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Assessing tilapia flour as an ingredient in bread

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Results show enhanced nutritional value, acceptable sensory scores



Results of this study showed that tilapia meal as an ingredient enhanced bread's nutritional value and produced acceptable sensory scores. Photo by Germano Roberto Schüür [CC BY-SA 4.0 (<https://creativecommons.org/licenses/by-sa/4.0/>)]

Consumer demand for healthier foods is growing. Bread manufactured with refined wheat flour is a low-cost staple food that is well accepted worldwide. However, it is rich in carbohydrates, mostly highly digestible starch with a high glycemic index (GI). A high GI may be associated with increased risk of diabetes and biliary-tract cancer. Moreover, bread is also low in protein.

Because bread is a good carrier of functional ingredients, a wide variety of studies have reported nutritional improvement after replacement of wheat flour by different industry by-products as fish flour or powder from several seafood sources, including tilapia, saithe surimi, red-tailed brycon (*Brycon cephalus*) and shrimp. However, the addition of byproduct ingredients in traditional bakery products may cause sensory changes and consumer rejection. To the best of our knowledge, no study has evaluated the consumer perception of bread enriched with tilapia flour (TF) made with mechanically separated meat (MSM) of Nile tilapia (*Oreochromis niloticus*).

Although Nile tilapia is one of the most commercially important freshwater fish species, it has a low fillet yield of only about 30 percent of the live weight, and therefore most processed tilapia is considered processing waste. The high cost of disposal for this processing waste reportedly has prompted the food industry to develop recycling techniques to decrease environmental pollution and improve profits. Among fish byproducts, tilapia flour manufactured from meat adhered to skin and bones yields about 8 percent of the whole-fish weight, and is considered an inexpensive source of essential nutrients, constituting an interesting alternative nutritional supplement for bakery products.

Considering the market requirements, one of the main challenges of the food industry is to produce convenience food with added nutritional value, accessible cost, and pleasant sensory properties. Also, there is a lack of understanding of consumer perceptions about bread enriched with fish flour, which is important to promote the use of fish processing byproducts in the healthy food markets.

This article – adapted and summarized from the **original publication** (<https://doi.org/10.1371/journal.pone.0196665>), – characterized formulations of bread fortified with different levels of tilapia flour made from MSM, from the point of view of nutritional value and sensory attributes; determined the overall liking for all bread formulations; and determined the cutoff point for wheat flour replacement by tilapia flour in wheat bread, using a consumer-based approach.

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Study setup

For the preparation of tilapia flour, a total of 9.0 ± 0.3 kg of tilapia MSM, packed in polyethylene bags, was purchased from a commercial fish farm in Rio de Janeiro, Brazil. The MSM was dried for 12 hours at 65 degrees-C in a commercial, forced-air convection oven in the bakery pilot plant, to obtain the tilapia flour.

Six bread formulations were prepared according to the protocol **described by Stokić et al.** (<https://www.infona.pl/resource/bwmata1.element.elsevier-a39da394-8e58-39b7-90e1-5f9490e5264e>), with slight modifications. The wheat flour replacement by TF was 0, 5, 10, 20, 30 and 40 percent, representing final bread formulations with 0, 2.5, 5, 10, 15 or 20 percent TF, which were termed BTF0%, BTF2.5%, BTF5%, BTF10%, BTF15%,

and BTF20%, respectively. All ingredients were purchased in a local bakery-products store. After preparation, breads were packed in high density polyethylene bags, and immediately analyzed for nutritional and sensory characterization.

For detailed information on bread production; proximate composition, energy content, and total dietary fiber; consumer study; sample preparation; experimental procedure; and statistical analyzes, please refer to the original publication.

Results and discussion

The substitution of wheat flour by TF increased the lipid, protein, and ash contents ($P < 0.05$), and decreased ($P < 0.05$) the levels of carbohydrate and total dietary fiber (Table 1). BTF15% and BTF20% had the highest ($P < 0.05$) moisture content and the lowest ($P < 0.05$) energy value. No differences ($P > 0.05$) were observed in moisture contents and energy values among other tilapia-bread formulations at 0, 2.5, 5 and 10 percent. These results are strongly related to the wheat and tilapia flour compositions. TF has a low carbohydrate level (< 1.5 percent) and high levels of protein (> 45 percent), lipid (> 25 percent), and ash (> 3 percent), while the wheat flour counterpart contains higher levels of carbohydrate (> 75 percent) and fiber (> 10 percent), and lower levels of protein (< 11 percent), lipid (≤ 1.5 percent), and ash (≤ 0.38 percent).

