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MICRONUTRIENT ENRICHMENT OF MEALS FED TO PUPILS USING HIGHLY NUTRITIOUS AND LOW-COST UNDERUTILIZED FISH UNDER THE SCHOOL FEEDING PROGRAMME IN GHANA

[ENRICHISSEMENT EN MICRONUTRIMENTS DES REPAS D' ELEVES NOURRIS EN UTILISANT DU POISSON HAUTEMENT NUTRITIF, A FAIBLE COUT ET SOUS-UTILISÉ SOUS LE PROGRAMME DE CANTINE SCOLAIRE AU GHANA

by/par

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Abstract

Four underutilized fish species, namely Woevi, or one-man-thousand, (*Sierathrissa leonensis*), Flying gurnard (*Dactylopterus volitans*), common bogue (*Boops boops*) and anchovies (*Anchoa guineensis*); as well as tuna frames obtained as factory remnants, were either solar-dried or mechanically dried and milled into dry powder. The powders were analysed for their proximate and mineral composition, biochemical and microbiological status, in addition to sensory and shelf life tests. Characterisation of the fish species showed that the selected fish are of high nutritional value in either human food supplements or formulations, with high protein content and optimal amino acid profile, abundance of polyunsaturated fatty acids, and high in micronutrients, particularly minerals. It showed the potential of these products for food supplementation in the school feeding programme, although generally the products might be regarded as fish for the poor. The sensory evaluation showed that the school children rated all the foods fortified with the fish powders well on the positive side of the hedonic scale. All the foods were accepted by the children, in particular banku with anchovies and okro stew, rice with tuna frames stew and rice with flying gurnard stew.

Key words: Fish powder, School feeding, Supplements, Micronutrients

Résumé

Quatres espèces de poissons sous-utilisés, appelé Woevi, ou one-man-thousand (*Sierathrissa leonensis*), Poule de mer (*Dactylopterus volitans*), bogue commun (*Boops boops*) et les anchois (*Anchoa guineensis*); ainsi que des restes des industries de thon , ont été soit séchés au soleil ou mécaniquement séchés et broyés en poudre. Les poudres ont été analysées pour leur composition organique et minérale, du statut biochimique et microbiologique, en plus des tests sensoriels et de durée de vie. La caractérisation des espèces de poisson a montré que les poissons sélectionnés sont d'une haute valeur nutritionnelle dans chacun des compléments ou formulations alimentaires, avec une haute teneur en protéines et un profil optimal en acide aminé, l'abondance des acides gras polyinsaturés, et riche en micronutriments, en particulier les minéraux. Il a été démontré le potentiel de ces produits pour les rations de l'alimentation fortifiée dans le programme de cantine scolaire, bien que généralement les produits pourraient être considérés comme poisson pour pauvres. L'évaluation sensorielle a montré que les écoliers ont donné un score positif sur l'échelle hédonique à tous les aliments enrichis avec les poudres de poissons. Tous les aliments ont été acceptés par les enfants, en particulier le banku avec les anchois et la sauce gombo avec restes de thon et riz avec soupe locale particulière.

Mots clés: Poudre de poisson, Alimentation scolaire, Suppléments, Micro-éléments nutritifs

1. INTRODUCTION AND LITERATURE REVIEW

Fish is of importance to the diet in the developing world. In about 30 low-income food-deficit countries in Africa and Asia, more than 1/3 of their daily intake of animal proteins comes from fish. Fish contains 70–80 percent water, 15–24 percent protein, 1–2 percent minerals and 0.1–22 percent fat (Clucas, 1985) high in fat-soluble vitamins like Vitamin A and D (Putro, 1990).

Fish contains macronutrients (proteins and fats) and micronutrients (vitamins and minerals) necessary for good nutrition, thus contributing effectively to food and nutrition security as an accompaniment to rice-based diets in

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Asia; and maize and cassava-based diets in Africa. In Africa, population rise has caused an increasing demand for fish products resulting in increased focus on processing and use of underutilized fish species to combat malnutrition. Deficiencies of micronutrients such as vitamin A, iron and iodine are of public health significance in Africa as deficiencies may have serious health impacts, such as blindness, poor learning capabilities, poor growth and increased morbidity and mortality rates. Mainstreaming nutrition issues using a food based approach can help alleviating problems of malnutrition in urban and rural households in Ghana.

