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Original article

Nutritional and sensory properties of a maize-based snack food (*kokoro*) supplemented with treated Distillers' spent grain (DSG)

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Summary The effect of treated Distillers' spent grain (DSG) supplementation on the nutritional and sensory properties of *kokoro*, a maize-based snack, was investigated. Treated DSG was used to replace 5%, 10%, 15%, 20%, 25%, 30% and 35% of maize flour. Mean water absorption capacity of DSG was 291%, swelling capacity 2.27 bulk density was 58%, oil absorption capacity 216, protein content of 27% and a total dietary fibre content 24.2%. The swelling, water and oil absorption capacities of the flour blends increased while bulk density decreased significantly. The ash, fat, protein, insoluble and total dietary fibre and total nonessential and essential amino acids contents of the flour blends increased with DSG inclusion. Processing the flour blends to *kokoro* slightly increased the ash, fat and protein contents, while the total nonessential and essential amino acids, total sugar and total dietary fibre decreased. The addition of DSG increased the lysine and tryptophan contents of *kokoro*. Although the sensory evaluation *results* indicate that *kokoro* with 5%, 10% and 15% DSG were well accepted and compared favourably with those made from whole maize for overall acceptability, it was observed that generally, there is a consumer dislike of the new product as the amount of DSG added increased.

Keywords Distillers' spent grains, *kokoro*, maize flour, nutritional value, supplementation.

Introduction

Protein energy malnutrition (PEM) is prevalent, particularly among rural women and children in developing countries where maize serves as a staple food and could be reduced by the availability of cheap, nutritious foods based on simple processes such as supplementation (Achi, 1999).

Kokoro is a finger-like maize-based snack food that is consumed alone or with roasted groundnuts (Adelakun *et al*., 2004; Uzor-Peters *et al*., 2008). Most often snack foods do not provide nutrients in adequate amounts because of their composition or the production process they go through (Omueti & Morton, 1996). Many people are now dependent on snack foods as part of their daily diet (Uzor-Peters *et al*., 2008). Therefore, it is important to produce a highly acceptable snack with improved nutritional quality as a means of reducing PEM and other nutrient deficiencies (Rosa *et al*., 2003).

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Food supplementation is the process of increasing the level of specific nutrients previously identified as inadequate using a source rich in that nutrient. This is usually done to prevent malnutrition in the developing countries (FAO, 1992). The levels of food supplementation depend on the nutritional needs of the consumers, the estimated consumption of the supplemented food, the availability of the supplement and the regulations in the country (Onis *et al*., 1993). The supplementation of staple cereal-based foods with legumes results in improved nutritional quality, especially protein quality and quantity (Gupta & Kapon, 1980). Supplementation of *kokoro* with soya bean flour led to an increase in protein and fat contents; carbohydrate content decreased as the soya bean flour proportion increased (Adelakun *et al*., 2004).

The potential to utilise Distillers' spent grain (DSG; products from wheat and other cereal grains) as a high protein and fibre ingredient in formulated foods has received increasing attention (Wu *et al*., 1984; Rasco *et al*., 1987a,b). DSG is a by-product of cereal fermentation in the production of alcoholic beverages. It contains high amounts of protein, ranging from 23% to 35% and total dietary fibre ranging from 27%

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to 55% (Rasco & McBurney, 1989). Similarly it contains yeast cells, vitamins B-complex and other nutrients formed during the fermentation and distillation processes (Kaiser, 2006). DSG has been used in animal feeds to prevent waste, but in recent times, it has also been utilised in human foods (Rasco *et al.*, 1987a). For instance, DSG has been added up to 35% by weight in brownies, chocolate chip and spice and lemon molasses cookies; about 30–50% in bread made with yeast and 30% in quick breads to produce highly acceptable products (Rasco & McBurney, 1989). Tsen *et al.* (1982) reported that chocolate chip cookies containing 15% dried distillers' grain residues were as acceptable as chocolate chip cookies without distillers' grain. Ozvural *et al.* (2009) also reported that the supplementation of frankfurters with Brewer's spent grain (BSG) increased the total dietary fibre content of the product.

Therefore, the possibility was investigated of producing an acceptable maize-based snack (*kokoro*), supplemented with DSG to enhance its nutritional quality.

Materials and methods

Materials

Yellow maize grain (ACR-91 Suwan-1-SRC) was obtained from the maize improvement programme at International Institute of Tropical Agriculture, Ibadan, Nigeria. The maize DSG resulting from the ethanol industry was obtained from the United State Department of Agriculture-Agricultural Research Service (USDA-ARS), North Dakota, USA. Refined vegetable oil, sugar, onion and salt were bought in a local market.

Treatment of DSG

To remove residual sugar and alcohol, 100 g of DSG was made into a suspension by dissolving in 400 mL of water and fermented with yeast (0.8 g) for 1 h to convert its residual sugar to alcohol. The fermented suspension was subjected to distillation to remove residual alcohol. The pH of the distilled suspension was adjusted to about 6.0–7.0 by adding sodium hydroxide (7 mL) and dried to a moisture content of 5.06 ± 0.05% (Rasco & McBurney, 1989). The fermented, distilled and dried product was identified as treated DSG and was used throughout the study.

Maize flour production

Maize grain was cleaned by hand to remove stones, chaff and damaged grains. The cleaned maize grain was dry-milled in an attrition mill and sieved to obtain a particle size of 750 μm (Adelakun *et al.*, 2004).

Formulation of DSG–maize flour blends

Maize flour and DSG were weighed and mixed in ratios as follows: 100:0%, 95:5%, 90:10%, 85:15%, 80:20%, 75:25%, 70:30%, and 65:35%. The various mixes were thoroughly blended with a laboratory blender, packed and sealed in low-density polythene bags until required (Adelakun *et al.*, 2004).

Recipe formulation of *kokoro*

Kokoro was produced as described by Adelakun *et al.* (2004) with a slight modification in the recipe used as onion and salt were used in place of sugar and salt. The ingredients used were 100 g flour blend, 8 g blended onion, 1.5 g salt and 50 mL water.