Parameters	BTF0%	BTF2.5%	BTF5%	BTF10%	BTF15%	BTF20%
Moisture	36.09±1.43b	34.82±1.12b	36.44±0.48b	37.16±0.21b	42.74±0.76a	42.39±0.81a
Protein	6.78±0.60e	8.71±0.54d	10.83±0.34c	12.01±0.35c	14.36±0.40b	16.28±0.28a
Lipid	1.39±0.07e	1.85±0.00d	2.51±0.12c	2.67±0.10c	2.97±0.13b	3.52±0.10a
Ash	1.93±0.01d	1.82±0.01d	2.13±0.08c	2.29±0.04bc	2.34±0.02b	2.89±0.06a
Carbohydrate	53.93±1.95a	52.70±1.65ab	48.10±0.10bc	45.88±0.08c	37.61±1.31d	34.93±0.57d
Energy value	255.33±6.04a	262.27±4.44a	258.27±2.84a	255.57±0.16a	234.55±2.44b	236.50±1.07b
Total dietary fibers	6.84±0.28a	5.82±0.14b	5.86±0.14b	5.79±0.11b	5.85±0.23b	5.87±0.16b

Table 1. Proximate composition (percent), energy value (kcal/100 grams) and total dietary fibers (%) of bread formulations with different tilapia flour levels. BTF0%, BTF2.5%, BTF5%, BTF10%, BTF15% and BTF20% means bread with tilapia flour inclusions at 0, 2.5, 5, 10, 15 and 20 percent (weight by weight, w/w), respectively. Different letters indicate significant differences ($P < 0.05$) among formulations. Results are expressed as means \pm standard deviation ($n=2$). Adapted from original.

Although wheat flour (13.50 percent) has a higher moisture content than TF (7.84 percent), the results of this study reflect differences in protein conformation, amino acid composition and surface polarity/hydrophobicity (the physical property of a molecule to be ostensibly repelled from a mass of water) between wheat and fish, leading to different water-binding capacities. Our findings for energy value are attributable to changes in the lipid, protein and carbohydrate contents due to use of TF in substitution of wheat flour, together with their respective individual weights. Similar nutritional compositions of bread enriched with different protein sources were found by other researchers.

In terms of the results of the acceptance evaluation, BTF0%, BTF2.5% and BTF5% received the highest ($P < 0.05$) liking scores among samples, BTF10% and BTF15% received intermediate acceptance ($P < 0.05$), while BTF20% received the lowest ($P < 0.05$) overall liking score. No difference ($P > 0.05$) was observed among BTF0%, BTF2.5%, and BTF5% and between BTF10% and BTF15% for hedonic scores [most widely used scale for measuring food acceptability] related to overall liking. Similar to our results, other authors have also reported successful acceptance after addition of 5 percent fish protein concentrate in biscuits, shrimp protein hydrolysate at 5 to 7.5 percent in extruded products, and fish powder at 3 to 7 percent in snacks.

The internal preference mapping analysis revealed that the majority of the participants preferred the bread with 0 and 2.5 percent TF, followed by the formulation with 5 percent TF. Bread formulations with higher amounts of TF (10, 15, and 20 percent) were less preferred by participants, especially BTF20% (Fig. 1). The inclusion of high levels of fish sources in foodstuffs is problematic, due to the fishy flavor and odor generated mainly by free fatty acids and volatile sulfur compounds. Despite this, protein enrichment of commercial products may be advantageous, depending mainly on product processing, seafood type, and the proportion used. Similar consumer responses were reported by other authors for bread enriched varying inclusion levels of flour from various fish and from shrimp.