Fish proteins are easily digested and of high biological value. The fat content of fish depends on species and the season in which it is caught. Fat from fish is the most important source of the polyunsaturated omega 3 fatty acids (PUFAs) namely EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid), essential for brain development of children, are also associated with protection against cardiovascular diseases.

Fish micronutrients are made up of both vitamins and minerals. Fish can be a rich source of vitamins, vitamin A and D from fatty species, as well as thiamine, riboflavin and niacin (vitamins B1, B2 and B3). Minerals in fish such as iron, calcium, zinc, iodine (from marine fish), phosphorus, and selenium are particularly present in the bones (Toppe *et al.*, 2007). These minerals are highly bioavailable in fish. Fish is a very good source of minerals, in particular if eaten whole.

Fish should be an integral component of the diet in preventing malnutrition. The development of affordable and acceptable fishery products for school children would enhance micronutrient intake, especially small-sized fish that are consumed whole. Although most of the minerals are found in high amounts in fish bones, consumption of bones of larger fish is rarely practiced. Increased use of seafood, including bones, could contribute significantly to increasing the micronutrients level and thus reducing protein malnutrition.

2. MATERIALS AND METHODS

Materials

Fish species used in this study were the West African pygmy herring (*Sierathrissa leonensis*), a *Clupeid* fish species (subfamily *Pellonulinae*) found in African inland waters and locally known as woevi, or one-man-thousand; flying gurnard (*Dactylopterus volitans*) (*Linnaeus*) otherwise known as *Cephalocanthus volitans* (local name in Accra is pampansre); Common bogue (*Boops boops*) known locally as otoe kpakpa (Anon, 1994); and anchovies (*Anchoa guineensis*). Tuna frames as by-product from processing tuna were obtained from Pioneer Fish Processing Limited at Tema. The one-man-thousand, was harvested in the Volta lake reservoir (fresh water), purchased at Kpong in the Eastern Region and conveyed to the laboratory on ice. The other freshly harvested fish species (all marine) were also immediately held on ice at 0 °C and conveyed from the Tema Fishing Harbour to the laboratory where they were frozen at -20 °C until analysis.

Methods

The fish were cut into thin fillets and strips and dried to a low moisture level by a GTZ solar dryer and a FRI gas-fuelled mechanical dryer. A hammer mill was then used to mill it into fine powder, bones included. The powders were placed in sterile polyethylene bags, sealed aseptically, labelled and stored for analyses, including shelf life studies.

Protein, moisture, total fat, fatty acids, ash, phosphorus, calcium and iron were determined by the methods of AOAC (1990). Microbiological analyses were carried out by means of International standardized procedures including aerobic plate count in cfu/g at 30 °C/72h (NMKL 86, 2006), *E. coli* count in cfu/g (NMKL 125, 2005) and *Salmonella* spp./25g (NMKL 71, 1990).

Four local foods were selected and used as vectors for inclusion of the milled fish products for acceptability tests on school children. Each of the fish powders was tested and mixed into each of the local dishes below:

1. Okro stew served with banku;
2. Aprapransa;
3. Jollof rice;
4. Plain rice served with tomato stew.

Consumer acceptability was investigated using the four varieties of fish powder (woevi, flying gurnard, anchovies and tuna frames) in the different foods, a total of 16 samples. One thousand four hundred and sixty

four (1464) school children were recruited for the test on the premises of the school. The children were divided into four groups; each group tested four different diets, all with different fish powders. Each portion included 10 g of fish powder. The school children were asked to rate on ballot sheets how much they liked each sample in terms of the following attributes: appearance, colour, aroma, texture, taste and overall acceptability. Rating was done on a 9-point hedonic scale with anchors 1-dislike extremely and 9-like extremely. Provision was also made on the ballot sheets for further comments from the school children for liking or disliking the samples. The children ate a meal per day during their lunch time in accordance with the school feeding programme.

