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QUALITY EVALUATION OF FUNCTIONAL BREAD FROM WHEAT, CARROT, TILAPIA, AND HERRING FISH FLOUR BLENDS

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ABSTRACT

The production and evaluation of bread from flour blends comprising wheat, carrot, tilapia, and herring fish were investigated. 100% wheat flour (WF100) was the control. Seven bread samples were formulated: a control (SWF100) and six composite variations with increasing substitution levels of carrot, tilapia, and herring fish flours. Functional properties of the flour samples were determined. Proximate, physical, and sensory properties of the bread samples were evaluated. The water absorption capacity of the blends ranged between 78.67g/ml to 104.33g/ml, oil absorption capacity, 73.33g/ml to 83.33g/ml; bulk density, 0.73g/cm3 to 0.83g/cm3; foaming capacity, 3.60% to 5.13%; and solubility, 11.67% to 14.35%. The moisture content of the bread samples ranged between 24.53% to 34.40%, protein, 14.49% to 16.94%; fat, 3.17% to 4.83%; ash, 2.10% to 3.41%; fibre, 0.40% to 0.50%; and carbohydrates, 40.67% to 54.71%. The weight of the bread samples ranged from 221.27g to 233.70g, length, 18.50mm to 21.17mm; and width, 12.33mm to 14.00mm. Bread samples from WF100 had the lowest value in all the nutritional attributes analyzed (protein, 9.24%; fat, 2.17%; ash, 0.57%; fibre, 0.33%), but the highest carbohydrate content (63.56%). The functional bread samples compared favorably with SWF100 in all the sensory attributes assessed. Bread samples from wheat (90%), carrot (5%), and herring fish (5%) (SWCH90:5:5), were the most acceptable with an overall acceptability score of 7.70 and compared favorably with SWF100 with an overall acceptability score of 7.95. The functional breads offer a nutritious alternative to wheat bread and can help address nutritional deficiencies in vulnerable populations.

Keywords: Functional Bread, Tilapia Fish, Herring Fish, Carrots, Wheat Flour

INTRODUCTION

Bread is one of the popular daily staple foods in many countries, with refined hard wheat flour commonly used in white bread formulations (Issaoui *et al*., 2021). Wheat bread is high in carbohydrates, hence an energy-giving food. However, it is relatively low in quantity and quality of protein (Seal *et al*., 2021). In addition, owing to the loss of important components in wheat during milling, it is necessary to increase the nutritional value and sensory properties of bread, which is frequently used in the daily diet (Seal *et al*., 2021). Nowadays, with increasing health consciousness, consumers generally tend to purchase functional foods (Dhen *et al*., 2018). This trend is also reflected in the bakery market, where products containing ingredients that have beneficial effects on health are attracting consumers' attention (Sajdakowska *et al*., 2021).

Food fortification or enrichment is the process of adding micronutrients to food or the practice of deliberately increasing the content of an essential micronutrient in food to improve the nutritional quality of the food (Akhtar *et al.,* 2021). The process of fortifying bakery products, such as bread, which are rich in carbohydrates and are the most common in our daily food consumption, with functional components is becoming more common day by day (Akhtar *et al.,* 2021). Functional bread produced by fortification with edible plant and animal derivatives such as tilapia fish, herring fish, and carrots will be a welcome development and have a positive impact on human health.

Carrot (*Daucus carota*) is grown on a large scale in northern Nigeria (Asagbara & Oyewole, 2020). However, it is widely consumed in all parts of Nigeria. Indeed, the consumption of carrots in Nigeria has increased tremendously in recent years because of increasing awareness of their benefits. Among vegetables, carrot is the best source of carotene, which is the precursor of vitamin A, an essential nutrient for maintaining health. In Nigeria, local utilization of carrots is mostly limited to direct, unprocessed eating. Carrots can be dehydrated, and dehydrated carrots could be processed into flour for foods to increase vitamin A and mineral content (Weiss, 2020). Carrot is a good source of various bioactive compounds, such as carotenoids, flavonoids, phenolic compounds, vitamins (B_1, B_2, B_6), and minerals, which help to provide biological and medicinal properties, such as improving digestion, regulating blood circulation, and improving eye vision (Varshney & Mishra, 2022). It is a good source of higher antioxidant compounds that show anti-carcinogenic and immune-enhancing properties. Also, it helps to control diabetes, cholesterol, and cardiac disease and has antihypertensive, hepatoprotective, and wound healing properties (Weiss, 2020).

