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FORTIFIED LOCAL CEREAL-BASED FOODS: NUTRITIONAL COMPOSITION AND CONSUMERS ACCEPTABILITY

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Abstract

Cereals are the most common and widely used food crops for production of complementary foods, snacks, and beverages, in many developing countries including Nigeria. However, due to lack of major nutrients in cereal crops, most of these foods are low in essential nutrients such as protein, vitamins, and minerals, thus causing micronutrient deficiency problems among vulnerable groups (children and pregnant women) in most African countries. This review aimed to provide information on existing methods of fortifying indigenous Nigerian cereal-based products, the chemical, amino acid composition, and consumers acceptability of the fortified foods. Fortification is a cheap means of increasing the nutrient intake of the populace to reduce specific nutrient(s) deficiency among the vulnerable groups. In this report, the nutrient profile of un-fortified and fortified indigenous weaning food, breakfast foods, alcoholic and non-alcoholic beverages, and snacks were explored. The findings of this study showed that fortification of cereal-based foods with 25% legumes and or 30% of fruits will produce nutritious and acceptable products. Information provided in this study will be useful for local food processors and food industries in expanding their production interest to include the manufacturing of highly nutritious local foods that will help to reduce/eliminate protein-malnutrition and micronutrient deficiency, which are major health problems in developing countries.

Keywords: Amino acid composition, chemical composition, snacks, food fortification, traditional foods, sensory attributes.

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Introduction

Food fortification is an inexpensive and effective means of increasing the intake of the essential nutrient of low-income people, and the general populace in developing countries such as

Nigeria, to prevent deficiency of one or more nutrients in the food. It is an approach that is adopted to restore nutrients removed during food processing, replace nutrients in substitute foods or to correct nutrient deficiencies in a population (Allen, 2006). Food fortification has been

successfully used to reduce the consequences of micronutrient deficiencies in developed countries. Among the advantages of food fortification is that it cost less, requires minimal changes in food habits, socially acceptable, and it is easily sustainable (Dary and Mora, 2002).

Larger percentage of traditional foods consumed in Nigeria is from cereal. Typical Nigeria cereal grains are; maize or corn, millet, sorghum, rice, guinea corn and wheat. These cereals are rich source of thiamine, riboflavin and niacin, and contain relatively high amount of vitamin E (McKevith, 2004). They supply about 80% of the energy requirement of Nigerians (Ismail *et al.*, 2010). However, cereals are deficient in some basic components such as essential amino acid (lysine). They are also low in minerals (especially iron and zinc) (FAO/WHO, 2002), and do not contain vitamins A, C, B₁₂, and beta-carotene, except for yellow corn. This indicates that most indigenous cereal-based foods in Nigeria are low in protein and major micronutrients, most especially minerals and vitamins. Thus, fortification of Nigerian cereal foods has become a more realistic option to prevent malnutrition and correct a demonstrated deficiency of one or more micronutrients among the vulnerable groups (children and pregnant women). Generally, fortification of local foods will receive less discrimination or rejection since people are already familiar with the product and taste, thus choosing them as ideal vehicle for fortification is appropriate. In addition, many Nigerian households do not consume processed foreign foods due to high cost of the foods.

Fortification of traditional cereal-based weaning/complimentary food (*ogi*)

Traditional breakfast meals and weaning foods are based on cereals, which are processed into porridge or gruel (*ogi*). *Ogi* is a popular traditional breakfast food (for adults and children) and a common weaning food in Nigeria, and other West African countries. It is commonly produced from fermented dry maize, sorghum (Adesokan *et al.*, 2011; Okafor *et al.*, 2018) or millet (Akinrinola *et al.*, 2014). Cooked *ogi* is called *akamu*, *Eko*, *agidi*, *kefa*, *mashew*, or *kenkey*, depending on its consistency (Sopade

and Kassum, 1992). Image of *akamu* and *Agidi* are shown in Figures 1 a and b, respectively. *Ogi* is a carbohydrate-based food with its major constituents been starch, with low levels of minerals and B-vitamins (Omole *et al.*, 2017). Thus, *ogi* has been contributed to the incidence of protein-energy malnutrition among toddlers and children of age 2 to 5, in most developing countries including Nigeria, due to low nutrients levels in the cereals used for *ogi* production.