Production of *kokoro*

Half of each blend was mixed and stirred in boiled water to make a paste. The remaining 50% was first mixed with salt and onion and then added to the paste with continuous stirring for about 3 min to form homogenous dough. The dough was allowed to cool to 40 °C and kneaded by hand on a chopping board. The kneaded dough was cut into pieces, rolled into cylindrical shapes, and deep-fried in hot vegetable oil (specific gravity 0.918, temperature 105 ± 5 °C) for 3 min, drained and left to cool (Fig. 1). The *kokoro* pieces were then packed in low-density polythene bags and stored at ambient conditions (30 ± 3 °C; Adelakun *et al.*, 2004; Uzor-Peters *et al.*, 2008).

Physical properties

Bulk density

This was determined using a standard laboratory method (AOAC, 1990). The flour samples were weighed (7 g) into a 50-mL graduated measuring cylinder. The cylinder was tapped gently against the palm of the hand until a constant volume was obtained. Bulky density was calculated as weight of sample/volume of sample after tapping.

Water absorption capacity and oil absorption capacity

The water absorption capacity (WAC) and oil absorption capacity (OAC) were determined using the method described by Beuchat (1977). Exactly 1 g sample each was mixed with 10 mL of distilled water for WAC and 10 mL of oil for OAC and blended for 30 s. The samples were allowed to stand for 30 min and centrifuged at 1303 ***g*** for 30 min at room temperature. The supernatant was decanted. The weight of water or oil absorbed by the flour was calculated and expressed as percentage WAC or OAC.

Figure 1 Flow chart for the production of *kokoro*.

Swelling capacity
The method described by Ukpabi & Ndimele (1990) was used. Flour samples (10 g) were placed in a washed, dried and weighed graduated measuring cylinder. Distilled water of 100 mL was added, stirred and allowed to stand for 1 h. The supernatant was discarded and the cylinder with its content weighed to obtain the weight of the net sample. The swelling capacity on volume basis was calculated as difference in final to initial volume of the sample.

Determination of chemical composition
Moisture, ash and fat contents were determined using standard laboratory procedures (AOAC, 1990). Protein content was determined by the Kjeldahl method using Kjeltec™ model 2300 protein analyzer (Foss Analytical Manual, 2003). A conversion factor of 6.25 was used to convert total nitrogen to percentage crude protein.

Total sugars and starch content analysis
Total sugars and starch content were analysed according to the method described by Dubois *et al*. (1956).

Soluble and insoluble dietary fibre
Samples were analysed for soluble (SDF) and insoluble dietary fibre (IDF) fractions using the enzymatic-gravimetric procedure (Prosky *et al*., 1988).

Total amino acid composition
Amino acids were identified and quantified by reverse phase liquid chromatography (Waters 1500 Series HPLC; Waters, Milford, MA, USA) with UV detection at 254 nm (Cohen *et al*., 1988) at the South African Grain Laboratory, Pretoria, South Africa.

Sensory evaluation
A 9-point hedonic preference scale and multiple comparison tests were used to test the acceptability of *kokoro* made from maize/DSG flour blends compared to whole maize *kokoro*. Ten trained panellists were selected from the staff and graduate students of IITA, Ibadan, and screened with respect to their interest and ability to differentiate food sensory properties as described by Iwe (2002). Selection tests included an odour and flavour identification test, colour test, and a

series of texture tests in which panellists' abilities to assess crispiness was measured. The panellists were then presented with coded samples to evaluate the effect of the different supplementation ratios on taste, crispiness, colour, flavour, appearance and overall acceptability using the 9-point hedonic scale, where 1 corresponds to like extremely and 9 corresponds to dislike extremely.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS, 2008) package (version 9.1; SAS Institute, Inc., Cary, NC, USA). The Fischer's protected least significant difference (LSD) test was used for mean separation.

Results and discussions

Physical properties

The physical properties of the treated and untreated DSG and maize flour: treated DSG blends are presented in Table 1. The treated DSG had significantly higher water absorption capacity, bulk density, swelling capacity and low oil absorption capacity. Mean water absorption capacity for the treated DSG was 291%, bulk density was 58%, swelling capacity was 2.27 and oil absorption capacity was 216%.

There were significant differences ($P < 0.05$) in the swelling capacity, water and oil absorption capacities and bulk density of the flour blends (Table 1). There was a significant increase in swelling capacity, bulk density and water absorption capacity in the treated DSG compared to the untreated DSG. Among the flour blends, adding treated DSG ≥15% resulted in a significant increase in swelling capacity and water absorption capacity and lower oil absorption capacity (Table 1). Swelling capacity is the volume of expansion of molecule in response to water uptake which it possessed until a colloidal suspension is achieved or until further expansion and uptake is prevented by intermolecular forces in the swollen particle (Houssou & Ayernor, 2002). The authors further observed that high quantity of carbohydrate or starches enhance swelling capacity of flour. This was not the case for maize flour with high starch content in this study. Mixing treated DSG with maize flour increased the swelling capacity of the flour blends. This might be because of high swelling capacity of DSG (probably because of its high fibre content).

The water absorption capacity of the flour blends ranged from 253% to 283% and it increased as the amount of added DSG increased in the blends. Water absorption capacity (WAC) is an important functional property in the development of a ready-to-eat cereal grain food, because a high WAC may assure product cohesiveness (Houssou & Ayernor, 2002). Protein is mainly responsible for the bulk of the water uptake and to lesser extent the starch and cellulose at room temperature (Afoakwa, 1996). Therefore, the observed high water absorption capacity may *be* attributed to the high protein content of DSG (Afoakwa, 1996). The results obtained in this study *are* comparable to the values (271.1–300%) reported by Fasasi *et al.* (2007) for fermented maize flour-tilapia mix *and those* reported by Adetuyi *et al.* *(*2009) for unmalted–soya bean (280%) blend. The OAC on the other hand is a critical

Table 1 Physical properties of different ratios of maize flour (M) and Distiller's spent grain (DSG) blends