All data obtained from the school children on the rating of sensory attributes of the foods were analysed using SPSS version 16. The means were tested for significance using one way analysis of variance (ANOVA) and Tukey's post test to determine significant differences between individual fish variety in each group and between the four food groups. Mean differences were considered significant at $p < 0.05$.

3. RESULTS AND DISCUSSION

Chemical composition of fish species

Moisture content (Table 1) for both the flying gurnard and common bogue were within 70–80 percent moisture as expected (Clucas, 1985). The protein content of both fish species were above the levels of 16 percent reported for pelagic fish (Windsor and Barlow, 1981), and within 15–24 percent reported (Clucas, 1985). This suggests that the fish is a good source of protein and may be used in fish protein concentrate production or in food supplements (Windsor and Barlow, 1981). Proximate and chemical composition of a number of species have been reported by a number of workers (Paetow *et al.*, 1966; Podsevalov and Perova 1975; Smith *et al.*, 1980; Bykov 1985) on commercially important species, in contrast to this study on commercially lesser known but economically viable species in Ghana.

The low fat content of both flying gurnard and common bogue were below the range of 1–8 percent reported for other pelagic species (King and Poulter, 1985; Bykov 1985) and so may not be suitable for fish oil production (Urdahl, 1992) but might still provide a significant amount of the essential fatty acids (Table 3). The low fat content of the fish, as suggested by Talabi *et al.* (1980) is an indication of the fact that most of the lipids are present as phospholipids which are a rich source of polyunsaturated fatty acids (PUFA). In species of higher fat percentage (1–3.8 percent) Talabi *et al.* (1980) reported comparatively lower percentages of PUFA.

The ash content for both fish species was higher than the range of 0.5–1.8 percent wet weight for most other fish species (Sidwell, 1981). The high calcium content of both fish (especially for common bogue) renders them useful even for compromised individuals to boost calcium supplementation when such fish are consumed, of particular importance to growing children and elderly women (osteoporosis). Values of 580 mg/100 g calcium have been reported for whole sardines, anchovy and other fish species (Da Costa and Stern 1956; Sidwell, 1981), in accordance with the levels of 2000–3000 mg/100 g in the dried fish powders (Table 5). The iron content of the common bogue was more than 30 mg/100 g, about 50 percent higher than for flying gurnard. Values for other fish species (not dried) are reported within a wide range of 0.8–373 mg/100 g (Egass and Braekkan 1977; Sidwell, 1981; Teeny *et al.*, 1984). The iron content of the common bogue was much higher than the reported range of 2–10 mg/kg from the Pacific coast of the USA (Gordon and Roberts 1977; Teeny *et al.*, 1984). The iron data of the common bogue includes bones, which might explain the much higher level of iron.

The nutritional composition of the fish species indicate that they could be used for the development of infant foods and other food products.

Table 1. Proximate and chemical compositions of fresh flying gurnard and common bogue (g/100 g)

Parameter	*Flying Gurnard	*Common Bogue
Moisture (wet weight basis)	74.0 ± 2.5	71.2 ± 2.5
Protein (N x 6.25)	22.3 ± 3.4	18.3 ± 3.2
Fat	0.7 ± 0.1	5.3 ± 1.5
Ash	3.3 ± 0.7	3.3 ± 0.7

** Values are means of three determinations ± standard deviation.*

Amino acid composition of fish species

The major amino acids (Table 2) present in the flying gurnard are glutamic acid and alanine; and in the common bogue is tyrosine. The flying gurnard is also a good source of lysine and leucine while threonine, alanine and leucine are observed for the common bogue. The percentage sulphur amino acid, methionine in the flying gurnard compares favourably to other species (Garrow and James, 1993; Batista *et al.*, 2001; Iwasaki and Harada, 1985). The overall profile of the essential amino acids of both fish species appear to suggest that they have a high class protein comparable to that of the mammalian meat which contains high levels of lysine and histidine (FAO, 1962; Garrow and James, 1993; Friedman, 1996). The fish may therefore be a good source of protein supplement in infants' diets and diets of school children involved in the school feeding programme.