Fish processed in flour form is more effective as a supplementation ingredient in food products than fresh fish, and the flour integrates more evenly with the main ingredients (Jung *et al.,* 2018). The flour form is also more durable, has wider applications, and is easier to package and store compared to the fresh fish (Jung *et al.,* 2018). Tilapia (*Oreochromis niloticus*) and herring fish (*Clupea harengus*) are low-cost dietary protein sources (Ibrahim *et al.,* 2014). Their fat is readily digestible, rich in unsaturated fatty acids, and they are also an excellent source of vitamins A and D (Ibrahim *et al.,* 2014). Tilapia and herring fish, known for their high omega-3 fatty acids, along with carrots, which are rich in vitamins, minerals, and antioxidants, offer an opportunity to enhance the nutritional profile of bread. The integration of fish and vegetable (carrot) flours into traditional bread formulations could contribute to improved dietary options, enhanced food security, and the promotion of the utilization of sustainable food resources. This functional bread will minimize dependence on imported wheat, provide food varieties for people with celiac disease, and consequently encourage optimum utilization of carrot, tilapia, and herring fish in the food industry. Therefore, this study aims to supplement wheat flour with readily available and protein-rich foods- tilapia, herring fish, and carrots to improve the nutritional quality of bread.

MATERIALS AND METHODS

Materials

Wheat flour, carrot, Tilapia, and Herring fish were obtained from Ikole central market in Ikole-Ekiti, Ekiti State. Other ingredients for bread production, such as sugar, yeast, salt, and vegetable fat, were purchased from Ikole central market in Ikole-Ekiti, Ekiti State.

Methods

Preparation of Carrot Flour

Carrot flour was prepared from fresh carrots according to the method of Gupta & Shukla (2017). The fresh carrots were sorted, washed, and then sliced into 2-3cm. After that, the sliced carrots were blanched at 95 °C for 2 min and then dried in the dehydrator at 50 °C, after which it was milled and sieved into carrot powder and stored in an airtight plastic jar.

Preparation of Herring Fish and Tilapia Fish Flour

Frozen Herring fish and Tilapia fish samples were washed thoroughly with clean water to remove all extraneous matter. Then the fish fillet(s) were removed with a sharp knife. The fish fillets were cut into 0.5 cm slices to decrease the drying period. Thereafter, they were dried in the dehydrator at 60 °C. The dried samples were ground to pass through a 60 mesh screen (0.25 mm) and were stored in an air-tight polyethylene plastic bag for further use (Zebib *et al.*, 2020).

Formulation of Flour Blends

Flour samples were mixed at different proportions using the method of Ichol *et al*. (2024) with slight modification as shown in Table 1. Sample A was the control with 100% wheat flour. The flour samples were stored at ambient temperature (29 °C ± 2 °C) in sealed polyethylene bags until required.

Table 1: Formulation of Flour Blends

Samples	Wheat flour (%)	Carrot flour (%)	Tilapia fish flour (%)	Herring fish flour (%)
WF100	100	0	0	0
WCT90:5:5	90	5	5	0
WCT75:10:15	75	10	15	0
WCT60:15:25	60	15	25	0
WCH90:5:5	90	5	0	5
WCH75:10:15	75	10	0	15
WCH60:15:25	60	15	0	25

Keys:
WF100: 100% Wheat flour (control)
WCT90:5:5: 90% wheat flour, 5% carrot flour, 5% Tilapia fish flour
WCT75:10:15: 75% wheat flour, 10% carrot flour, 15% Tilapia fish flour
WCT60:15:25: 60% wheat flour, 15% carrot flour, 25% Tilapia fish flour
WCH90:5:5: 90% wheat flour, 5% carrot flour, 5% Herring fish flour
WCH75:10:15: 75% wheat flour, 10% carrot flour, 15% Herring fish flour
WCH60:15:25: 60% wheat flour, 15% carrot flour, 25% Herring fish flour

Functional Properties of Flour Blends

Functional properties of the flour blends were determined according to the method described by Onwuka (2018).

