https://dx.doi.org/10.4314/gjas.v54i2.3

Physicochemical properties and sensory attributes of local snacks fortified with powdered fish processing by-products and an underutilised fish species

L. ABBEY, M. GLOVER-AMENGOR*, L. HAGAN & F. P. MBOOM
(L.A, M.G-A, L.H & F.P.M.: CSIR-Food Research Institute, P.O. Box M 20, Accra)
**Corresponding author's email: mayamen11@yahoo.com*

ABSTRACT

Fish processing by-products and small pelagic fish could provide minerals and protein in diets of vulnerable populations as these could be more affordable than seafood. The study objectives were to determine the proximate nutrient content of tuna processing by-products and burrito fish and also assess the acceptability of fish powder-fortified local carbohydrate snacks. Tuna trimmings, gills, frames and burrito were dried at 55°C for eight hours to moisture levels of 4.8% (trimmings), 8.9% (frames), 6.8% (gills) and 6.9% (burrito). The products were milled and incorporated at varying levels into four local snacks namely: mpotompoto, yakayake, abolo and yam balls. Proximate nutrient levels of both fortified and non-fortified snacks were determined by Official Methods of Analysis (AOAC). Protein contents of mpotompoto-fortified fish products ranged from 3.75% to 8.5%. Ash also ranged from 1.12% to 5.54%. The control contained 1.17%. Acceptability tests were conducted on the fortified snacks using a 5-point hedonic scale. On the whole, fortified products showed significantly higher levels of protein and ash over the non-fortified snacks. Acceptance of the snacks by pupils (11-12) years was high enough to warrant incorporation of the fish powders into a school lunch menu.

Keywords: Tuna; gills; trimmings; frames; local snacks; fortification
Original scientific paper. Received 12 Dec 2018; revised 15 Aug 2019

Introduction

Inadequate food supply in terms of meeting energy requirements affects at least 925 million people worldwide (FAO, 2010). Poor rural and urban areas where limited economic resources prevent diversity in diets result in the prevalence of micronutrient deficiency diseases. Fish products are considered as a good source of many micro-minerals, most of which are found in high amounts in fish bones (Abbey *et al,* 2017; Gordon & Owusu-Adjei, 2011; Ashitey & Flake, 2010). However, apart from eating small-sized fish species with bones inclusive, bones of larger fish are rarely consumed. Increased use of seafood, including bones, could contribute significantly to reducing micro-mineral and protein malnutrition (Toppe, 2014). Many vulnerable groups, however, cannot afford to buy seafood, particularly in areas where seafood is scarce.

Small pelagic fish which are among the most affordable and healthy fish (Toppe, 2014), could be promoted to solve the economic and logistic challenges in making seafood

accessible and affordable to vulnerable groups.

By-products from fish processing represent in many cases more than 50% of the fish being processed. These by-products are of high nutritional value, and yet are in many cases low-cost products (Toppe, 2014; Kabahenda *et al.,* 2011), so could serve as good dietary supplements for vulnerable groups. The products should, however, be accepted by the target population, and should be introduced into local diets with relative ease. This study is part of an FAO/CSIR-FRI collaborative project, 2015 that aimed at developing low-cost nutrient-dense fish products for National School Feeding Initiatives using low value (underutilized) fish and edible fish by-products. The first part of the study assessed the nutrient content of the fish powders (Abbey *et al.,* 2017). The current study sought to:

- Determine the physicochemical properties of powdered fish-fortified local snacks
- Test the acceptability of powdered fish-fortified local snacks by school pupils on the Ghana National School Feeding Programme.

Materials and Methods

Production of tuna by-products (trimmings, gills and frames) and burrito powder

Tuna trimmings, gills and frames were dried with a Council for Scientific and Industrial Research-Food Research Institute (CSIR-FRI) gas-fuelled dryer for 8 hr to moisture levels of 4.8% (trimmings), 8.9% (frames), 6.8% (gills) and 6.9% (burrito). The dried fish products were milled with a 250 μm sieve hammer mill (Model 160 B; Jacobson, Machinery works, Minneapolis). The fish powders were packaged into polypropylene bags and stored at -18ºC until use. The detailed procedure for the preparation of the powdered fish products is described elsewhere (Abbey *et al.,* 2017).