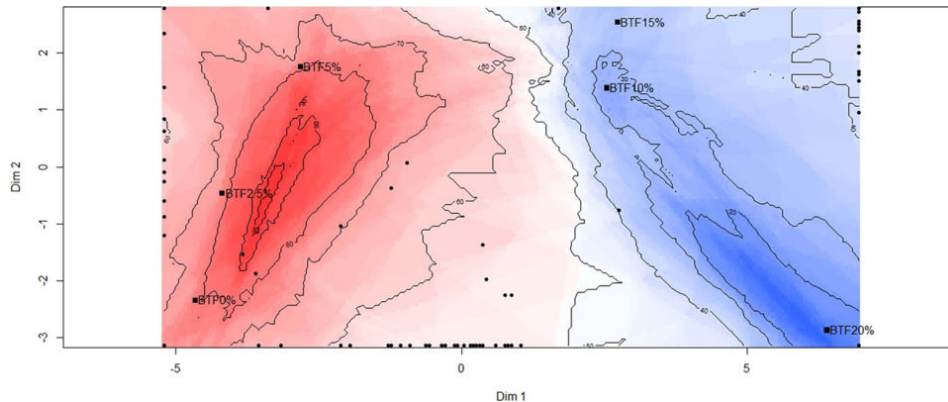


Fig. 1: Color counter plot of the average overall liking scores by consumers (n=100) evaluating BTF0%, BTF2.5%, BTF5%, BTF10%, BTF15% and BTF20%. BTF: bread with TF at 0, 2.5, 5, 10, 15 and 20 percent (weight by weight, w/w), respectively. Red areas indicate samples with higher overall liking.

The tilapia flour in substitution of wheat flour changed the following 12 sensory attributes: *cream color, moist, crumbly, salty taste, hard, raw, acid taste, sticky in the teeth, cheese flavor, oil, and cheese aroma* (Table 2). The airy appearance was increased by small amounts of added tilapia flour (up to 5 percent) and decreased in formulations enriched with larger amounts (10, 15 and 20 percent).

Terms	BTF0%	BTF2.5%	BTF5%	BTF10%	BTF15%	BTF20%
Overall liking [‡]	6.3a	6.3a	6.0a	4.6b	4.4b	3.3c
Cream color***	18	29	35	37	43	21
Clear color	74	64	52	22	18	9
Dark color	0	1	1	25	26	60
Compact appearance	38	25	19	57	48	69
Airy appearance***	26	28	40	12	17	4
Moist*	14	20	22	21	33	26
Crumbly***	10	22	34	42	39	40
Raw***	5	7	12	16	22	27
Yeast aroma	24	28	25	30	32	33
Bread aroma	64	60	44	13	10	2
Strong aroma	6	6	7	25	28	48
Odd aroma	4	6	10	24	31	41
Cheese aroma***	5	7	18	28	21	34
Yeast flavor	23	19	20	31	28	27
Odd flavor	7	7	19	46	50	58
Cheese flavor***	6	9	32	40	33	41
Salty taste***	10	15	17	27	26	28
Acid taste**	2	2	6	11	7	15
Compact texture	36	25	25	49	60	72
Hard***	8	7	0	5	5	28
Soft	60	68	58	34	38	14
Sticky in teeth*	22	23	34	29	29	18
Spongy	16	14	15	11	15	8
Oily***	3	3	4	4	19	21

Table 2. Average overall liking scores and frequency of the CATA terms used by consumers (n=100) for all bread formulations with different TF levels. Terms in bold indicate differences among samples. BTF0%, BTF2.5%, BTF5%, BTF10%, BTF15% and BTF20% means bread with tilapia flour at inclusion levels of 0, 2.5, 5, 10, 15 and 20 percent (weight by weight, w/w), respectively. ***P<0.0001; **P<0.01; *P<0.05. [‡]Evaluated in a 9-point category scale (1 = dislike extremely to 9 = like extremely). a – c Different letters indicate significant differences (P<0.05) among formulations. Adapted from original.

The locations of the samples and terms can be seen in the first two dimensions in Fig. 2. The two dimensions explained 94.39 percent of the total variance (Dim 1: 83.50 percent and Dim 2: 10.89 percent) and separated the bread formulations into four groups (BTF0% and BTF2.5%; BTF5%; BTF10% and BTF15%; and BTF20%).