Samples	WAC (%)	Bulk density (%)	Swelling capacity	OAC (%)
TDSG	291 ± 0.03[a]	58 ± 0.00[e]	2.27 ± 0.03[a]	216 ± 0.02[b]
UDSG	208 ± 0.00[g]	55 ± 0.01[f]	1.91 ± 0.03[e]	236 ± 0.06[a]
100% M:0% DSG	258 ± 0.04[ef]	72 ± 0.02[a]	2.04 ± 0.04[d]	204 ± 0.04[cd]
95% M:5% DSG	256 ± 0.05[ef]	70 ± 0.00[b]	2.07 ± 0.04[cd]	193 ± 0.03[f]
90% M:10% DSG	253 ± 0.07[f]	70 ± 0.00[b]	2.05 ± 0.02[cd]	197 ± 0.03[ef]
85% M:15% DSG	261 ± 0.00[de]	68 ± 0.02[c]	2.32 ± 0.05[a]	207 ± 0.02[c]
80% M:20% DSG	265 ± 0.02[d]	64 ± 0.00[d]	2.11 ± 0.02[bc]	200 ± 0.00[de]
75% M:25% DSG	276 ± 0.00[c]	64 ± 0.00[d]	2.27 ± 0.00[a]	205 ± 0.01[cd]
70% M:30% DSG	281 ± 0.04[bc]	62 ± 0.01[d]	2.27 ± 0.07[a]	203 ± 0.01[cd]
65% M:35% DSG	283 ± 0.01[b]	64 ± 0.00[d]	2.18 ± 0.06[b]	202 ± 0.02[cde]
Mean	263.20	64.70	2.15	206.30
Minimum	208.00	55.00	1.91	193.00
Maximum	291.00	72.00	2.32	236.00
$P < 0.5$ level	*	*	*	*

Means with different letters in the same column are significantly different at $P \leq 0.05$. Values are means ± standard deviations from triplicate samples on as is basis.

UDSG, Untreated Distiller's spent grain, TDSG (use as DSG), treated Distiller's spent grain; WAC, water absorption capacity; OAC, oil absorption capacity.

assessment of flavour retention that increases the palatability of foods (Kinsella, 1976). The oil absorption capacity of the blends ranged between 193% and 207% (Table 1). Fasasi *et al*. (2007) reported values ranging from 176% to 246% for OAC of fermented maize flour and maize-fermented tilapia mix that are similar to those obtained in this study. A similar range (120–220%) was also reported by Adetuyi *et al*. (2009) for malted and unmalted maize.

Bulk density reduced from 72% for 100% maize flour to 62% for 70% maize flour: 30% DSG blend. Adetuyi *et al*. (2009) reported that the bulk density of unmalted maize flour decreases from 77% to 66% after mixing with soya bean flour. This was in accordance with the observation in this study. A similar observation was also made by Edema *et al*. (2005) for bulk density of maize supplemented with soya bean. This decrease in bulk density could be attributed to variation in the nature of protein sources and level of supplementation (Fasasi *et al*., 2007). Low bulk density food is desired where packaging is a serious problem (Ikujenlola, 2008); thus, 70% maize flour: 30% DSG blend would require the least packaging material because of its bulk density.

Chemical composition of flour blends

There were significant differences ($P < 0.05$) for all the investigated parameters (Table 2). Treating the DSG resulted in a significant reduction in ash, moisture content, total sugars and starch content. The mean ash content was 1.87% with a range of 1.30–4.11%. Ash content is a reflection of the mineral status, even though contamination can indicate a high concentration in a sample (Baah *et al*., 2009). Among the flour blends, the ash content was highest (1.72%) in 70% maize flour: 30% DSG blend, while 100% maize flour had the lowest (1.30%). The result indicates that mixing maize flour with DSG increases its ash content. This might be attributed to high ash content of DSG. Comparable ash content (1.39–3.20%) with the flour blends was reported for cowpea–maize flour and their *ogi* (fermented maize gruel) blends by Zanna & Milala (2004). The lower the initial moisture content of a product, the better its storage stability is (Sanni *et al*., 2006). The 100% maize flour had the highest moisture content, while 65% maize flour: 35% DSG blends had the lowest (Table 2). This implies that all the blends might be stored for a long period of time before being utilised. The results of the blends were in accordance with the values (5.90–11.69%) reported by Fasasi *et al*. (2007) for maize flour–tilapia mix as well as the values (4–9.31%) for cowpea–millet blend reported by Zanna & Milala (2004).

The fat content of the treated DSG was 9.63% and that of the flour blends ranged between 5.13% and 6.84%, with 65% maize flour: 35% DSG blend having the highest value and 100% maize flour had the least (Table 2). The higher the proportion of DSG in the blends, the higher the fat content is. This might be attributed to the high fat content of DSG. Similar values (5.90–11.69%) with the flour blends was reported by Fasasi *et al*. (2007) for maize–tilapia mix, but lower values (2.705–4.24%) was reported by Zanna & Milala (2004) on cowpea–millet mixes. The total sugar content of the blends was observed to be highest (5.42%) in the 100% maize flour; the least value (2.73%) was found in 65% maize flour: 35% DSG flour blend (Table 2). The result of this study indicates that as the proportion of

Table 2 Chemical composition (%) and pH of different ratios of maize flour (M) and Distillers' spent grain (DSG) blends