Fortification of carbohydrate foods with tuna by-products and burrito powders

Four local, low nutritional value snacks – *mpotompoto* (yam porridge with added palm oil), *yakayake* (steamed cassava grits), *abolo* (baked dehulled and slightly fermented maize paste) and yam balls (boiled, mashed yam made into balls and fried) were prepared in the test kitchen of CSIR-FRI. The snacks were then fortified with the fish powders at percentages of 5, 8.8, 12.5, and 16.3 to determine the acceptable levels of inclusion in the products through sensory evaluation. The powdered fish products were added and homogenized as described by Abbey *et al.* (2015) in the snacks before cooking. Also, each snack had a control with no inclusion of any powder thus having five samples each. The snacks were then assessed in-house for the sensory attributes of appearance, colour, aroma, taste, texture, mouthfeel and overall acceptability on a 9-point hedonic scale by ten semi-trained adult panelists in the sensory laboratory at CSIR-FRI. Following results from the in-house sensory evaluation, three well-accepted products were further developed for the school acceptability testing. These were *yakayake*, *abolo* and *mpotompoto*. Inclusion levels for the various fish products were based on the outcome of the in-house sensory results.

TABLE 1
Percentage levels of fish powders inclusion in three food products

Food Item	*Burito*	*Trimmings*	*Frames*	*Gills*
Yakayake	8.8	8.8	8.8	12.5
Abolo	5.0	5.0	5.0	5.0
Mpotompoto	12.5	12.5	8.8	12.5

School Acceptability Test
The study was carried out in the Greater Accra region of Ghana in one of the coastal communities

Sampling Method/Procedure
The school for the study was purposively selected in the La Municipality because it was participating in the Ghana School Feeding Programme (GSFP). Class registers were pooled together from class five and six to obtain a sampling frame. All eligible children (ages 11-12 years), present in school on the day of testing and whose caregivers had given assent to their participation (N=116) were enrolled. There were four groups of fish products so children were made to pick Group 1, 2, 3 or 4 to fall into one of these groups. The children were asked to assess the following attributes of the products: appearance, colour, taste, aroma, texture, mouthfeel and overall acceptability. They were requested to give numerical values to each sensory characteristic assessed using the five 5-point hedonic scale (5-1) with 5 meaning like extremely and 1 meaning dislike extremely. The mean scores for the sensory characteristics of the dishes and the overall acceptance were calculated. The children independently assessed the dishes after the research team explained the terminology to them in English and also the local languages. Hot food was transported in food warmers to the school just before lunchtime, so hot food was served to the children. A sample was served at a time and each pupil received about 3 g of food. Ethical clearance for the study was obtained from the Institutional Review Board (IRB) of the Council for Scientific and Industrial Research (CSIR). Parents willing to allow their children to participate in the study either signed or thumb-printed an assent form after the objectives and benefits of the study were explained to them.

Physicochemical analysis of products
The proximate composition of all fish fortified products and the non-fortified products were determined by standard methods. Moisture content was determined by AOAC 925.10 (AOAC, 2000). Water activity and pH were determined using the Hygrolab water activity meter and bench type pH meter respectively. Ash was determined by AOAC 923.03 (AOAC, 2000). Fat was determined by AOAC 923.39C (AOAC, 2000). Energy was determined by atwater factor. Protein was determined by Kjedahl method (Anon, 1983). Tests were run in duplicates.

Statistical Analysis
Statistical analysis was done with Statistical Package for Social Scientists **(**SPSS) version 16. (SPSS, 2005). Analysis of variance (ANOVA) was used to compare the fortified dishes (burrito, frames, gills and trimmings) with the controls.

Results and Discussions

Physicochemical properties of fish powder-fortified snacks
Physicochemical properties of the food products are shown in Tables 2, 3 and 4. The protein contents of *mpotompoto* fortified with

12.5% burrito, 8.8% tuna frames, 12.5% tuna gills and 12.5% tuna trimmings were 7.59%, 3.75%, 6.12% and 8.5% respectively. Ash contents also ranged from 1.12% for 12.5% trimmings to 5.54% for 8.8% tuna frames. The control (non-fortified) contained 1.17%. Energy contents ranged from 104.09% for 8.8% inclusion of tuna frames to 149.04% for 12.5% inclusion of tuna gills. The control had an energy content of 86.45%. Most inclusions for *abolo* and *yakayake* also showed high values of nutrients.

