 0.03^{a}	1.23 ± 0.03^{b}	0.53 ± 0.03^{a}

Values presented as mean ± standard error of mean (SEM). Different superscript along the column indicates significant difference at $P < 0.05$.

Table 6. Comparison of organoleptic assessment of the samples

Qualities of samples	Sample A	Sample B	Sample C	Sample D	Sample E
Appearance	$4.09\pm0.23^{\Omega,¥}$	$3.59\pm0.26^{£,\Omega}$	$5.09\pm0.10^{\beta,\pi,¥}$	$3.16\pm0.27^{\beta,\Omega,£}$	$4.53\pm0.18^{¥}$
Sourness	$3.59\pm0.26^{£,\Omega}$	$3.31\pm0.30^{£,\Omega,£}$	$4.61\pm0.15^{\pi}$	4.03 ± 0.14	$4.69\pm0.12^{\pi}$
Flavour	$3.25\pm0.23^{£,\pi}$	$2.75\pm0.25^{£,\pi,¥}$	4.63 ± 0.10	$3.60\pm0.17^{£,\pi}$	4.66 ± 0.08
Taste	$3.47\pm0.23^{\Omega,£}$	$2.84\pm0.26^{\Omega,£,¥}$	4.91 ± 0.10	$3.88\pm0.16^{\Omega\,£}$	$4.78\pm0.13^{\Omega}$
Aroma/smell	$3.26\pm0.21^{\Omega,£}$	$2.88\pm0.27^{\Omega,£,¥}$	4.69 ± 0.09	$3.89\pm0.16^{\Omega,£}$	4.63 ± 0.13
Acceptability	$3.13\pm0.27^{\Omega,£}$	$3.00\pm0.28^{\Omega,£,¥}$	4.72 ± 0.11	$3.91\pm0.19^{\Omega}$	4.66 ± 0.07
Comparability	$3.59\pm0.27^{£,\Omega}$	$3.06\pm0.25^{£,\Omega,¥}$	4.59 ± 0.16	3.97 ± 0.22	4.69 ± 0.13

Values are presented as mean ± standard error of mean (SEM). Different superscript across the row indicate significant difference at $P < 0.05$; Key: β - comparison of D with other samples, A sorghum + Bambara nut; π - comparison of A with other samples, B Bambara nut only; Ω - comparison of E with other samples, C maize + Bambara nut; £ - comparison of B with other samples, D millet + Bambara nut, E sorghum + maize + millet

Table 7. Comparison of the qualities of the 'ogi' samples based on sensory analysis

Samples	Data of samples' quality analysis
Sample A	$79.00\pm3.89^{£,\Omega}$
Sample B	$67.29\pm3.87^{\Omega,¥,£}$
Sample C	$120.00\pm2.25^{\beta,\pi,¥}$
Sample D	$88.86\pm3.56^{\pi,\Omega,£}$
Sample E	$117.86\pm1.24^{\beta,\pi,¥}$

Values are presented as mean ± standard error of mean (SEM). Different superscript across the row indicate significant difference at $P < 0.05$; Key: β - comparison of D with other samples, A sorghum + Bambara nut; π - comparison of A with other samples, B Bambara nut only; Ω - comparison of E with other samples, C maize + Bambara nut; £ - comparison of B with other samples, D millet + Bambara nut, E sorghum + maize + millet

The combined analysis of the qualities of the samples measured i.e. (taking each of the products as an entity) also confirmed the above outcomes. For the purpose of simplicity and based on the mean values, panellist's preference for the 'ogi' samples can be summarized as (starting from the highest to the lowest): C > E >D>A> B (Table 7).

It must, however, be borne in mind that despite the fact that the other samples were not favourably acceptable in the organoleptic assessment that it will be statistically incorrect to say that they will be universally unacceptable. This is because their unfavourable acceptance may have been the result of comparison with the other samples. Furthermore, this study was carried out in the south-western part of Nigeria where maize constitutes 90% of cereal are consumed (Ekpenyon et al., 1977) and where a large number of people regularly consumes 'ogi' made from maize. Their familiarity with the flavour, taste and aroma of it may have affected their preference. There is a chance that in the northern part of the country or the world where a lot of people depend on 'ogi' made from millet and sorghum this study may produce a different organoleptic assessment outcome. Lower levels of Bambara fortification of these cereals may stand a good chance of being acceptable as the outcome of the organoleptic assessment suggest.

Conclusion

Fortification of maize, sorghum and millet with 40% Bambara nut has shown convincing proofs and promises as one of the ways to go in fortifying 'ogi'. This is due to the fact that it culminated in the increase of the mineral and nutritive contents of 'ogi' on one hand and good acceptability on the other. It also provided a basis and direction for other fortification efforts using Bambara nut with either millet or sorghum. In the case of Maize-bambara 'ogi', the issue of flavour and aroma which are the most frequent complaints in some former efforts, did not surface at all. Most importantly, low nutritive and mineral content of 'ogi', which has been identified as its major drawback, was improved as a result of this effort.

It therefore follows that Bambara-maize 'ogi' may be considered for use for weaning, convalescence and everyday use.

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