Samples	Ash	Moisture	Protein	Fat	Sugar	Starch	pH
UDSG	4.11 ± 0.02^{a}	12.33 ± 0.19^{a}	27.18 ± 0.08^{b}	9.34 ± 0.10^{b}	6.98 ± 0.15^{a}	26.06 ± 0.70^{h}	4.19 ± 0.00^{i}
TDSG	2.37 ± 0.02^{b}	5.06 ± 0.04^{h}	29.80 ± 0.13^{a}	9.63 ± 0.02^{a}	3.37 ± 0.06^{d}	23.86 ± 0.40^{g}	5.70 ± 0.01^{h}
100% M:0% DSG	1.30 ± 0.02^{g}	8.88 ± 0.02^{b}	10.04 ± 0.22^{j}	5.13 ± 0.04^{g}	5.42 ± 0.13^{b}	67.33 ± 0.80^{a}	6.28 ± 0.02^{a}
95% M:5% DSG	1.34 ± 0.00^{fg}	8.64 ± 0.09^{cd}	10.96 ± 0.00^{i}	5.34 ± 0.02^{e}	4.23 ± 0.11^{c}	64.85 ± 0.38^{b}	6.28 ± 0.01^{a}
90% M:10% DSG	1.39 ± 0.13^{f}	8.66 ± 0.01^{c}	12.00 ± 0.04^{h}	5.24 ± 0.02^{f}	3.42 ± 0.06^{d}	63.68 ± 0.07^{c}	6.24 ± 0.01^{b}
85% M:15% DSG	1.60 ± 0.05^{de}	8.52 ± 0.07^{d}	13.00 ± 0.08^{g}	5.69 ± 0.03^{d}	3.17 ± 0.04^{e}	62.09 ± 0.60^{d}	6.12 ± 0.02^{c}
80% M:20% DSG	1.58 ± 0.01^{e}	8.32 ± 0.11^{e}	14.33 ± 0.10^{f}	5.61 ± 0.05^{d}	3.06 ± 0.04^{ef}	61.34 ± 0.30^{de}	6.08 ± 0.01^{d}
75% M:25% DSG	1.62 ± 0.03^{de}	8.02 ± 0.01^{f}	15.49 ± 0.15^{e}	6.82 ± 0.06^{c}	2.98 ± 0.02^{fg}	60.90 ± 0.15^{e}	6.03 ± 0.02^{e}
70% M:30% DSG	1.72 ± 0.01^{c}	8.02 ± 0.02^{f}	16.52 ± 0.17^{d}	6.84 ± 0.01^{c}	2.88 ± 0.04^{g}	60.53 ± 0.08^{e}	5.93 ± 0.04^{f}
65% M:35% DSG	1.67 ± 0.02^{cd}	7.47 ± 0.02^{g}	17.48 ± 0.31^{c}	6.84 ± 0.12^{c}	2.73 ± 0.04^{h}	54.47 ± 0.82^{f}	5.83 ± 0.01^{g}
Mean	1.87	8.39	16.68	6.65	3.82	54.51	5.87
Minimum	1.30	5.06	10.04	5.13	2.73	54.47	4.19
Maximum	4.11	12.33	29.80	9.63	6.98	26.06	6.28
P level	*	*	*	*	*	*	*

Means with different letters in the same column are significantly different at $P \le 0.05$. Values are means ± standard deviations from triplicate samples on as is basis.
UDSG, Untreated Distillers' Spent Grains, TDSG (DSG), Treated Distillers' Spent Grains; M, Maize flour.

DSG increases in the blends, there is a decrease in total sugars. This could be attributed to a dilution factor as the treated DSG had half the amount of total sugars compared to the untreated DSG. The amount of total sugars in the maize flour was slightly higher than the values (1–3%) reported by Boyer & Shannon (1987) for total sugar content in maize.

Starch content of the flour blends on the other hand ranged between 54.47% and 67.33%. The 100% maize flour had the highest; 65% maize flour: 35% DSG blend had the lowest. There was a decrease in starch content of the flour blends as the proportion of DSG increased (Table 2). This might be attributed to both the dilution factor and the low starch content of DSG. The starch content of maize flour investigated was closer to the range of values (72–73%) reported for maize by Boyer & Shannon (1987).

The protein content of the flour blends ranged from 10.04% to 17.48%. The 65% maize flour: 35% DSG blend had the highest protein content compared to 100% maize flour. Protein is essential in the human diet for growth and repair of worn-out tissue (Baah *et al.*, 2009). The protein content of untreated and treated DSG was comparable with the range of values (23–35%) reported by Rasco & McBurney (1989) as well as the values (27.60–34.9%) reported by Ranhotra *et al.* (1982). The results indicate that the higher the proportion of DSG in the flour blends, the higher the protein content is, and this might be responsible for the increase in the WAC and decrease in bulk density of the blends. The protein content of the maize flour was comparable with the values (8–11%) reported by Landry & Moureaux (1982) as well as values (5.2–13.70%) reported by Cortez & Wild-Altamirano (1972) for maize. Fasasi *et al.* (2007) reported 11.69% protein for maize flour, which was slightly higher compared to the protein content of maize flour in this study. The protein content of the flour blends fall within the range of values (9.10–19.96%) reported by Zanna & Milala (2004) for the protein content of cowpea–maize flour blend.

Amino acid composition of different ratios of maize flour and Distiller's spent grain

The amino acid analysis of food products is an important index of its protein quality and can produce useful information on the nutritional quality and authenticity of food products and the sources of raw materials used in food manufacture (Alozie *et al.*, 2009). The results of the amino acid analysis of the flour blends show that total essential amino acids with histidine ranged from 3.84 g/100 g to 6.56 g/100 g and that without histidine ranged from 3.50 g/100 g to 6.02 g/100 g. The 65% maize flour: 35% DSG blend had the highest value, while 100% maize flour had the lowest value (with and without histidine; Table 3). The 80% M: 20% DSG flour blend had the highest (1.37 g/100 g) total conditionally nonessential amino acids, while 100% maize flour had the lowest amount (0.88 g/100 g). The values of the total nonessential amino acids of the flour blends ranged from 5.73 g/100 g sample to 9.63 g/100 g sample. The 65% maize flour: 35% DSG blend had the highest value, while that of 100% maize flour had the lowest (Table 3). Leucine contributes the highest amount of the total essential amino acid and tryptophan. This was in agreement with the observation made by Mertz *et al.* (1975) and Hogan *et al.* (1955) on common maize. Glutamic acid contributed the highest amount of the total nonessential amino acids, while glycine contributed the lowest.