TABLE 2
Proximate results of Mpotompoto with various levels of fish powders inclusion based on the sensory evaluation

Parameter	*Control*	*12.5(%) Burrito*	*8.8 (%) Frames*	*12.5 (%) Gills*	*12.5 (%) Trimmings*
Moisture g/100 g	81.51	*69.22	*73.33	*67.45	*70.95
Ash g/100 g	1.17	*2.34	*5.84	*4.67	1.12
Fat g/100 g	3.45	*6.4	*4.15	*7.5	*6.02
Protein g/100g	1.1	*7.49	*3.75	*6.12	*8.5
Carbohydrate g/100 g	12.78	*14.56	12.94	*14.27	13.41
Energy Kcal/100 g	86.45	*146.28	*104.09	*149.04	*141.82

Values with asterisk are significantly higher at 5% level of probability than the control.

TABLE 3
Results of Abolo with inclusion of the various fish powders based on the sensory evaluation

Parameter	*Control*	*5 (%) Burrito*	*5 (%) Frames*	*5 (%) Gills*	*5 (%) Trimmings*
Moisture (g/100g)	61.99	*48.76	*44.24	*46.44	*54.02
Ash (g/100g)	0.76	*2.77	*4.34	*3.21	*0.83
Fat (g/100g)	0.35	*0.9	*0.9	*0.85	0.5
Protein (g/100g)	4.27	*6.25	*6.97	*8.60	*8.90
Carbohydrate (g/100g)	32.63	*41.32	*43.56	*40.91	*35.76
Energy (Kcal/100g)	150.75	*198.38	*210.22	*205.67	*183.14

Values with asterisk are significantly higher at 5% level of probability than the control

TABLE 4
Proximate results of Yakayake with various levels of fish powders inclusion based on the sensory evaluation

Parameter	*Control*	*8.8 (%) Burrito*	*8.8 (%) Frames*	*12.5 (%) Gills*	*8.8 (%) Trimmings*
Moisture (g/100g)	51.44	*67.305	*49.62	*48.915	*48.19
Ash (g/100g)	1.41	1.29	*5.97	*2.07	*1.78
Fat (g/100g)	0.025	0.15	*0.3	*0.6	*0.4
Protein (g/100g)	0.69	*7.05	*3.13	*8.79	*7.30
Carbohydrate (g/100g)	46.45	*24.21	*40.99	*39.63	*42.34
Energy (Kcal/100g)	188.75	*126.37	*179.16	*199.08	*202.14

Values with asterisk are significantly higher at 5% level of probability than the control

There were significantly higher levels of protein in all the fortified products than the control (Table 2). Similarly, ash values were significantly higher in *yakayake* for all the tuna by-products. That for burrito, however, was not higher than the control value. With *mpotompoto*, ash contents were significantly higher, except for tuna trimmings, whilst with *abolo*, all fish products showed significantly higher values of ash. Energy contents were also higher significantly for all fish powder inclusions (Tables 2-4). These results for food-food fortification imply that the fish products could be used to increase protein and mineral contents of these low nutrient foods. Earlier work showed that the fish powders contained high levels of protein and iron (Abbey *et al.,* 2017). Being less expensive than the traditional seafood, they could be accessible to low-income groups. Additionally, processing is cheap as they could be dried as in the current study or even smoked (Gordon & Owusu-Adjei, 2011) to produce fish powder that could be stored for convenient use.