Enrichment of traditional complementary foods is achieved by fortifying or supplementing cereals-based gruels with protein-rich local crops such as legumes and proteinized seeds (Egounlety, 2002; Bolarinwa *et al.*, 2016). For example, high-protein–energy weaning foods were prepared by supplementing maize-*ogi* with soybeans (30%) or the blends of cowpea (40%) and melon seed (10%) (Table 1). Protein and energy contents of legume-fortified weaning foods (soy-*ogi* and cowpea-*ogi*) were reported to be above the recommended levels for conventional weaning foods (Egounlety, 2002). Apart from the use of legumes for *ogi* enrichment, acceptable and nutrient-dense *ogi* was also produced from okra seeds. The protein content of the okra seeds fortified *ogi* was between 50 - 90% higher than the un-fortified *ogi* (Akinrinola *et al.*, 2014), and also contains significantly higher calcium, sodium, iron, and vitamin C than the traditional maize-*ogi* (Otunola *et al.*, 2007). Fortification of *ogi* with whey significantly increased the essential amino acid content of the fortified product compared to the un-fortified counterpart (Omole *et al.*, 2017). In another study, the addition of 50% groundnut to sorghum *ogi* increased the protein, fat and ash contents of the sorghum groundnut-*ogi* significantly. Furthermore, the *ogi* was acceptable at >50% groundnuts supplementation level (Ajanaku *et al.*, 2012).

Fortification of maize-*ogi* with moringa leaves was reported to increase the protein content of 15% moringa leaves fortified *ogi* by 94% compared to the un-fortified maize-*ogi*. Higher crude fibre and mineral levels (calcium, magnesium, iron, potassium, zinc, and copper) were also recorded for the moringa leave fortified *ogi* (Abioye and Aka, 2015). According

to the study, 10% moringa leave fortified *ogi* was rated close to the un-fortified *ogi* in terms of sensory attributes.

Fortification of traditional cereal-based breakfast foods (*Masa* and *Mumu*)

Masa

Masa is an important breakfast cereal food commonly consumed with spices and groundnut cake in the Northern part of Nigeria. It is a yeast-fermented batter from cereals. Although *masa* is commonly produced from millet or rice, it can also be prepared with sorghum or maize. Image of *masa* is shown in Figure 2. *Masa* is produced by grinding cereal grain into flour, addition of sieved flour into boiled water and boiling for few minutes, followed by addition of raw flour (1:2), yeast fermentation (12-16 h), neutralization with trona (*konwa*) and frying to obtain a cup-like depression shape called *masa* (Badau *et al.*, 2017). Generally, the nutrient composition of *masa* is very low, since it is mainly produced from cereals (Table 1). However, many studies have attempted to improve the nutrient contents of *masa* through fortification or supplementation of cereals with legumes such as cowpea and groundnut (Nkama and Malleshi, 1998).

Supplementation of rice-*masa* with 20% cowpea and millet-*masa* with 13% cowpea resulted in a 75% increment in the lysine content of millet-cowpea *masa*, and 9% increment in lysine content of rice-*masa* (Nkama and Malleshi, 1998). Lysine content of rice-cowpea-groundnut *masa* also increased by 20% compared to the level of lysine in rice-*masa* (Table 2). The addition of cowpea and or groundnut to rice or millet *masa* also increased the levels of other essential amino acids such as threonine, histidine, valine, and isoleucine (Table 2) and resulted in a slight increment in the protein content of the fortified *masa* (Table 1). Consumers' acceptability of legume fortified *masa* samples were compared with those of cereal-based *masa* (Nkama and Malleshi, 1998). On the other hand, *masa* samples supplemented with soybean or crayfish recorded low sensory scores for appearance, taste, aroma, and overall

acceptability (Samuel *et al.*, 2015), indicating that supplementation of *masa* with soybeans or crayfish did not produce acceptable *masa* product. Chemical composition of traditional cereal-based breakfast foods and their fortified products is presented in Table 1.

Mumu

Mumu is a traditional cereal-based food product commonly made from roasted maize, however, it can also be prepared from sorghum and millet. *Mumu* is prepared by reconstituting roasted cereal (maize or sorghum or millet) in cold water with sugar or honey and consume as a snack or convenience food by both adults and children. It is sometimes taken as breakfast porridge (Ingbian and Adegoke, 2007a). Supplementation of *mumu* with 15-25% groundnuts and soybeans significantly ($p < 0.05$) increased the protein and fat contents of the supplemented products, with soybeans supplemented products having a higher protein efficiency ratio than groundnuts supplemented products (Ingbian and Adegoke, 2007b).