Table 2. Amino acid composition of salt soluble proteins of total protein in flying gurnard and common bogue (ug/mg total protein)

Amino acids	* Flying Gurnard	*Common Bogue
Aspartic	6.05 ± 0.45	6.25 ± 0.21
Glutamic	9.9 ± 0.22	4.39 ± 0. 05
Hydroxy Proline	1.39 ± 0.11	1.24 ± 0.10
Serine	4.76 ± 0.13	2.20 ± 0.18
Glycine	6.98 ± 0.22	1.38 ± 0.35
Histidine	0.71 ± 0.07	2.74 ± 0.26
Arginine	5.59 ± 0.04	0.66 ± 0.12
Threonine	4.88 ± 0.08	7.32 ± 0.01
Alanine	12.07 ± 0.17	7.54 ± 0.44
Proline	3.46 ± 0.39	2.39 ± 0.56
Tyrosine	4.48 ± 0.05	8.35 ± 0. 31
Valine	5.9 ± 0.03	5.43 ± 0.02
Methionine	3.21 ± 0.34	1.20 ± 0.40
Cysteine	1.0 ± 0.06	1.80 ± 0.12
Isoleucine	4.31 ± 0.02	4.85 ± 0.01
Leucine	8.27 ± 0.10	7.29 ± 0.23
Phenylalanine	3.34 ± 0.01	4.80 ± 0.16
Tryptophane	5.34 ± 0.09	6.04 ± 0.14
Lysine	8.31 ± 0.64	5.26 ± 0.37

** Values are means of three determinations ± standard deviation.*

Fatty acids profile of fish species

From the fatty acids profiles (Table 3) the flying gurnard showed comparatively higher relative values of Poly Unsaturated Fatty Acids (PUFA) as compared to the common bogue. However, the ω3 content, predominantly EPA and DHA, represented about 50 percent of total fat in both species. Total fat content in common bogue was more than 7 times higher (Table 1), making common bogue a seven times better source of the ω3 fatty acids.

Table 3. Fatty acid profile of the flying gurnard and common bogue (g/100 g total fat)

Fatty acid	*Flying Gurnard	Common Bogue
Σ Saturated	20.2 ± 1.4	18.4 ± 1.2
Σ Mono unsaturated	12.6 ± 1.0	7.1 ± 0.6
Σ Poly unsaturated	63.6 ± 0.7	38.9 ± 0.4
Total ω3 content	51 ± 3.7	48.13 ± 1.3

** Values are means of three determinations ± standard deviation.*

Similar observations were made by Pozo *et al,* (1992) and Batista *et al.* (2001) in their studies on pelagic fish. The abundance of ω3 fatty acids suggests an additional advantage for the use of the fish in the formulation of infant foods as they help in the healthy growth and development of the brain, the nervous system and functioning of the eye (Bjerve *et al.*, 1992; Koletzko, 1992; Newman *et al.*, 1993; Agostoni *et al.*, 1995; Cockburn, 1997).

Consequence of drying methods for fish powder production

Solar and mechanically dried flying gurnard and anchovies processed into fish powder (Table 4) contained high levels of protein, adequate enough for protein supplementation of meals for school children involved in the school feeding programme in Ghana. Especially so is fish powder obtained from mechanically dried flying gurnard. The fat content of the flying gurnard was higher than that of the anchovies; however, its oleic acid was comparatively lower than observed in the anchovies. Thus the keeping quality of fish powder prepared with flying gurnard could be higher.