Table 3 Proximate composition (%) of *kokoro* produced from different ratios of maize flour (M) and Distiller's Spent Grain (DSG) blends

Samples	Ash	Moisture	Protein	Fat	Sugar	Starch
100% M:0% DSG	2.31 ± 0.01^{a}	10.06 ± 0.01^{c}	10.72 ± 0.06^{h}	16.49 ± 0.08^{h}	3.24 ± 0.04^{a}	77.79 ± 0.67^{a}
95% M:5% DSG	2.09 ± 0.01^{e}	10.86 ± 0.01^{a}	11.30 ± 0.06^{g}	19.72 ± 0.12^{g}	1.98 ± 0.04^{e}	53.75 ± 0.34^{b}
90% M:10% DSG	2.15 ± 0.01^{d}	9.92 ± 0.06^{c}	12.20 ± 0.04^{f}	25.76 ± 0.07^{e}	2.38 ± 0.09^{c}	52.18 ± 0.55^{d}
85% M:15% DSG	2.20 ± 0.00^{c}	10.85 ± 0.05^{a}	13.50 ± 0.12^{e}	20.72 ± 0.12^{f}	2.84 ± 0.04^{b}	52.94 ± 0.56^{c}
80% M:20% DSG	2.15 ± 0.00^{d}	10.48 ± 0.14^{b}	15.14 ± 0.28^{d}	27.82 ± 0.04^{c}	1.87 ± 0.05^{e}	48.39 ± 0.33^{e}
75% M:25% DSG	2.22 ± 0.01^{b}	10.54 ± 0.27^{b}	15.91 ± 0.26^{c}	26.24 ± 0.16^{d}	2.89 ± 0.06^{b}	44.14 ± 0.33^{f}
70% M:30% DSG	1.93 ± 0.01^{g}	10.85 ± 0.02^{a}	16.58 ± 0.13^{b}	29.63 ± 0.02^{b}	2.34 ± 0.09^{c}	43.27 ± 0.11^{g}
65% M:35% DSG	2.02 ± 0.02^{f}	10.55 ± 0.03^{b}	18.06 ± 0.14^{a}	35.11 ± 0.08^{a}	2.13 ± 0.09^{d}	40.71 ± 0.31^{h}
Mean	2.13	10.51	14.18	25.19	2.46	51.65
Minimum	1.93	9.92	10.72	16.49	1.87	40.71
Maximum	2.31	10.86	18.06	35.11	3.24	77.79
CV (%)	0.46	1.05	1.13	0.39	2.69	0.84
P level	*	*	*	*	*	*

Means with different letters in the same column are significantly different at $P \leq 0.05$. Values are means ± standard deviations from triplicate samples on as is basis.

Chemical composition of *kokoro*

When the flour blends were processed to *kokoro*, a maize-based snack result obtained for chemical determinations indicates that ash content ranged from 1.93% to 2.31% with a mean of 2.13%. The 70% maize flour: 30% DSG blend *kokoro* had the lowest ash content, while that of 100% maize had the highest (Table 4). The ash content of *kokoro* products was slightly higher than that of their respective flour blends. This might be attributed to other ingredients such as onion and salt mixed with the flour blends during the production of *kokoro*. The ash content of the *kokoro* products was in agreement with the values reported by Adelakun *et al.* (2004) for soy-maize *kokoro* but higher than the values reported by Uzor-Peters *et al.* (2008), for *kokoro* from a defatted soya bean/groundnut cake-maize blend.

The moisture content of the products ranged from 9.92% and 10.86% with a mean of 10.51% (Table 4). There was some level of significant difference ($P \leq 0.05$) in the moisture content of *kokoro* products. The results are comparable with the values of defatted groundnut cake–maize blend *kokoro* but higher than that of soya bean–maize blend as reported by Uzor-Peters *et al.* (2008).

The fat content of the *kokoro* products has a mean of 25.19% and ranged from 16.49% to 35.11% (Table 4). The *kokoro* from 100% maize flour had the lowest fat content and that of 65% maize: 35% DSG had the highest value. There was a significant difference ($P < 0.05$) in the fat content of the *kokoro* that was in accordance with the values for defatted groundnut cake–maize blend *kokoro* reported by Uzor-Peters *et al.* (2008) as well as the values reported by Adelakun *et al.* (2004) for that of soya bean–maize blend.

Significant differences ($P < 0.05$) were observed for total sugars among the products. Total sugar content of the *kokoro* products ranged from 1.87% to 3.24% with a mean of 2.46% (Table 4). There was a significant slight reduction in total sugars with the addition of DSG and also when compared to the flour blends. This could be attributed to the contribution of total sugars to *kokoro* colour formation during frying.

There were significant ($P < 0.05$) differences in starch content for the different products. The starch content of *kokoro* ranged from 40.71% to 77.79% with a mean of 51.65% (Table 4). The starch content of *kokoro* was significantly reduced compared to their respective blends except for that from 100% maize flour.

Table 4 Amino acid composition of different ratios of maize flour (M) and Distiller's spent grain (DSG) blends

Amino acids (g/100 g sample)	TDSG	UDSG	100% M:0% DSG	95% M:5% DSG	90% M:10% DSG	85% M:15% DSG	80% M:20% DSG	75% M:25% DSG	70% M:30% DSG	65% M:35% DSG
Methionine	0.49	0.48	0.16	0.15	0.21	0.28	0.28	0.29	0.30	0.33
Aspartic acid	2.15	1.93	0.69	0.75	0.83	0.88	0.90	0.97	1.10	1.20
Glutamic acid	6.22	5.57	2.26	2.44	2.65	2.75	3.00	3.03	3.38	3.66
Serine	1.74	1.52	0.57	0.66	0.69	0.82	0.90	0.95	0.95	0.99
Glycine	1.24	1.16	0.38	0.45	0.49	0.55	0.64	0.68	0.66	0.69
Histidine	0.87	0.78	0.34	0.38	0.40	0.48	0.52	0.55	0.50	0.53
Arginine	1.34	1.29	0.50	0.66	0.57	0.71	0.77	0.82	0.75	0.78
Threonine	1.24	1.11	0.39	0.44	0.49	0.56	0.61	0.65	0.66	0.67
Alanine	2.45	2.14	0.85	0.99	1.02	1.23	1.34	1.41	1.38	1.46
Proline	2.79	2.42	0.99	1.12	1.21	1.39	1.56	1.69	1.56	1.63
Tyrosine	1.07	1.05	0.38	0.33	0.35	0.52	0.60	0.52	0.54	0.56
Valine	1.45	1.25	0.44	0.54	0.58	0.65	0.75	0.74	0.77	0.82
Isoleucine	1.09	0.97	0.34	0.39	0.44	0.46	0.49	0.52	0.59	0.60
Leucine	3.87	3.20	1.31	1.43	1.59	1.67	1.79	1.82	2.17	2.26
Phenylalanine	1.66	1.39	0.53	0.57	0.66	0.66	0.71	0.75	0.89	0.82
Lysine	0.82	0.77	0.26	0.28	0.30	0.28	0.30	0.34	0.43	0.43
Tryptophan	0.23	0.20	0.07	0.10	0.08	0.10	0.11	0.10	0.12	0.10
TAa	30.72	27.21	10.45	11.68	12.56	13.97	15.25	15.85	16.77	17.53
TEAa with histidine	11.73	10.13	3.84	4.28	4.75	5.14	5.55	5.77	6.44	6.56
TEAa without histidine	10.85	9.36	3.50	3.90	4.36	4.66	5.03	5.22	5.94	6.02
TCNAa	2.42	2.34	0.88	0.99	0.92	1.23	1.37	1.34	1.30	1.34
TNAa	16.58	14.74	5.73	6.41	6.89	7.61	8.33	8.73	9.03	9.63

Values are for a single sample on as is basis.