The protein quality of all the legume fortified cereal complementary and breakfast foods as revealed by various studies showed that they contain relatively high amounts of essential amino acids (Table 2). Lysine, leucine, methionine, threonine and valine levels in the fortified foods are within the requirement of essential amino acids for adults, while the level of histidine, isoleucine, phenylalanine, and tryptophan are closer to their requirements for adults. This could be because the levels of essential amino acids in legume seeds compared well with the FAO/WHO/UNU amino acid scoring pattern for adults and children (FAO/WHO/UNU, 1985).

Fortification of Non-alcoholic (*Kunun-Zaki*) and Alcoholic (*Pito*, *Burukutu* and *Sekete*) Beverages

Kunun-Zaki

Kunun-Zaki is a traditional fermented non-alcoholic beverage commonly consumed in Nigeria. It is a popular breakfast food in

Northern Nigeria, whereas it is used as a beverage in other parts of the country, and as weaning food in some communities. *Kunun* is a fermented gruel of low viscosity, sweet-sour taste and milky cream colour produced from millet, sorghum or maize (Bolarinwa *et al.*, 2015). It is prepared by grinding dried cereal grains into flour, followed by mixing the flour with a small amount of cold water to form a thick paste that is poured into a pot of hot water until a smooth paste or gruel is formed. The gruel is then allowed to ferment for 1 to 3 days for flavour development. Spices and sweeteners are added to the gruel to taste, and the *kunun* is ready to be consumed hot or cold (Uzogara *et al.* 1990).

Kunun-zaki is low in nutritional value, containing 0.1-1.1% protein, 0.6-0.7% fat, 1.1% fibre, 0.7% ash and 9-28.6% carbohydrate (Ayo and Akoka, 1998; Bolarinwa *et al.*, 2015). Given the low nutrient compositions of *kunun*, many researchers have investigated the potentials of increasing the nutrient value of the beverage through fortification of *kunun-zaki* with legumes (Gaffa *et al.*, 2002; Bolarinwa *et al.*, 2015), nuts (Olaoye *et al.*, 2016) and fruits (Sengev *et al.*, 2012). According to Gaffa *et al.* (2002) and Bolarinwa *et al.* (2015), the addition of 5% soybean and 25% *Vigna-racemosa* legume to *kunun-zaki* increased the protein content of the beverage by 117 and 330%, respectively. Incorporation of 30% tigernuts milk into *kunun-zaki* was also reported to enhance the protein and ash contents of the fortified *kunun* by 23.8% and 64.6%, respectively, and the B-vitamins by 48-60%. Tigernuts milk fortified *kunun* was acceptable at a 30% supplementation level (Olaoye *et al.*, 2016). Similarly, incorporation of 4% soybeans to *kunun-zaki* was reported to produce acceptable *kunun* with higher protein content (8.67%) than the 1% fortified *kunun* (4.59%) (Gaffa *et al.*, 2002), while 50% soybean supplementation increased the protein content of the *kunun* by 177%, calcium by 71%, phosphorus by 80% and potassium by 33% (Adeniji and Keshinro, 2015). In another study, instant *kunun-zaki* flour produced by fortifying *kunun-zaki* with 20% mango mesocarp, enhanced the *kunun* flour with beta-carotene (139.13 µg/100g), and also increased the ash and

crude fibre of the instant *kunun* flour blends by 34 and 32%, respectively (Sengev *et al.*, 2012).

Fortification of *kunun-zaki* with 25% sprouted African bread-fruit milk was reported to produce acceptable *kunun* with higher protein content (102% increment) and ash content (42% increment) than the un-fortified *kunun* (Lawal *et al.*, 2016). The use of cocoa powder for fortification of *kunun-zaki* beverage has also been reported (Abidoye, 2017). According to Abidoye (2017), addition of 20% cocoa powder to *kunun* increased the protein content of the fortified *kunun* by 123%, ash and fat content by 138% and 145%, respectively. However, there was reduction in the carbohydrate and energy value of the cocoa powder fortified *kunun* (Table 3).

Generally, fortification of *kunun* with the nutrient components of other crops resulted in product with high nutrient profile. For instance, fortification of *kunun* with legumes significantly increased the protein and mineral content of the beverage while nuts and fruits fortification enhanced its vitamins and ash contents (Table 3). Fortification of *kunun* with soymilk also increased the calcium content of the soy-*kunun* to the recommended calcium allowance (400 mg) for children, and provides more than half of the recommended calcium allowance for adults (FAO/WHO, 2002). This suggests that soy-*kunun* can also be used as weaning and complementary foods to complement the mineral intake of infants and children.