Sensory Evaluation

The results of the in-house sensory evaluation are presented in Tables 5-8

TABLE 5

Mean scores and standard deviations for sensory characteristics and overall acceptability of yakayake fortified with fish powder

	Quality Assessed[2]						
SAMPLE	*APPEARANCE*	*COLOUR*	*TASTE*	*AROMA*	*TEXTURE*	*MOUTHFEEL*	*OVERALL ACCEPTABILITY*
5(%) Tuna Frames	6.73±1.67bc[1]	6.73±1.39bc	6.00±1.57bcd	6.33±1.54bcd	6.60±1.4bcd	6.47±1.41bcd	6.53±1.46bcd
8.8(%) Tuna Frames	6.80±1.42bc	6.87±1.4bcd	6.20±1.15bcd	6.13±1.41bcd	6.73±1.10cd	6.33±1.50bcd	6.27±1.16abcd
12.5(%) Tuna frames	6.33±1.39abc	6.60±1.35bc	5.93±1.53abc	5.60±1.59abc	6.20±1.82abc	5.73±1.83ab	5.93±1.71abc
16.3(%) Tuna Frames	6.40±1.72bc	6.27±1.58bc	5.27±1.71ab	5.27±1.58ab	6.27±1.58abcd	5.53±1.81abc	5.67±1.78abc
5(%) Trimmings	5.60±1.59abc	5.67±1.72abc	6.27±1.58bcd	6.07±1.16bc	6.53±1.41bcd	5.93±1.39abc	5.93±1.49abc
12.5(%) Trimmings	4.47±2.17a	4.67±2.16a	5.07±1.59ab	4.8±1.74a	5.67±1.23abc	4.87±1.81a	5.27±1.53abc
16.3(%) Timmings	4.00±2.20a	4.06±2.12a	4.73±1.71a	4.53±1.81a	5.33±1.68abbc	4.60±1.96a	4.73±1.44a
8.8(%) Trimmings	5.33±1.84ab	5.46±1.88abc	6.07±1.33bcd	5.87±1.18abc	6.47±1.51bcd	5.73±1.58bcd	6.07±1.49bcd
Control	7.93±1.03cd	8.07±1.03d	7.60±1.18e	7.27±1.28cd	7.47±1.19e	7.47±0.92e	7.73±0.96e
12.5(%) Gills	6.07±1.67abc	6.07±1.75bc	5.87±1.60abc	5.80±1.61abc	6.33±1.23bbc	6.33±1.23bc	6.00±1.41abc
8.8(%) Gills	5.87±1.68abc	6.47±1.68bc	6.00±1.46bcd	5.86±1.66abc	6.47±1.41bbc	5.80±1.78bc	6.07±1.67bc
16.3(%) Gills	5.53±2.03ab	5.13±1.96ab	5.20±1.86ab	5.07±1.83abc	6.07±1.39	5.00±1.77	5.40±1.76
5(%) Gills	7.13±1.19bc	7.13±0.99d	6.67±0.98bcd	6.67±1.11bcd	6.93±1.16	6.73±1.22	6.87±0.92
5(%) Burito	8.07±0.88d	7.87±0.83cd	7.67±1.11e	7.40±1.45cde	7.67±1.05	7.67±1.05	7.47±1.64
12.5(%) Burito	6.20±1.90abc	5.87±1.73abc	5.87±1.96abc	5.87±1.46abc	6.40±1.45	5.53±1.81	5.67±1.40
8.8(%) Burito	7.27±1.22bc	7.13±0.99cd	6.60±1.35bcd	6.13±1.88abc	6.53±1.92	6.33±1.50	6.27±1.98
16.3(%) Burito	5.47±2.17a	5.27±2.12abc	4.87±1.81a	5.13±1.85ab	5.80±2.18	5.20±1.90	5.13±1.97

[1] Means in the same column followed by different alphabets are significantly different at 5% level of probability; [2] sensory attributes were evaluated on a 9-point hedonic scale as follows: 1- dislike extremely, 2-dislike very much, 3-dislike moderately, 4-dislike slightly, 5-neither like nor dislike, 6-like slightly, 7-like moderately, 8-like very much, 9-like extremely

TABLE 6
Mean scores and standard deviations for sensory characteristics and overall acceptability of *abolo* fortified with fish powder