Table 4. Proximate analysis of solar and mechanically dried fish powder (g/100 g)

Parameter	Flying Gurnard		Anchovies	
	Solar dried	Mechanical dried	Solar dried	Mechanical dried
Moisture	6.0	5.0	18.0	17.7
Fat	12.9	13.6	3.9	4.2
Protein	64.2	74.3	57.0	66.2
Free fatty acids (oleic)*	29.2	5.3	64.1	48.7

** g free fatty acids/100 g total fat.*

The moisture content of the flying gurnard was very low and indicative of good keeping properties during storage of the powder for use as supplement for the local foods. The low moisture content of the powder would inhibit the growth of many opportunistic mesophilic and pathogenic microorganisms. Both drying methods used seem to dry the fish adequately. However, solar drying resulted in a much higher level of free fatty acids in the flying gurnard due to oxidation processes. In the case of common bogue, both drying methods resulted in high free fatty acids content.

Micronutrient content of fish and recommended daily allowances

Table 5 shows the mean values of the minerals in the fish powder while Table 6 shows the percentage Recommended Daily Allowances (RDAs) in 20 g of fish powder for the various micronutrients. The micronutrient content of the dried fish powder showed highest level of zinc in Tuna, highest Iron content in flying gurnard, high calcium content in all the fish species but, especially in the flying gurnard (Table 5). Also magnesium content was highest in the anchovies, followed by woevi. With respect to selenium, the highest content was in woevi.

Table 5. Micronutrient content of dried fish powder from the fish species

Fish type	Mean Values				
	Zn mg/100 g	Fe mg/100 g	Ca mg/100 g	Mg mg/100 g	Se µg/100 g
Woevi	29.0	17.2	2994.0	852.0	184.0
Flying Gurnard	7.0	31.6	3448.0	345.0	168.0
Tuna	36.9	20.2	1786.0	667.0	111.0
Anchovies	10.1	26.1	2852.0	1095.0	174.0

Table 6. Percentage recommended daily allowance in 20 g fish powder

Minerals mg/100 g	RDA				
	RDA mg/day	Percentage in 20 g Fish Powder (%)			
		Woevi	Flying Gurnard	Tuna	Anchovies
Zn	14	41	10	53	14
Fe	18	19	35	22	29
Ca	1200	50	57	30	48
Mg	370	46	19	36	59

Microbiological analysis of dried fish powder

Microbial examination of a processed food product provides information that serves as the most important criterion for judging the success of the process using the effectiveness of the production controls as well as the microbiological stability and safety of the food. It was observed that due to the effectiveness of the drying process, all the samples had low and acceptable bacterial and fungal loads. Significantly, pathogens were absent

from the fish, indicating the wholesomeness of the dried fish and fitness for human consumption. The absence of *Escherichia coli* in the dried fish products showed that there was no faecal contamination of the fish. Coliforms, other than *Escherichia coli* are a good indicator of unsatisfactory processing techniques or sanitation procedures during handling. The absence of these organisms therefore showed that proper and hygienic procedures were used during the drying process employing both mechanical and solar dryers.

Sensory evaluation of fish powder in foods fed to school children

Appearance: The appearances of all the foods were liked with mean score above 7.0 (Table 7). However, apranpransa with tuna frames, rice with tuna frames stew, rice with anchovies stew, banku with flying gurnard okro stew, apranpransa with flying gurnard, banku with woevi okro stew, jollof with woevi stew, jollof with tuna frames, banku with anchovies okro stew and rice with flying gurnard stew were rated highest on appearance with a mean score above 8.0. On the 9-point hedonic scale, a score above 8.0 implies that the appearances of all those foods were liked very much. ANOVA indicated that the mean rating of 7.49 for rice with woevi stew was significantly lower than that of the other foods. Nevertheless, on the hedonic scale, 7.49 correspond to moderate liking, thus showing that the sample was acceptable in appearance.

Colour: As with appearance, the school children liked the colour of all the meals, giving a rating of above 7.0 which indicated a moderate liking on the hedonic scale (Table 7).

Aroma: Rice with woevi stew had a mean score of 6.9 which means it was liked slightly. On the whole, the aromas of all the meals were acceptable as is evident by the fact that none of them was rated below 6 (like slightly) on the hedonic scale (Table 7).