Pito and burukutu

Pito and *burukutu* are traditional Nigerian fermented alcoholic beverages produced from maize, sorghum or mixture of both. *Pito* is cream coloured liquor with a characteristic sour taste (Orji *et al.*, 2003) while *burukutu* is a brown coloured suspension with vinegar-like flavour (Alo *et al.*, 2012; Onyenekwe *et al.*, 2015). The preparation of *pito* is similar to that of *burukutu* except that the pH of *burukutu* increases from about 4.2 to 6.2 within 24 h of fermentation and it decreases further to 3.7 after 48 h fermentation (Kolawole *et al.*, 2007). They are prepared by steeping the cereal grains for

24–48 h, followed by malting, mashing, fermentation of the wort using lactic acid bacteria and yeast, and maturation (Onyenekwe *et al.*, 2015).

Pito and *burukutu* are commonly consumed in the Northern part of Nigeria (Alo *et al.*, 2012). Although these fermented beverages contain nutrients such as iron, manganese, magnesium, phosphorus, calcium, vitamins, starch, and protein (Fadahunsi *et al.*, 2013). The potentials of increasing the nutrient composition of *pito* through fortification with fruits has been investigated. According to Adelekan *et al.* (2013), the addition of fruits (orange, banana, and pineapple) to *pito* increased the protein, fat, carbohydrate, minerals, and vitamin contents of the fortified *pito* (Table 3).

Sekete

Sekete is a traditional alcoholic drink prepared from sprouted maize, following Lactic acid bacteria and yeast fermentation. It is a popular refreshing drink in the South Western part of Nigeria. Although *sekete* is rich in important amino acids such as alanine, leucine, tyrosine, and lysine (Fapohunda, 1988), its protein and vitamin contents are relatively low (Table 3). This is probably due to low nutrient contents in the major raw material (maize) used for *sekete* production. Indeed, regular consumption of *sekete* has been reported to be the cause of malnutrition diseases (kwashiokor and beriberi) among the South Western people of Nigeria (Sanni, 1989).

Fortification of *sekete* with 25% soymilk was reported to improve the sensory attributes of the drink, but have no significant effect on its chemical composition (Table 3) (Obatolu *et al.*, 2016). There is need for further investigations on fortifications of *sekete* with fruits, nuts and other legumes, to improve its nutrient contents.

Fortification of traditional cereal-based snacks (kokoro, elekute and aadun)

Kokoro

Kokoro (Corn cake) is a popular traditional snack made from maize flour. It is a fried snack

from dough produced from a mixture of maize flour, salt, sugar, and water. Image of *kokoro* is shown in Figure 3. *Kokoro* is consumed at any time of the day by both adults and children in the South-Western Nigeria (Adeola *et al.*, 2011). Since *kokoro* is a maize-based snack, it is low in nutrients such as protein especially lysine, calcium, and other minerals, due to the low level of these nutrients in maize grain (especially white maize) (Haug *et al.* (2010). Thus, many researchers have investigated the possibilities of improving the nutrient contents of *kokoro* through fortification with legumes (Adeola *et al.*, 2011; Idowu, 2015; Ewulo *et al.*, 2017), moringa leaf (Ewulo *et al.*, 2017), and distillers' spent grain (Awoyale *et al.*, 2011).

Fortification of maize with 20% pigeon pea flour for *kokoro* production resulted in acceptable pigeon pea-maize *kokoro* with a significant increase in the protein content (55%) of the fortified *kokoro* product compared to the unfortified product (Adeola *et al.*, 2011). Similarly, Idowu (2015) also reported a significant increase in the protein and ash contents of African yam beans fortified *kokoro* products compared to the control sample (Table 4). In another study, fortification of maize with 10% soybeans increased the protein contents of soy-*kokoro*, while 10% moringa leaves flour fortification increased the vitamin contents (thiamine, niacin and ascorbic acid) of the fortified *kokoro* products (Ewulo *et al.*, 2017). Fortification of *kokoro* with distillers' spent grain resulted in a slight increase in the ash, fat, and protein contents of the *kokoro*, and also increased the lysine and tryptophan contents of the fortified *Kokoro* (Awoyale *et al.*, 2011).

Elekute and Aadun

Elekute and *Aadun* are snacks produced from toasted maize. They are commonly consumed snacks in South-Western Nigeria. Image of *Elekute* and *Aadun* are shown in Figure 4 a and b, respectively. *Elekute* is produced by milling toasted maize into fine powder, to which sugar is added (Abdurrahman and Kolawole, 2006). *Aadun* is prepared by adding red oil, salt, and

pepper to toasted maize powder (Oluwamukomi, 2004). *Aadun* is reddish, has a fine texture, and disintegrate easily in the mouth (Idowu and Adedokun, 2011).