	Quality Assessed[2]						
SAMPLE	*APPEARANCE*	*COLOUR*	*TASTE*	*AROMA*	*TEXTURE*	*MOUTHFEEL*	OVERALL ACCEPTABILITY
Control	7.63±0.89e[1]	7.56±0.81e	7.63±0.81e	7.56±0.96e	7.19±1.05e	7.44±0.89e	7.38±0.96e
8.8(%) Trimmings	4.75±1.88abc	4.50±1.86 abc	4.88±1.63 abc	4.94±1.57 abc	4.88±1.78abc	4.88±1.78abc	5.06±1.65abcd
16.3(%) Timmings	3.88±1.86a	3.56±1.96a	4.67±1.54abc	4.50±1.51abc	4.00±1.67bc	4.53±1.68abc	4.06±1.48a
8.8(%) Gills	6.19±1.33bcde	6.00±.1.26 bcde	6.19±1.60 bcde	5.81±1.42 bcde	5.94±1.44 bcde	5.67±1.39 bcde	5.88±1.20bcde
5(%) Trimmings	5.69±1.45bcde	5.50±1.63 abcde	5.94±1.53 abcde	5.75±1.39 abcde	6.06±1.44 bcde	6.06±1.18 bcde	6.13±1.20cde
5(%) Gills	6.63±1.15cde	6.69±1.08de	6.81±1.38de	6.50±1.21cde	6.63±1.54cde	6.63±1.36cde	6.63±1.31de
12.5(%) Trimmings	4.25±1.95abc	4.06±1.91ab	4.56±1.59abc	4.69±1.49abc	4.13±2.13ab	4.63±1.71abc	4.38±1.63abc
5(%) Burito	7.47±0.99de	7.40±1.06de	6.87±1.30de	6.53±1.81de	6.80±1.52de	6.67±1.91de	6.87±1.60e
16.3(%) Burito	5.07±2.02bcd	5.20±2.08abcd	4.40±1.76abc	4.40±1.76abc	5.20±1.78abcd	4.07±1.98a	4.33±1.76ab
8.8(%) Burito	6.80±1.08de	6.87±1.46de	5.87±1.88de	5.47±1.85de	6.33±1.84de	5.27±2.28de	5.60±1.92abcde
12.5(%) Burito	5.67±2.26bcde	5.73±2.21bcde	5.40±2.06abcd	4.73±2.09ab	6.00±1.81bcd	4.87±1.99abc	5.00±2.07abcd

[1] Means in the same column followed by different alphabets are significantly different at 5% level of probability; [2] sensory attributes were evaluated on a 9-point hedonic scale as follows: 1- dislike extremely, 2-dislike very much, 3-dislike moderately, 4-dislike slightly, 5-neither like nor dislike, 6-like slightly, 7-like moderately, 8-like very much, 9-like extremely

TABLE 7
Mean scores and standard deviations for sensory characteristics and overall acceptability of yam balls fortified with fish powder

	Quality Assessed[2]						
SAMPLE	*APPEARANCE*	*COLOUR*	*TASTE*	*AROMA*	*TEXTURE*	*MOUTHFEEL*	*OVERALL ACCEPTABILITY*
16.3(%) Burito	5.13±1.85abcd[1]	5.13±1.73abcd	5.57±1.87abcd	5.60±1.80abcd	5.80±1.89abcde	5.27±1.98abcd	5.20±1.78abcd
12.5(%) Burito	5.87±1.68bcde	5.67±1.68abcd	5.53±1.60abcd	5.93±1.83bcd	5.80±1.52bcd	5.73±1.62bcd	5.43±1.50abc
8.8(%) Burito	6.60±1.45de	6.45±1.55de	6.73±1.39de	6.80±1.42de	6.27±1.94de	6.67±1.59de	6.67±1.35de
5(%) Burito	7.67±0.82e	7.60±0.63e	7.80±0.41e	7.73±0.59e	7.80±0.68e	7.93±0.59e	8.00±0.38e

[1] Means in the same column followed by different alphabets are significantly different at 5% level of probability; [2] sensory attributes were evaluated on a 9-point hedonic scale as follows: 1- dislike extremely, 2-dislike very much, 3-dislike moderately, 4-dislike slightly, 5-neither like nor dislike, 6-like slightly, 7-like moderately, 8-like very much, 9-like extremely

TABLE 8

Mean scores and standard deviations for sensory characteristics and overall acceptability of mpotompoto fortified with fish powder