Preparation of Bread

Bread samples were produced from the flour blends and the ingredients in Table 2 using the method described by Ichol *et al*. (2024). Bread samples produced from 100% wheat flour (SWF100) served as the control. Bread samples were named following their composite flours as SWCT90:5:5, SWCT75:10:15, SWCT60:15:25, SWCH90:5:5, SWCH75:10:15, and SWCH60:15:25.

Table 2: Ingredients for Bread Production

Ingredients	Quantity
Flour	500g
Water	250ml
Yeast	20g
Salt	2.5g
Sugar	30g
Fat	30g

Source: Ichol *et al*. (2024)

Proximate Composition of Bread Samples

Moisture, ash, protein, fat, and crude fibre contents of the bread samples were determined by methods described by AOAC (2012). Available carbohydrate was determined by difference (Onwuka, 2018).

Determination of Physical Properties of the Bread Samples

The physical properties of loaf weight, loaf volume, specific volume, and loaf height were determined as described by Ichol *et al*. (2024).

Sensory Evaluation
A panel of 20 semi-trained panelists was used for this study, where a 9-point hedonic scale was used, with 9 representing like extremely and 1 representing dislike extremely. The bread samples were evaluated for crust color, appearance, aroma, crumb texture, taste, and overall acceptability (Ichol *et al*., 2024).

Statistical Analysis
Data was generated in triplicate and subjected to analysis of variance (ANOVA). Means were tested for significant differences using Duncan's multiple range test (DMRT). Significance was accepted at $p < 0.05$ (Ichol *et al*., 2024).

RESULTS AND DISCUSSION

Functional Properties of Flour Samples

The results for the functional properties of the composite flour samples are presented in Table 3. The functional properties of the composite flour samples are significantly ($p \leq 0.05$) different. Functional properties are critical in determining how flour blends behave during processing, and they affect dough formation, baking quality, texture, and mouthfeel (Awuchi *et al*., 2019). The water absorption capacity (WAC) of the composite flour samples ranged from 78.67 g/ml to 104.33 g/ml. WCT90:5:5 had the least WAC (78.67 g/ml), while WCT60:15:25 and WCH60:15:25 had the highest WAC (104.33 g/ml) compared to WF100 (100 % wheat flour) with a WAC of 67.00 g/ml. The incorporation of carrot flour, Tilapia fish flour, and Herring fish flour into wheat flour notably influenced the water absorption capacity (WAC), oil absorption capacity (OAC), bulk density (BD), foaming capacity, and solubility of the flour blends. The WAC of the composite flour samples increased with increased inclusion of carrot, tilapia, and herring fish flour. It was also observed that the WAC of the composite flour samples was higher (78.67 g/ml to 104.33 g/ml) than the WAC of the control sample WF100 (67 g/ml), and this suggests that the increased inclusion of carrot, tilapia, and herring fish flour significantly increased the WAC of the composite flour samples. The increased WAC with increasing levels of carrot, tilapia and herring fish flour substitution could be attributed to the fact that tilapia and herring fish flour which are protein-rich, has more hydrophilic groups (–OH, –NH2), which attract water and carrot flour has high fiber and pectin content, which are known to bind water effectively (Iwe *et al.,* 2019). Adeleke & Odedeji (2010) also reported that WAC increased from 57.80% to 66.00% with 20% fish flour substitution in wheat. Kaur & Singh (2005) observed that the presence of dietary fiber from plant-based sources enhances WAC due to its ability to form hydrogen bonds with water molecules. Ibidapo *et al.* (2017) found that carrot flour-enriched biscuits showed increased WAC, improving softness and texture. The high WAC of the composite flour sample is beneficial in bakery applications as it improves dough handling and yields moister bread with improved mouthfeel (Elkhalifa & Bernhardt, 2018).