Aadun is low in protein, high in fat, calorie, phosphorus, and magnesium, while *elekute* is low in almost all nutrients except carbohydrate and sodium (Table 4). Because of the low nutrient compositions of maize-based products, *Elekute* and *aadun* flour were each fortified with 20% soy and cowpea flour, and the fortified *elekute* was reported to contain higher protein, fat and energy value than the un-fortified product (Oluwamukomi, 2004), with cowpea fortified product having the highest acceptability. In another study, African oil bean seed flour (AFOBf) was used to fortify maize flour for *elekute* production (Lawal and Enujiugha, 2016). According to the study, the protein and mineral content of the AFOBf fortified *elekute* increased with increasing addition of AFOBf flour in the product, and the sample fortified with 40% AFOBf had the highest protein content (23.1%).

Challenges and Future Prospects

This review has attempted to report different inexpensive methods of fortifying cereal-based foods using other classes of food. The findings showed that little efforts have been made to carry out a cost comparison between non-conventional and conventional fortification method. This aspect needs to be investigated further to promote large-scale use of non-conventional fortification approach. Despite lack of cost information, the use of low-cost nutrient-rich crops as fortificant by food industries (for enrichment of cereal-based foods) are strongly recommended due to their local availability, consumers acceptability, and cost-effectiveness. Industries will benefit from reduced production costs, increased profits, and maximum outputs. Consumers, on the other hand, will benefit from highly nutritious local foods at affordable cost compared to conventional products.

Further investigation on nutrient retention, bioavailability, product storage condition, shelf life, and packaging materials should be

provided. Optimum processing conditions (temperature and time) for optimum nutrient retention in cereal foods should be provided. Information on nutrient retention and bioavailability of non-conventionally fortified cereal foods and non-fortified cereal foods must also be made available, so that consumers can compare the two products.

Researchers should focus more on the conversion of some protein and vitamin-rich foods such as legumes and fruits into instant powdered products. This will make them readily available for use as fortificant, thus reduce processing cost and time, problem of un-availability during off-season, and high cost during offseason.

Conclusion

This review showed that Nigeria cereal-based foods are fortified with other plant foods that are rich in protein, minerals, and or vitamins. This method provides an inexpensive means of enhancing the nutrient composition of cereal foods. Besides, cereal foods that are fortified through the addition of other plant foods nutrients have a greater chance to be acceptable by consumers compared to foods fortified with synthetic chemicals. This is because in most cases the food crops used for nutrient supplementation are usually indigenous to the country. Thus, fortification of cereal-based foods with legumes such as soybeans, cowpeas, and groundnuts are recommended due to the potential of these plant foods to significantly increase the protein contents and quality of the fortified foods. This will aid in reducing protein-energy malnutrition which is a major problem in Nigeria. Fortifications of cereal-based beverages with fruits are also recommended to combat micronutrient deficiency syndrome, which is a major nutritional problem among children and pregnant women. Based on the findings of this review, the addition of up to 25% of legume and or 30% of fruit to cereal-based foods will significantly improve the nutrient composition of the food, and also produce acceptable products.

Figure Legend**Figure 1:** Image of *akamu* and *Agidi***Figure 2:** Image of *Masa***Figure 3:** Image of *Kokoro***Figure 4:** Image of *Elekute* and *Aadun***Table Legend****Table 1:** Chemical composition of traditional cereal-based breakfast and weaning food, and their fortified products**Table 2:** Amino acid composition (mg/g) of traditional Nigerian breakfast and weaning food, and their fortified products**Table 3:** Chemical composition of traditional cereal-based beverages and their fortified product(s)**Table 4:** Chemical composition of traditional cereal-based snacks and their fortified product(s) **Figure 1:** Image of (a) *akamu* and (b) *Agidi* **Figure 2:** Image of *Masa* **Figure 3:** Image of *Kokoro*

Figure 4: Image of (a) *Elekute* and (b) *Aadun*

Table 1: Chemical composition of traditional cereal-based breakfast and weaning food, and their fortified products