SAMPLE	*APPEARANCE*	*COLOUR*	*TASTE*	*AROMA*	*TEXTURE*	*MOUTHFEEL*	*OVERALL ACCEPTABILITY*
5(%) Burittoo	8.00±0.53b[1]	8.00±0.53b	6.93±1.33ab	7.33±0.90b	7.60±0.83b	7.47±1.13b	7.67±0.72b
16.3(%) Burito	6.60±0.74ab	6.47±1.13ab	5.86±0.95a	6.31±1.28ab	6.07±1.28a	6.27±0.96ab	6.27±0.88ab
8.8(%) Burito	7.47±0.83ab	7.73±0.59b	7.47±1.25b	7.47±1.19b	7.60±0.91b	7.53±0.99b	7.47±0.99b
12.5(%) Burito-	6.33±1.18a	6.27±1.22ab	6.40±1.55ab	6.80±1.01ab	6.80±1.37ab	6.80±1.15b	6.73±1.03ab

[1] Means in the same column followed by different alphabets are significantly different at 5% level of probability; [2] sensory attributes were evaluated on a 9-point hedonic scale as follows: 1- dislike extremely, 2-dislike very much, 3-dislike moderately, 4-dislike slightly, 5-neither like nor dislike, 6-like slightly, 7-like moderately, 8-like very much, 9-like extremely

Acceptability of products during school feeding test

Results of the acceptability of the three products for the school feeding trial are presented below.

Abolo

The sensory profile (Figure 1) indicates that *abolo* fortified with the powder of tuna frames was rated highly compared to the *abolo* fortified with other fishes. Panelists liked the taste of all the *abolo* samples except the *abolo* fortified with trimmings.

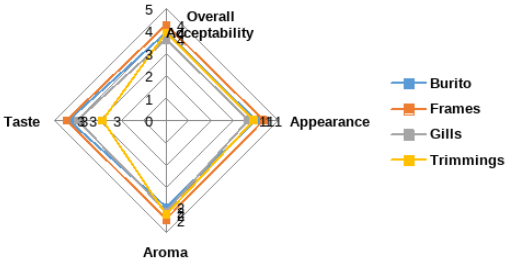

Fig. 1: Sensory profile of *Abolo* fortified with different varieties of fishes

Yakayake

Yakayake fortified with the various fishes rated lower in terms of appearance, aroma, and taste. However, trimmings in *yakayake* was rated high (4) in terms of overall acceptability.

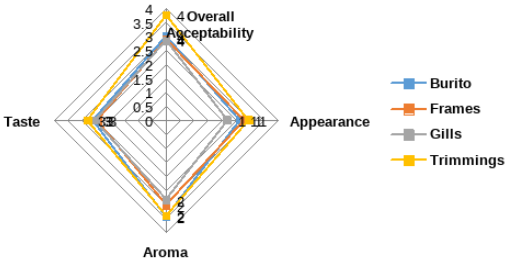

Fig. 2: Sensory profile of *Yakayake* fortified with different varieties of fish

Mpotompoto

The profile in Figure 3 shows that *mpotompoto* fortified with the various fishes was rated highest in all attributes. A general trend of a somewhat even rating was observed for all the varieties of fish used.

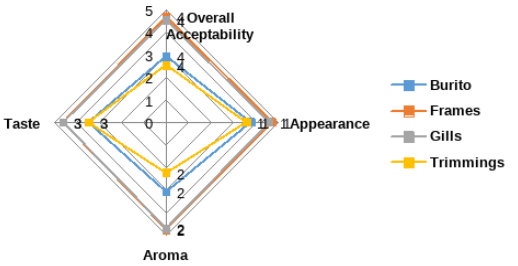

Fig. 3: Sensory profile of *Mpotompoto* fortified with different varieties of fish

In house Panelists

The appearance of the food products fortified with the various fishes was liked extremely except the appearance of the food products made from trimmings that were liked slightly according to the hedonic scale used. In exception of the higher concentrations of gills the appearance of the reference samples was not significantly different from all the other samples (Table 5, 6 and 8). The colour of all the samples was liked very much except the colour of food products fortified with trimmings (Table 5, 6, 7 and 8) and was significantly different from the reference sample (Tables 5 and 6). The aromas of all the samples were liked and were not significantly different from each other. On the whole, the taste of the fishes in the food products was acceptable to the panelists as is evident by the fact that the taste was not rated below 5 except the taste of food products with trimmings. The taste for the samples with trimmings was not accepted because of its bitterness. On the other hand, the taste of *mpotompoto* was rated high (above 7) on the hedonic scale, meaning panelists liked the taste of the fishes in the *mpotompoto* even with the high concentrations. According to the analysis of variance, there was no significant difference in panelists liking of the taste of samples but there was difference between the samples with trimmings and the reference samples. Consequently, panelists liked the mouthfeel for all the samples but did not like the mouthfeel for the high concentrations of the fishes in the food products. The ratings for these samples were below 5 on the hedonic scale.