UDSG, untreated Distillers' Spent Grains; TDSG (used as DSG), Treated Distillers' spent grains; TAa, total amino acids; TEAa, total essential amino acids; TCNAa, total conditionally nonessential amino acids; TNAa, total nonessential amino acids.

Significant differences ($P < 0.05$) were observed for protein content. The protein content ranged from 10.72% to 18.06% with a mean of 14.18%. *Kokoro* from 100% maize flour had the lowest value, while that of 65% maize flour: 35% DSG had the highest (Table 4); this might be attributed to the high protein content of the DSG in the blends. The results were within the range of values for that of partially defatted groundnut cake–maize reported by Uzor-Peters *et al.* (2008). The protein content of 100% maize *kokoro* was higher than the value reported by Uzor-Peters *et al.* (2008).

Amino acid composition of *kokoro*

The results of the amino acid analysis of the *kokoro* products show that total indispensable amino acids with histidine ranged from 3.18 g/100 g to 4.87 g/100 g and that without histidine ranged from 2.94 g/100 g to 4.48 g/100 g (Table 5). *Kokoro* from 100% maize flour had the lowest total indispensable amino acid while that of the 65% maize flour: 35% DSG blend had the highest values (with and without histidine), with leucine contributing the highest amount and tryptophan the least (Table 5). This implies that *kokoro* from the 65% maize flour: 35% DSG blend contains the highest amount of amino acids that must be supplied to the human body from food or supplement (Finnin & Peters, 1996).

The results of the total conditionally dispensable amino acids ranged from 0.77 g/100 g to 1.21 g/100 g (Table 5). The 100% maize flour *kokoro* had the lowest total conditionally dispensable amino acids; 65% maize flour: 35% DSG has the highest values, with arginine contributing the highest amount and tyrosine the least (Table 5). This implies that *kokoro* from 65% maize flour: 35% DSG blend contains the highest amount of amino acids which depends on the ability of the human body to actually synthesize them from other amino acids (Finnin & Peters, 1996).

The values of the total dispensable amino acids of the *kokoro* products ranged from 4.67 g/100 g to 7.10 g/100 g. The 100% maize flour *kokoro* had the lowest total dispensable amino acids and that of 75% maize flour: 25% DSG had the highest values, with glutamic acid contributing the most and glycine the least (Table 5). This implies that *kokoro* from the 75% maize flour: 25% DSG blend contains the highest amount of amino acids that can be synthesized by the human body from other amino acids (Finnin & Peters, 1996).

The indispensable and dispensable amino acid compositions of *kokoro* (with high protein content) were slightly lower than in their respective flour blends. This

Table 5 Amino acid composition of *kokoro* produced from different ratios of maize flour (M) and Distiller's spent grain (DSG) blends

Amino acids (g/100 g sample)	100% M:0% DSG	95% M:5% DSG	90% M:10% DSG	85% M:15% DSG	80% M:20% DSG	75% M:25% DSG	70% M:30% DSG	65% M:35% DSG
Methionine	0.15	0.15	0.17	0.21	0.21	0.20	0.24	0.28
Aspartic acid	0.55	0.61	0.66	0.77	0.78	0.88	0.85	0.85
Glutamic acid	1.79	2.03	2.13	2.41	2.47	2.73	2.52	2.50
Serine	0.48	0.53	0.57	0.64	0.67	0.73	0.71	0.72
Glycine	0.31	0.35	0.38	0.44	0.46	0.51	0.49	0.51
Histidine	0.26	0.29	0.30	0.34	0.35	0.39	0.39	0.39
Arginine	0.46	0.47	0.52	0.58	0.60	0.64	0.63	0.64
Threonine	0.32	0.35	0.38	0.42	0.44	0.49	0.49	0.50
Alanine	0.71	0.79	0.83	0.94	0.98	1.05	1.02	1.04
Proline	0.83	0.90	0.95	1.06	1.10	1.21	1.17	1.20
Tyrosine	0.31	0.29	0.35	0.43	0.47	0.45	0.57	0.57
Valine	0.37	0.42	0.45	0.51	0.55	0.60	0.59	0.59
Isoleucine	0.28	0.32	0.34	0.38	0.41	0.46	0.44	0.43
Leucine	1.11	1.25	1.32	1.48	1.54	1.65	1.59	1.60
Phenylalanine	0.45	0.50	0.53	0.62	0.63	0.70	0.67	0.68
Lysine	0.19	0.16	0.17	0.22	0.24	0.26	0.30	0.30
Tryptophan	0.05	0.05	0.06	0.07	0.07	0.08	0.07	0.10
TAa	8.62	9.44	10.13	11.52	11.97	13.00	12.71	12.89
TIAa with histidine	3.18	3.48	3.74	4.25	4.43	4.81	4.77	4.87
TIAa without histidine	2.92	3.20	3.44	3.91	4.08	4.43	4.38	4.48
TCDAa	0.77	0.75	0.87	1.01	1.07	1.09	1.19	1.21
TDAa	4.67	5.21	5.52	6.26	6.46	7.10	6.75	6.81

Values are for a single sample on as is basis.

TAa, total amino acids; TIAa, total indispensable amino acids; TCDAa, total conditionally dispensable amino acids; TDAa, total dispensable amino acids.

implies that processing of the flour blends to *kokoro* resulted in lower protein quality. This may be attributable to chemical reactions among the different components such as between protein and carbohydrate. In addition, frying at high temperature may result in loss of amino acids.