Parameters	<i>Millet-Masa and Rice-masa*</i>	Rice-cowpea masa and millet-cowpea masa [#]	Rice-cowpea-ground nut masa	Rice-soybeans masa ^s	Maize-ogi	Soy-ogi and cowpea-ogi ²	Maize - pigeon pea ogi	Whey-maize ogi and Okra-ogi~
Protein (%)	4.2-7.0 ^{a,b} (9.6)	10.8(11.1) ^a	11.4 ^a	7.1(7.2) ^b	10.7-14.95 ^{c,d,f,g}	9.12-20.0 ^{c,e,j} (18.6)	32.69 ^d	11.72 ^g (9.3-12.4) ^{h,i}
Ash (%)	0.4-2.2 ^{a,b} (2.0)	2.9(2.9) ^a	2.7 ^a	0.5(1.2) ^b	0.7-1.11 ^{c,d,f,g}	0.9-3.0 ^{c,e,j} (1.2)	0.77-2.98 ^d	1.37 ^g (0.11-1.40) ^{h,i}
Fat (%)	8.5-19.9 ^{a,b} (9.7)	10.4(10.1) ^a	12.7 ^a	20.8(18.8) ^b	1.1-10.2 ^{c,d,f,g}	0.79-10.5 ^{c,e,j} (8.4)	13.36-19.27 ^d	8.10 ^g (1.61-2.34) ^{h,i}
Crude Fibre (%)	0.34 ^b	-	-	0.9(0.6) ^b	0.05-0.62 ^{d,f,g}	1.27 ^e	0.79 ^d	0.05 ^g (0.34) ^h
Carbohydrate (%)	28.1-80.3 ^{a,b} (77.1)	74.1(74.4) ^a	71.5 ^a	22.7(21.9) ^b	74.6-83.4 ^{c,d,f,g}	20.87-69.6 ^{c,e} (71.9)	42.58-68.04 ^d	72.82 ^g (73.74-74.51) ^{h,i}
Energy (kcal/100)	308-426 ^{a,b} (434)	433(434) ^a	446 ^a	306(284) ^b	389.88-418 ^{c,f}	400-448 ^{c,j} (437)	-	-
Calcium (mg/100g)	13.2-32 ^{a,b} (29)	27.4(30.4) ^a	29.9 ^a	14.1(27.3) ^b	0.75-199.6 ^{d,f}	430.00 ^j	174.45-367.88 ^d	- (27.0-129) ^{h,i}
Magnesium (mg/100g)	129.9(69.9) ^a	1,969(898) ^a	2,997 ^a	-	36.42-189.7 ^{d,f}	-	200.51-373.8	-

0g)							9 ^d	
Iron (mg/100g)	1.9-3.6 ^{a,b} (8.0)	44.9(79.9) ^a	36.0 ^a	0.03(2.5) ^b	0.07-20.89 ^{d,f}	-	6.72-27.85 ^d	-(1.39-4.0) ^{h,i}
Phosphorus (mg/100g)	125(103) ^a	167.6(129.1) ^a	159.1 ^a	-	70.41-287.85 ^{d,f}	440.0 ^j	272.95-309.40 ^d	-(8.62) ⁱ
Zinc (mg/100g)	1.5-1.8 ^{a,b} (4.7)	19.5(39.4) ^a	20.0 ^a	1.58(1.68) ^b	0.07 ^f	-		-
Sodium (mg/100g)	149.9(159.6) ^a	1397(1596) ^a	1,499 ^a		14.96-91.85 ^d	-	77.91-109.45 ^d	-(6.00) ^h
Potassium (mg/100g)	-	-	-	-	116.2-312.76 ^{d,f}	-	298.5-334 ^d	-(127.5) ⁱ
Manganese (mg/100g)	0.9(0.3) ^a	10(5.0) ^a	11.5 ^a	-	-	-	-	-
Vitamin B ₁ (mg/100g)	-	-	-	-	0.32-0.57 ^d	-	0.75-1.34 ^d	-
Vitamin B ₂ (mg/100g)	-	-	-	-	0.14-0.37 ^d	-	0.87-1.51 ^d	-
Niacin (mg/100g)	-	-	-	-	1.86-2.21 ^d	-	2.74-7.79 ^d	-

^a Nkama and Malleshi, 1998; ^bSamuel *et al.* (2015); ^cEgounlety *et al.*(2002); ^dOkafor *et al.*(2018); ^eAdesokan *et al.* (2011); ^fIjarotimi *et al.*(2012); ^gOmole *et al.*(2017); ^hOtunola *et al.* (2007); ⁱAkinrinola *et al.* (2014); ^jAkinrele and Edwards (1971).

* Values outside parentheses are composition of rice masa, while values in parentheses are for millet masa (Nkama and Malleshi, 1998).