Texture: Only apranpransa had the texture rated and were rated on the positive side of the hedonic scale (Table 7). Apranpransa with woevi had the lowest rating with mean score of 7.14 which on the hedonic scale means liked moderately and texture of apranpransa with Flying Gurnard was liked very much (8.17).

Mouthfeel: The school children did not really like how the rice with woevi stew felt in their mouth (6.7), however they liked how the other foods felt. The other foods had mean rating above 7.3 which is moderately liked on the hedonic scale. Banku with anchovies okro stew was liked very much (8.3). According to ANOVA, the foods were not significantly different from each other except rice with woevi which was rated low (Table 7).

Taste: In terms of taste, only rice with woevi stew was slightly liked. All the foods were rated high with a mean score above 7.4; especially banku with anchovies okro stew was liked very much. Turkey's post test showed that the taste of the foods were liked very much and were not significantly different from each other (Table 7).

Overall Acceptability: For overall acceptability, the school children rated all the foods on the positive side of the hedonic scale (Table 7). All the foods were accepted by the children especially banku with anchovies okro stew (8.4). According to the analysis of variance, Tukey's test, the foods were not significantly different from each other.

Table 7. Means (±SD) and significance[1] for consumer acceptance testing of underutilized fish incorporated in fish samples

	Sensory Attributes[2]						
Food Sample	**Appearance**	**Color**	**Aroma**	**Texture**	**Mouthfeel**	**Taste**	**Overall Acceptability**
Rice with woevi stew	7.5 ± 2.3^{a}	7.0 ± 2.5^{a}	7.0 ± 2.3^{a}	0.0 ± 0.0	6.7 ± 2.2^{a}	6.8 ± 2.3^{a}	6.9 ± 2.2^{a}
Jollof with anchovies	7.6 ± 1.6^{a}	7.6 ± 1.7^{a}	7.3 ± 1.6^{a}	0.0 ± 0.0	7.4 ± 1.3^{ab}	7.5 ± 1.4^{ab}	7.5 ± 1.2^{ab}
Banku with tuna f. okro stew	7.9 ± 1.6^{ab}	7.0 ± 1.9^{a}	7.5 ± 1.7^{abcd}	0.0 ± 0.0	7.3 ± 1.6^{ab}	7.5 ± 1.6^{bc}	7.5 ± 1.4^{ab}
Jollof with flying g.	7.9 ± 1.6^{abc}	7.9 ± 1.6^{b}	7.9 ± 1.3^{bcd}	0.0 ± 0.0	7.5 ± 1.3^{bcd}	7.7 ± 1.3^{bcd}	7.8 ± 1.1^{abcde}
Aprapransa with anchovies	7.9 ± 1.7^{abc}	7.8 ± 1.6^{b}	7.8 ± 1.8^{bcd}	0.0 ± 0.0	7.9 ± 1.9^{bcdef}	7.7 ± 1.8^{bcd}	7.8 ± 1.7^{bcde}
Aprapransa with woevi	8.0 ± 1.7^{abc}	7.4 ± 1.8^{ab}	7.5 ± 1.6^{abcd}	0.0 ± 0.0	7.5 ± 1.6^{bc}	7.5 ± 1.8^{ab}	7.5 ± 1.8^{ab}
Aprapransa with tuna f.	8.1 ± 1.5^{abc}	7.7 ± 1.4^{ab}	7.6 ± 1.5^{abcd}	7.4 ± 1.4^{b}	7.8 ± 1.3^{bcdef}	7.4 ± 1.5^{ab}	7.7 ± 1.3^{bc}
Rice with tuna frames stew	8.2 ± 0.9^{abc}	8.2 ± 0.8	8.1 ± 1.0^{cd}	7.1 ± 1.6^{b}	8.0 ± 1.0^{bcdef}	8.0 ± 1.2^{bcd}	8.4 ± 1.1^{bcde}
Rice with anchovies	8.2 ± 1.3^{abc}	7.5 ± 1.5^{ab}	7.6 ± 1.6^{abcd}	7.8 ± 1.7^{c}	7.6 ± 1.3^{bcde}	7.7 ± 1.5^{bcd}	7.7 ± 1.1^{bcde}
Banku and flying g. okro stew	8.2 ± 0.9^{abc}	7.7 ± 1.2^{ab}	7.5 ± 1.7^{abcd}	0.0 ± 0.0	7.9 ± 1.1^{bcdef}	8.1 ± 0.9^{bcd}	7.9 ± 1.0^{bcde}
Aprapransa with flying gurnard	8.3 ± 0.8^{bc}	8.3 ± 0.7^{cdef}	8.3 ± 0.6^{ed}	8.2 ± 0.8^{d}	8.2 ± 0.8^{def}	8.3 ± 0.6^{d}	8.2 ± 0.7^{cde}
Banku and woevi okro stew	8.4 ± 0.9^{bc}	8.2 ± 0.9^{cdef}	8.1 ± 0.9^{cd}	0.0 ± 0.0	8.2 ± 1.0^{cdef}	8.2 ± 0.8^{cd}	8.2 ± 0.8^{cde}
Jollof with woevi stew	8.5 ± 0.8^{bc}	8.5 ± 0.7^{def}	8.2 ± 0.9^{cd}	0.0 ± 0.0	7.5 ± 1.1^{bcd}	8.1 ± 1.2^{bcd}	8.0 ± 0.6^{bcde}
Jollof with tuna f.	8.6 ± 0.6^{bc}	8.6 ± 0.6^{def}	8.3 ± 0.7^{de}	0.0 ± 0.0	7.9 ± 0.9^{bcdef}	7.9 ± 0.8^{bcd}	8.2 ± 0.6^{cde}
Banku with anchovies okro stew	8.6 ± 0.5^{bc}	8.3 ± 0.5^{def}	8.2 ± 0.8^{de}	0.0 ± 0.0	8.3 ± 0.7^{f}	8.3 ± 0.7^{d}	8.4 ± 0.6^{e}
Rice with flying g. stew	8.6 ± 0.7^{c}	8.3 ± 0.9^{def}	8.2 ± 1.1^{de}	0.0 ± 0.0	8.3 ± 0.9^{ef}	7.7 ± 1.3^{bcd}	8.4 ± 0.9^{de}