Table 3: Functional Properties of Flour Blends

Samples	Water absorption capacity (g/ml)	Oil absorption capacity (g/ml)	Bulk density (g/cm^3)	Foaming capacity (%)	Solubility (%)
WF100	67.00^e ±1.73	89.67^a±3.06	0.85^a ±0.01	3.40^c±0.17	10.67^d±1.16
WCT90:5:5,	78.67^d ±0.58	83.33^b±1.53	0.81^b ±0.01	3.97^b±0.06	11.67^b±0.58
WCT75:10:15	87.00^c ±2.65	81.67^b±1.16	0.79^b ±0.01	4.43^b±0.21	13.67^{ab}±1.53
WCT60:15:25	104.33^a±4.16	77.33^c±2.08	0.75^b±0.02	5.13^a±0.25	14.33^a±1.53
WCH90:5:5	81.00^d ±1.00	76.33^c±2.31	0.83^{ab} ±0.32	3.60^b±0.20	12.33^c±0.38
WCH75:10:15	97.67^b ±2.31	74.33^d±3.22	0.81^b ±0.15	3.70^b±0.10	13.00^b±1.00
WCH60:15:25	104.33^a±2.08	73.33^d±1.16	0.73^c±0.15	4.80^a±0.00	14.00^a±0.00

Values are mean ± standard deviation. Means with same superscript across a column are not significantly different at $p<0.05$
Keys:
WF100: 100% Wheat flour (control)
WCT90:5:5: 90% wheat flour, 5% carrot flour, 5% Tilapia fish flour
WCT75:10:15: 75% wheat flour, 10% carrot flour, 15% Tilapia fish flour
WCT60:15:25: 60% wheat flour, 15% carrot flour, 25% Tilapia fish flour
WCH90:5:5: 90% wheat flour, 5% carrot flour, 5% Herring fish flour
WCH75:10:15: 75% wheat flour, 10% carrot flour, 15% Herring fish flour
WCH60:15:25: 60% wheat flour, 15% carrot flour, 25% Herring fish flour

The oil absorption capacity (OAC) of the composite flour samples ranged from 73.33 g/ml to 83.33 g/ml. WCH60:15:25 had the least OAC (73.33 g/ml) while WCT90:5:5 had the highest OAC (83.33 g/ml) compared to the control WF100 (100 % wheat flour) with OAC of 89.67 g/ml. The result showed that the OAC of the composite flour samples decreased with increased inclusion of carrot, tilapia, and herring fish flour. It was also observed that the OAC of the composite flour samples was lower (73.33 g/ml to 83.33 g/ml) than the OAC of the control WF100 (89.67 g/ml). The high OAC observed in WF100 suggests that wheat flour retains more oil than the alternative flours (carrot, herring fish, and tilapia fish) (Adelakun *et al.,* 2018). In addition, the decrease in OAC observed as the substitution of carrot flour, tilapia fish flour, and herring fish flour increased may result from lower lipid affinity in the protein matrix of fish flour compared to gluten, or a tighter matrix that does not trap oil as effectively (Adelakun *et al.,* 2018). Kalu (2023) stated that high OAC is associated with the presence of non-polar side chains in proteins and starch granules, which may be disrupted by fish flour proteins. The lower OAC of composite flour samples, especially in WCH60:15:25, could affect mouthfeel and flavor retention but may be advantageous for reducing overall fat uptake in food and bakery products (Adebowale *et al.,* 2005).
The bulk density of the composite flour samples ranged from 0.73 g/cm^3 (WCH60:15:25) to 0.83 g/cm^3 (WCH90:5:5). It was also observed that the bulk density of the composite flour samples was lower (0.73 g/cm^3 to 0.83 g/cm^3) than that of WF100 (0.85 g/cm^3). The bulk density of the composite flour samples decreased with increased inclusion of carrot, tilapia, and herring fish flour. Bulk density is defined as the mass of a material, such as flour, per unit volume, including the space between the particles, and it affects the ability of dough to rise and hold gas (Onuwka, 2018). Low bulk density means that the flour is light and airy, which may improve mixing and

aeration but can affect handling in large-scale processing, while high bulk density allows more product to be packed into a given space, reducing packaging and transport costs (Adebowale *et al*., 2005). Therefore, WF100 with high bulk density will be denser and more compact, while composite flour samples (WCT90:5:5 to WCH60:15:25) with low bulk density suggest a lighter and less compact flour matrix, and this affects packaging and flow properties, and a lower bulk density may be useful in producing lighter-textured baked goods (Adebowale *et al*., 2005). Onwuka (2018) also emphasized that reduced bulk density indicates increased air entrapment, beneficial for baking. Akubor & Badifu (2004) also reported similar findings with breadfruit–wheat composite flours, where bulk density reduced as breadfruit content increased.