Overall Acceptability

All the products were acceptable as they were rated above 6 (like slightly) and they were not significantly different from the reference samples except food products with trimmings.

School-Based Testing

Panelists liked the taste of all the *abolo* samples except the *abolo* fortified with trimmings. *Yakayake* fortified with the various fishes rated lower in terms of appearance, aroma, and taste. However, trimmings in *yakayake* was rated high (4) in terms of overall acceptability. The profile in Figure 3 shows that *mpotompoto* fortified with the various fishes was rated highest in all attributes. A general trend of a somewhat even rating was observed for all the varieties of fish used. Hence these fish powders have the potential for improving the nutritional status of children on School Feeding Programmes, and would help reduce protein and mineral malnutrition.

Conclusion

The fortified foods contained significantly higher levels of protein, ash and energy over the controls, and thus have the potential to improve the nutritional status of low-income populations as they are more accessible and affordable. All the products were accepted by the panelists except the food products with trimmings which were not acceptable because of the bitterness. Consuming small-sized fish species whole, and bones of large fish could, therefore, contribute significantly to reducing the level of mineral and protein malnutrition in vulnerable groups.

Conflict of Interest

There is no conflict of interest.

Acknowledgement

The authors wish to thank the Food and Agriculture Organization (FAO) and the Food Research Institute of the Council for Scientific and Industrial Research (CSIR-FRI) for the financial support towards this study.

REFERENCES

Abbey, L., Glover-Amengor, M., Atikpo, M., Atter, A., Dowuona, S., Mireku. E., Mboom FP., Manu, S., Toppe. J., & Kiran, M. (2015) Report on Development of Low-Cost Nutrient Dense Fish Products Based on Low-Value Fish and Fish Byproducts using small and medium scale Processing and Preservation methods that Stabilize the Nutritional Value and ensure the safety of the products. Submitted to the FAO, Rome. CSIR-FRI/CR/ALD/2015/002.

Abbey, L., Glover-Amengor, M., Atikpo, M. O., Atter, A. & Toppe J. (2017) Nutrient content of fish powder from low-value fish and fish byproducts. *Food Science and Nutrition*, **5** (3), 374 – 379.

Anon. (1983) Determination of Kjeldahl Protein in fish and fish products using the Kjeltec Auto System and Se or Hg Catalyst. Application Note. ASN 56, 1 – 2.

Ashitey, E. & Flake, L. (2010) Exporter guide. Global Aquaculture Information Network. GAIN Report No: GH1002. pp. 16.

FAO (2010) The state of food insecurity in the world 2010: eradicating world hunger key to achieving the Millennium Development goals. Rome.

Gordon, A., Pulis, A. & Owusu-Adjei, E. (2011) Smoked marine fish from Western Region, Ghana: A value chain assessment. WorldFish Center. USAID Integrated Coastal and Fisheries Government.

Kabahenda, M. K, Amega, R., Okalany, E., Husken, S. M. C. & Heck, S. (2011) Protein and Micronutrient Composition of Low-Value Fish Products Commonly Marketed in the Lake Victoria Region. *World Journal of Agricultural Sciences* **7** (5), 521 – 526.

Official Methods of Analysis. (2000a) Association of official analytical chemists. AOAC 925.10 17th ed. AOAC International, Washington DC, USA.

Official Methods of Analysis. (2000b) Association of official analytical chemists. AOAC 923.03 17th ed. AOAC International, Washington DC, USA.

Official Methods of Analysis. (2000c) Association of official analytical chemists. AOAC 923.39C 17th ed. AOAC International, Washington DC, USA.

SPSS 16 for Windows. (2005) SPSS 16 for windows. Illinois, Chicago.

Toppe, J. (2014) The nutritional benefits of fish are unique. EUROFISH Magazine, Issue 3.