[1] *values in the same column with different superscripts are significantly different at $p<0.05$.*

[2] *sensory attributes were evaluated on a 9-point hedonic scale as follows: 1- dislike extremely/ 9- like extremely.*

4. CONCLUSION AND RECOMMENDATIONS

This study shows the potential of using low cost, but highly nutritious fisheries resources found locally in combating malnutrition. The combination of low cost, high nutritional value, simple technology and acceptability among the children testing the products is unique. Characterisation of the fish species showed that the selected fish are of high nutritional significance in either human food supplements or formulations, as it has high protein content, good general amino profile and abundance of polyunsaturated fatty acids. As for all the tested fish products, the high nutritional content of one-man-thousand was notable; although generally regarded as fish for the poor, it was well accepted in the tested diets for food supplementation in the school feeding programme. The other products tested were also of high nutritional value and could contribute significantly in the fight against malnutrition. The high level of acceptance among the children, who ate and evaluated the different products, showed that the products tested were not only highly nutritious, but also highly accepted by schoolchildren. Of particular interest was the high acceptance of the powder made of tuna frames, since this is a product available in high quantities and at low cost. The product based on tuna frames was highly accepted, and could also open up the possibility of using this highly nutritious ingredient as a supplement in traditional foods.

The study revealed the potential use of fish powder in local foods in combating malnutrition, which should be further explored. Cost analyses and optimization of the technology should be further developed. The technology should be extended and transferred to local producers at artisanal level and eventually for the industrial level of fish powder production to meet the needs of Ghanaian households in the rural and urban communities in order for better applicability. With such approach, the fish powder will be extensively utilised in both homes and schools in Ghana. Research into the health and nutritional benefits of using this product in local diets should be further encouraged, and the use of this product in local foods could be promoted. Getting fish products into the menu of existing school feeding programmes would be key to the success of introducing this highly nutritious product.

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