The mixing of DSG with maize flour for *kokoro* production increased both its lysine and tryptophan contents (limiting amino acids of maize) (Table 5). The lysine content of the *kokoro* products ranged from 0.16 g/100 g to 0.30 g/100 g; the tryptophan content ranged from 0.05 g/100 g and 0.10 g/100 g. *Kokoro* from 95% maize flour: 5% DSG blend had the lowest lysine content; 65% maize flour: 35% DSG had the highest. Similarly, *kokoro* from 100% maize flour and 95% maize flour: 5% DSG blend had the lowest tryptophan content; 65% maize flour: 35% DSG had the highest value (Table 5). This implies that the inclusion of DSG increased the amount of the limiting amino acids in maize flour. This was in agreement with the observation made by FAO (1992).

FAO/WHO/UNN (1985) reported that the total indispensable amino acids requirement (g/100 g protein) for school children aged 10–12 years is 24.1 (with histidine) and 22.2 (without histidine). For adults, the values are 12.7 g/100 g and 11.1 g/100 g. Based on this information, *kokoro* from this investigation that had a total indispensable amino acid content (g/100 g protein) range of 26.97–31.50 (with histidine) and 24.80–28.95 (without histidine) might be able to improve the total essential amino acid level when consumed by the target group.

Dietary fibre content of different ratios of maize flour and Distiller's spent grain blends and *kokoro* products

Dietary fibre (DF) – commonly called fibre – describes a number of different substances such as cellulose, pectin, lignin and guar, all of which are naturally found only in plants and are resistant to digestion and absorption by humans (IFST, 2007; Bauer & Türler-Inderbitzin, 2008). The TDF content of the flour blends ranged between 9.96% and 13.49%. The 70% maize flour: 30% DSG blend had the highest value; 100% maize flour had the least (Table 6). This might be linked to the increase in WAC and swelling capacity and decrease in bulk density of the blends. The 70% maize flour: 30% DSG blend had the highest IDF content compared to the 100% maize flour. It was observed that the 100% maize flour had the highest SDF content, while the 65% maize flour: 35% DSG flour blend had the least.

The total dietary fibre (TDF) content of *kokoro* ranged from 7.71% to 12.18% with the insoluble dietary fibre (IDF) contributing the highest amount and the soluble dietary fibre (SDF) contributing the least. This might be attributed to the high IDF and low SDF of the blends as the DSG increases. The IDF content of the products ranged from 6.85% to 11.61% with a mean of 9.31%; SDF ranged from 0.57% to 0.87% with a mean of 0.65%. *Kokoro* from 100% maize flour had the lowest IDF and the highest SDF content; 65% maize flour: 35% DSG had the highest IDF and the lowest SDF content (Table 6).

Deep frying reduced the SDF, IDF and TDF of the blends except for the SDF from 65% maize flour: 35%

Table 6 Dietary fibre content (%) of *kokoro* and different ratios of maize flour (M) and Distiller's spent grain (DSG) blends

	Flour blends			*Kokoro* products		
Samples	IDF	SDF	TDF	IDF	SDF	TDF
UDSG	23.79	0.73	24.52	–	–	–
TDSG	23.53	0.67	24.20	–	–	–
100% M:0% DSG	8.59	1.37	9.96	6.85	0.87	7.71
95% M:5% DSG	10.10	1.17	11.27	7.21	0.66	7.87
90% M:10% DSG	10.52	1.05	11.57	8.75	0.65	9.40
85% M:15% DSG	11.39	0.98	12.37	8.78	0.58	9.36
80% M:20% DSG	12.26	0.99	13.26	9.98	0.64	10.62
75% M:25% DSG	12.11	0.78	12.89	10.27	0.62	10.89
70% M:30% DSG	12.83	0.65	13.49	11.06	0.64	11.70
65% M:35% DSG	12.81	0.52	13.34	11.61	0.57	12.18
Mean	13.79	0.89	14.69	9.31	0.65	9.97
Minimum	8.59	0.52	9.96	6.85	0.57	7.71
Maximum	23.79	1.37	24.52	11.61	0.87	12.18

Values are for a single sample on as is basis.

UDSG, Untreated Distillers' Spent Grains; TDSG (DSG), Treated Distillers' spent grains; IDF, insoluble dietary fibre; SDF, soluble dietary fibre; TDF, total dietary fibre.

DSG blend (Table 6). This was similar to the observation made by Fornal *et al*. (1987) on the reduction of food DF after processing. Food can only be used as a source of DF when the product contains at least 3 g/100 g fibre. It is considered high in DF when the product contains at least 6 g/100 g fibre (IFST, 2007). Intake of DF could therefore be increased by the consumption of *kokoro* from all the flour blends or by incorporating the blends into other readily acceptable snack foods. A high intake of DF is positively related to different physiological and metabolic effects (Baah *et al*., 2009). Thus, consumption of *kokoro* supple-

Table 7 Sensory evaluation of *Kokoro* produced from different ratios of maize flour (M) and Distiller's spent grain (DSG) blends

Samples	Taste	Crispiness	Colour	Aroma	Appearance	Overall acceptability
100% M:0% DSG	2.60 ± 1.17^{d}	2.40 ± 1.43^{d}	2.20 ± 0.79^{c}	2.50 ± 0.71^{d}	2.40 ± 0.84^{c}	2.60 ± 0.97^{d}
95% M:5% DSG	2.90 ± 0.74^{cd}	3.60 ± 1.26^{cd}	2.50 ± 1.08^{c}	2.60 ± 0.97^{d}	2.80 ± 1.03^{bc}	2.70 ± 1.16^{d}
90% M:10% DSG	3.10 ± 0.74^{cd}	3.70 ± 1.42^{cd}	3.20 ± 1.23^{bc}	2.80 ± 1.03^{d}	3.60 ± 1.51^{bc}	3.30 ± 1.16^{d}
85% M:15% DSG	3.10 ± 0.99^{cd}	3.80 ± 1.40^{cd}	3.90 ± 1.37^{b}	3.00 ± 0.82^{cd}	3.70 ± 1.34^{b}	3.60 ± 1.58^{d}
80% M:20% DSG	3.90 ± 0.88^{c}	4.30 ± 1.95^{bc}	4.00 ± 0.67^{b}	3.40 ± 1.26^{cd}	3.90 ± 0.74^{b}	3.70 ± 0.82^{cd}
75% M:25% DSG	4.00 ± 1.94^{c}	3.90 ± 2.33^{bc}	6.00 ± 2.00^{a}	3.90 ± 1.45^{bc}	5.60 ± 1.71^{a}	4.80 ± 1.40^{bc}
70% M:30% DSG	5.40 ± 2.22^{b}	5.30 ± 1.83^{b}	5.90 ± 1.37^{a}	4.60 ± 1.07^{b}	6.10 ± 1.66^{a}	5.30 ± 1.42^{b}
65% M:35% DSG	7.00 ± 1.83^{a}	7.60 ± 1.26^{a}	6.70 ± 1.57^{a}	5.70 ± 1.16^{a}	6.50 ± 1.84^{a}	7.00 ± 1.63^{a}
Mean	4.00	4.33	4.30	3.56	4.33	4.13
Minimum	2.60	2.40	2.20	2.50	2.40	2.60
Maximum	7.00	7.60	6.70	5.70	6.50	7.00
CV (%)	35.65	38.15	30.72	30.37	32.15	31.40
P level	*	*	ns	ns	*	ns