Values in parentheses are for millet-cowpea (83:13) masa composition (Nkama and Malleshi, 1998).

\$ Values in parentheses are chemical composition of rice-crayfish (80:20) masa (Samuel *et al.*, 2015).

² Values in parentheses are chemical composition of cowpea-ogi (50% maize: 40% cowpea: 10% melon seeds) (Egounlety *et al.*, 2002).

~ Values in parentheses are chemical composition of Okra-ogi (50% maize: 50% okra seeds).

Dash (-) indicates not available.

Table 2: Amino acid composition (mg/g) of traditional Nigerian breakfast and weaning food, and their fortified products

Amino acid	Masa*	Rice-cowpea masa and Millet-cowpea masa [#]	Rice- cowpea- groundnut- masa ^{\$}	Maize- ogi	Maize- pigeon pea ogi	Whey- maize ogi	Soy- ogi
Aspartate	6.9(4.5)	7.1(6.1)	7.6	6.5 ^c	-	-	-
Glutamate	16(17.3)	15.3(17.6)	16.5	18.5 ^c	-	-	-
Serine	6.9(5.6)	6.1(5.8)	6.6	-	-	-	9.76 ^d
Glycine	8.0(3.9)	6.9(4.8)	8.1	5.9 ^c	-	-	-
Histidine	2.9(0.6)	1.9(1.5)	1.0	0.28- 4.2 ^{b,c}	-	5.20 ^b	4.88 ^d
Arginine	7.2(2.3)	5.9(2.7)	6.2	3.00 ^c	-	-	-
Threonine	3.8(2.8)	3.1(3.5)	4.4	10.5- 21.6 ^{b,c}	-	47.80 ^b	7.63 ^d
Alanine	13.3(26.6)	17.3(17.6)	14.1	12.0 ^c	-	-	-
Proline	6.3(7.6)	6.0(7.1)	5.5	8.3 ^c	-	-	-
Tyrosine	2.0(1.1)	1.6(1.5)	1.8	3.5 ^c	-	-	-
Valine	6.8(5.9)	6.2(6.9)	6.6	0.08- 5.1 ^{a,b,c}	3.99- 6.83 ^a	0.83 ^b	9.76 ^d
Methionine	2.2(1.4)	1.3(1.4)	1.2	0.9- 1.0 ^{b,c}	-	13.23 ^b	2.75 ^d
Cysteine	-	-	-	-	-	-	3.05 ^d
Isoleucine	3.9(3.9)	4.4(4.7)	4.3	2.53- 4.2 ^{b,c}	-	8.30 ^b	8.85 ^d
Leucine	9.5(12.2)	9.9(11.8)	8.6	12- 76.61 ^{a,b,c}	4.15- 10.96 ^a	12.40 ^b	17.69 ^d
Phenylalanine	4.1(3.3)	4.0(4.4)	4.1	3.5-4.85 ^{a,b}	5.09- 8.62 ^a	6.25 ^b	10.68 ^d
Lysine	3.3(1.6)	3.6(2.8)	3.7	0.53- 3.92 ^{a,b,c}	4.48- 9.39 ^a	0.90 ^b	9.46 ^d
Tryptophan	-	-	-	0.015 ^b	-	2.40 ^b	2.10 ^d

^aOkafor *et al.* (2018); ^bOmole *et al.* (2017); ^cBanigo and Muller, 1972; ^dAkinrele and Edwards. (1971).

* Values outside parentheses are composition of rice masa, while values in parentheses are for millet masa.

[#] Values in parentheses are for millet-cowpea masa composition from Nkama and Malleshi (1998).

dash(-) indicates not available. ^{\$}Values for rice-cowpea-groundNutri masa are from Nkama and Malleshi (1998).

Table 3: Chemical composition of traditional cereal-based beverages and their fortified product(s)