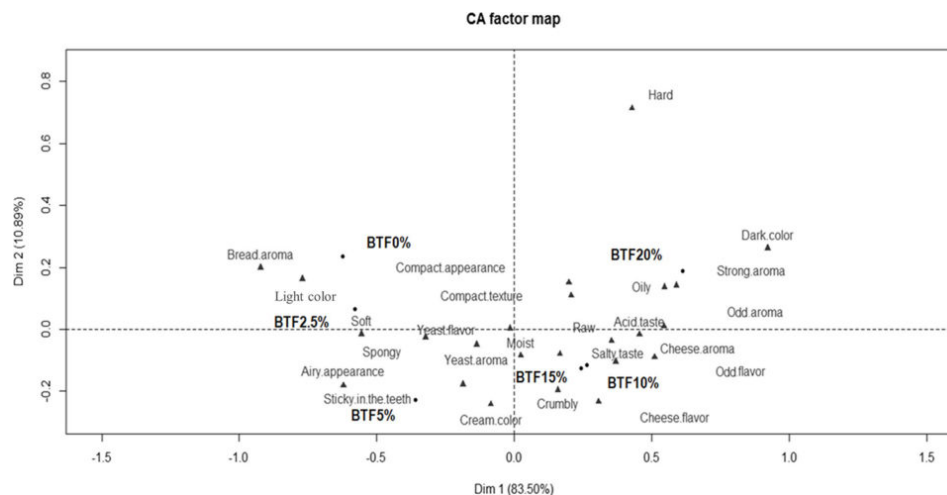


Fig. 2: Representation of the bread samples and terms in the first and second dimension of the correspondence analysis for the BTF0%, BTF2.5%, BTF5%, BTF10%, BTF15% and BTF20% (n = 100). BTF: bread with tilapia-MSM flour at 0, 2.5, 5, 10, 15 and 20 percent (w/w), respectively.

In our study, the perception of oiliness in bread with high levels of tilapia flour can be associated with the higher lipid content in tilapia flour compared to wheat flour, in accordance with our results for proximate composition. On the other hand, the consumers described bread containing more than 5 percent TF as compact in appearance and texture, raw, moist, crumbly, and hard, which may be related to a starch-protein interaction and a consequently reduced dough expansion. Likewise, aroma and flavor changes due to the TF added to bread – such as strong aroma, odd aroma, cheese aroma, salty taste, acid taste, cheese flavor, and odd flavor – can be attributed to several compounds from fish (e.g., free fatty acids and volatile sulfur compounds), which lend the fishy flavor and odor to products.

In addition, the color change in the enriched bread is due to color differences between the two flours, as TF is visually darker than wheat flour. Previous studies observed similar sensory changes in bakery products enriched with seafood sources. However, natural alternatives are currently available to enhance the quality of bakery products, such as texture enhancers (e.g., hydrocolloids) and flavoring agents (e.g., oleoresins and essential oils derived from spices).

Notably, the overall liking was positively driven by *soft*, *airy appearance*, *spongy*, *bread aroma* and *light color*, which were descriptive terms perceived for BTF0%, BTF2.5% and BTF5%. Overall, our findings suggest that wheat flour replacement by TF up to 10 percent was not enough to affect the sensory characteristics of the bread and did not compromise the overall liking.

Based on our findings, both levels of tilapia flour (12.17 and 6.86 percent) were enough to contribute to nutritional enrichment of bread. TF is easy to prepare, has good chemical stability at room temperature, and has a high nutritional value containing essential amino acids and fatty acids that are beneficial to human health. Also, fish flour is a low-cost raw material, and its use reduces environmental impact, representing a sustainable alternative for the commercial fishing industry.

Regarding consumer interest, the majority of the consumers (72 percent) stated that they were interested in eating bread with higher amounts of proteins and minerals. Today's consumers require foods that are functional, convenient and healthy, which may explain the high interest in the bread with added TF. Reinforcing our findings, consumer demand is increasing for the fish matrix, more-sustainable foods, and ready-to-eat products, due to their high nutritional value, rapid preparation and extended stability during storage.

Therefore, based on our results, the substitution of wheat flour by TF (≤ 10 percent) resulted in a convenient, sustainable and healthy bread product with high nutritive value (more protein, ash, lipid, and reduced energy value) without perceptible sensory changes compared to traditional breads, thereby meeting the demand of the consumer

market.

Perspectives

The replacement of wheat flour by TF improved the nutritional composition of the bread. Although replacement of wheat flour by TF at or above 20 percent have caused changes in sensory characteristics including appearance, aroma, flavor/taste, texture, and mouthfeel, our results show that lower replacement levels (5 percent and 10 percent) could be used without detrimental effects on overall liking.

In addition, our results indicate that the intention to consume and to purchase enriched bread can be maintained with levels < 12.17 percent and < 6.86 percent of TF, respectively.

Finally, the results suggest that bread fortified with TF at 5 percent can be a potential alternative for the food industry to satisfy the current nutritional and sustainability requirements of consumers.

References available from original publication.

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