Means in the same column with different letters are significantly different at $P \leq 0.05$. Values are means ± standard deviations.

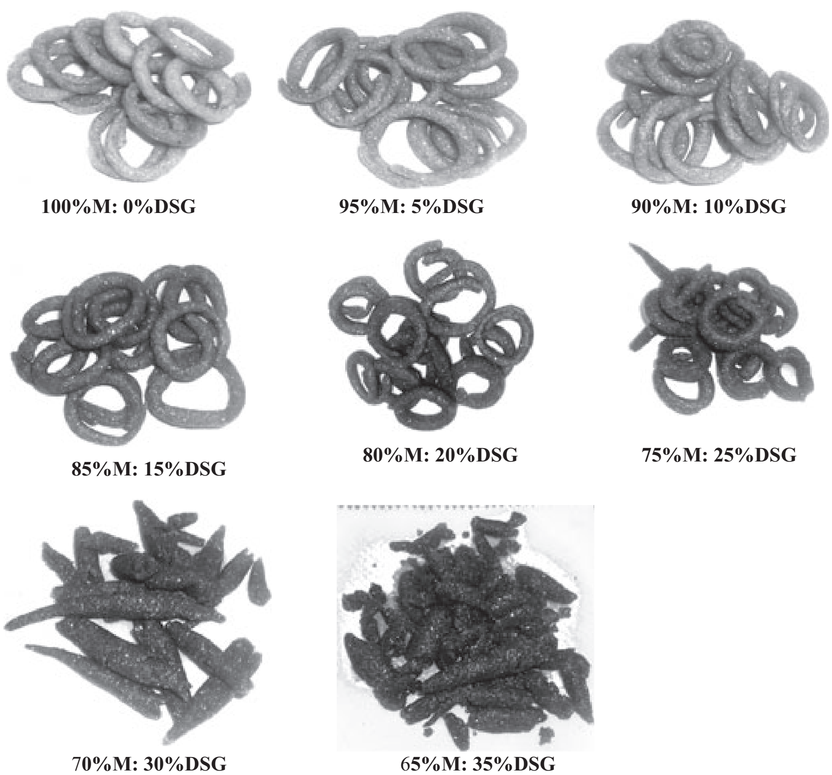

Figure 2 Effect of Distillers' spent grain (DSG) supplementation on *kokoro* produced from different ratios of maize flour (M) and DSG blends.

mented with DSG may contribute to protection against certain types of cancer such as colon cancer by enhancing physiological functions such as bowel movement.

Sensory properties

An increase in the level of replacement of the maize flour with DSG generally reduced the level of acceptance of all the sensory characteristics studied. There was a significant difference ($P < 0.05$) between the *kokoro* from 100% maize flour and that of all the maize flour:DSG blends in terms of taste, crispiness and general appearance. There were no significant differences ($P < 0.05$) in colour, aroma and overall acceptability among the *kokoro* products of 100% maize flour, 95% maize flour: 5% DSG, and 90% maize flour: 10% DSG as well as 85% maize flour: 15% DSG blend. The significant difference in taste might be attributed to the characteristic smell of DSG (Table 7). As the proportions of DSG increased, it became more difficult to cut the paste into shape, specifically the products from 70% maize flour: 30% DSG and 65% maize flour: 35% DSG blends (Fig. 2). The difference in crispiness might be because of the decrease in starch content as the ratios of DSG increased in the blends. This difference in crispiness might also be because of the increase in WAC of the blends as the level of DSG increases. The 5%, 10% and 15% levels of DSG were not enough to mask the colour (Fig. 2) and aroma of the maize flour, thus, there was no significant difference. *Kokoro* from the 95% maize flour: 5% DSG, 90% maize flour: 10% DSG and 85% maize flour: 15% DSG were as acceptable as that of the 100% maize flour (Table 7). This is in agreement with the observations made by Uzor-Peters *et al*. (2008) and Adelakun *et al*. (2004) on the sensory acceptability of *kokoro* made from 10% soya bean replacement of maize flour. *Kokoro* from 70% maize flour: 30% DSG and 65% maize flour: 35% DSG blends were not acceptable for all the sensory parameters as there was significant difference between them and that of 100% maize flour. However, *kokoro* made from 95% maize flour: 5% DSG, 90% maize flour: 10% DSG and 85% maize: 15% DSG were well accepted and compared favourably with *kokoro* produced from 100% maize flour in terms of taste, aroma, crispness and overall acceptability (Table 7). The appearance and colour of the products were not acceptable above the 10% DSG substitution.

Conclusion

The consumption of the *kokoro* products from this investigation by the target group (children and adults) may improve their protein essential amino acid intakes and as a result contribute to the reduction of PEM as well as serve as a good source of dietary fibre. Although an increase in the level of substitution of the maize flour with DSG resulted in reduction of the level of acceptance in all the sensory parameters studies, kokoro with a higher nutritional content can be made with composite flours of maize flour and treated DSG, and the maximum levels of replacement which were acceptable are 5% DSG, 10% DSG and 15% DSG blends.

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Conflict of interest

There is no conflict of interest.

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