Parameters	<i>Kunun-zaki</i>	<i>Tigernut-Kunun</i>	<i>Vigna racemos a-Kunun</i>	<i>Soy-kunun</i>	<i>Mango-kunun*</i>	<i>Cocoa powder-kunun</i>	<i>Pito and Burukutu[#]</i>	<i>Orange-pito</i>	<i>Seke-te</i>	<i>Soy-seke-te</i>
Protein (%)	1.13-4.96 ^{a,b,e,f}	6.14 ^a	4.86 ^b	4.59-9.86 ^{c,e}	9.77 ^d	2.64 ^f	1.97-5.42 ^{g,h,i} (3.1-5.80) ^{g,h}	2.87-2.98 ⁱ	3.1-16.1 ^{k,l}	3.37-3.57 ^k
Ash (%)	0.7-2.09 ^{a,e,f}	3.44 ^a	0.93 ^b	1.11-2.5 ^{c,e}	1.53 ^d	0.38 ^f	0.001-4.0 ^{g,h,i} (0.04-4.8) ^{g,h}	1.06-1.34 ⁱ	1.0-1.5 ^{k,l}	1.0-1.1 ^k
Fat (%)	0.71-17.6 ^{b,e,f}	-	1.16 ^b	0.39-18.0 ^{c,e}	2.19 ^d	0.93 ^f	0.1 ⁱ	0.50-0.75 ⁱ	0.7-1.0 ^k	0.73 ^k
Crude Fibre (%)	0.84-1.07 ^{a,b}	0.75 ^a	0.93 ^b	-	2.96 ^d	-	1.05 ^g (1.36-2.49) ^{g,j}	-	0.03-1.5 ^{k,l}	0.07-0.17 ^k
Carbohydrate (%)	3.8-28.63 ^{a,b,e,f}	0.14 ^a	25.2 ^b	0.96-6.03 ^{c,e}	74.97 ^d	5.75 ^f	0.2-80.16 ^{g,i} (82.85) ^g	0.85-1.66 ⁱ	11.3-12.3 ^k	11.4-11.7 ^k
Energy value (kcal/100g)	175-368.21 ^{d,f}	-	-	-	356.67 ^d	164 ^f	- (5.34-64.04) ^j	-	-	-
Calcium (mg/100g)	5.6-280 ^{a,e,f}	6.14 ^a	3.33 ^b	480 ^e	-	5.8 ^f	11.1 ^h (0.79-15.8) ^{h,j}	5.8-6.40 ⁱ	199 ^l	-
Magnesium (mg/100g)	34.9-85 ^{a,f}	63.7 ^a	-	-	-	170 ^f	110.0 ^h (16.22-114.0) ^{h,j}	7.21-7.31 ⁱ	160 ^l	-
Iron (mg/100g)	4.6-21.2 ^{a,b,f}	18.6 ^a	2.47 ^b	-	-	6.0 ^f	53 ^h (1.14-2.1) ^{h,j}	5.91-6.03 ⁱ	-	-
Phosphorus (mg/100g)	2.1-150 ^{a,e}	6.7 ^a	-	270 ^e	-	-	-	-	91 ^l	-
Zinc (mg/100g)	3.4-5.0 ^{b,f}	-	0.64 ^b	-	-	7.4 ^f	-	-	-	-
Sodium (mg/100g)	21.5 ^a	-	-	-	-	-	- (1.07-1.58) ^j	-	23.8 ^l	-
Potassium (mg/100g)	140.2-199 ^{a,e,f}	148.9 ^a	-	200 ^e	-	155 ^f	- (56.16-97.62) ^j	-	242 ^l	-
Manganese (mg/100g)	0.2-2.0 ^{b,e}	-	0.39 ^b	1.3 ^e	-	-	- (1.60-4.71) ^j	-	-	-

Vitamin B1 (mg/kg)	0.71 ^a	1.05 ^a	-	-	-	-	-	-	0.06-0.08 ^k	0.05-0.07 ^k
Vitamin B2 (mg/kg)	0.35 ^a	0.56 ^a	-	-	-	-	-	-	0.10-0.20 ^k	0.07-0.10 ^k
Niacin (mg/kg)	1.17 ^a	0.59 ^a	-	-	-	-	-	-	0.27-0.40 ^k	0.27-0.37 ^k
Vitamin C (mg/kg)	0.7-1.87 ^{a,c}	12.91 ^a	-	1.7 ^c	-	0.001-0.002 ^j	3.36-3.56 ⁱ	-	-	-

^aOlaoye *et al.* (2016); ^bBolarinwa *et al.* (2015); ^cGaffa *et al.* (2002); ^dSengev *et al.* (2012); ^eAdeniji and Keshinro, (2015); ^fAbidoye (2017); ^gFadahunsi *et al.* (2003). ^hKolawole *et al.* (2007); ⁱAdelekan *et al.* (2013); ^jOgbonna *et al.* (2016); ^kObatolu *et al.*, 2016; ^lSanni (1989).

*Values are for mango mesocarp kunun-zaki flour blends (10% Malted sorghum: 65% Unmalted sorghum: 25% Mango mesocarp flour).

[#]Values in parentheses are chemical composition of *burukutu*.

Dash(-) indicates not available.

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