The foaming capacity of the composite flour samples ranged from 3.60 % (WCH90:5:5) to 5.13% (WCT60:15:25). It was also observed that the foaming capacity of the composite flour samples was higher (3.60 % to 5.13 %) than that of WF100 (3.40 %). The foaming capacity of the composite flour samples increased with increased inclusion of carrot, tilapia, and herring fish flour. Foaming capacity is the ability of a substance, typically a protein-containing flour or food ingredient, to trap air and form a stable foam when whipped, shaken, or agitated in water, and it is essential, especially where volume, lightness, and texture are desired (Adebowale *et al*., 2005). The increase in foaming capacity of the composite flour samples with higher substitution of carrot, tilapia, and herring fish flour may be due to the presence of high-quality proteins from tilapia and herring fish flour, which reduce surface tension and trap air, thereby stabilizing foams. Adeleke & Odedeji (2010) found that the foaming capacity of wheat–fish blends increased up to 7.9% which supports the current findings, and Kinsella & Melachouris (2009) also highlighted that proteins with flexible structures are better foaming agents, which may explain the increase due to fish protein. The high foaming capacity of the composite flour samples can lead to enhanced volume and texture in baked foods, may be useful in creating aerated products, and may also reflect the emulsifying potential of proteins in the composite flour samples (Adebowale *et al*., 2005).

The solubility of the composite flour samples ranged from 11.67 % (WCT90:5:5) to 14.33 % (WCT60:15:25). The solubility of the composite flour samples increased with increased inclusion of carrot, tilapia, and herring fish flour. It was also observed that the solubility of the composite flour samples was higher (11.67 % to 14.33 %) than that of WF100 (10.67 %). Solubility is the ability of a substance, such as flour or protein, to dissolve in a solvent, typically water, and it determines how much of the component of the flour goes into solution when mixed with water (Onwuka, 2018). It was observed that solubility rose with increased substitution of carrot, tilapia, and herring fish flour, and it is likely due to the partial solubility of proteins in fish flour and polysaccharides in carrot flour, and the high solubility of the composite flour sample is desirable in food powders and reconstitutable products (Onwuka, 2018). Adeleke & Odedeji (2010) also reported that solubility increased when starch was replaced by proteinaceous materials in food formulations. Soluble proteins are often more digestible, and higher solubility can contribute to a smoother product texture (Onwuka, 2018).

Proximate Composition of Bread Samples

The results for the proximate composition of the bread samples from wheat, carrot, tilapia, and herring fish flour samples are presented in Figure 1. The result showed that the proximate compositions of the bread samples are significantly different at $p \leq 0.05$. Proximate composition provides insight into the nutritional value of the bread samples. The moisture content of the composite bread samples ranged from 24.53 % (SWCH90:5:5) to 34.40 % (SWCT60:15:25). The moisture content of SWF100 (24.13 %) was lower than that of the composite bread samples (24.53 % to 34.40 %). The result also showed an increase in the moisture content of the bread samples with increased inclusion of carrot, tilapia, and herring fish flour. This could be attributed to the fact that carrots are rich in water and hygroscopic fiber, and herring and tilapia fish flours have a moderate water-holding capacity (Ezeocha *et al*., 2023). Moisture content is a critical indicator of product shelf-life stability; the lower the moisture content, the better the shelf-life stability (Ogunjemilusi *et al*. 2023). The moisture content observed in this study is similar to the moisture content (30.32 % to 33.23 %) reported by Masresha *et al.* (2023) for functional bread prepared from wheat, banana, and carrot flour. The higher moisture content of the composite bread samples can enhance softness and palatability of bread, but it can also increase perishability of the bread; therefore, the moisture-retaining ingredients (herring fish flour, tilapia fish flour, and carrot flour) must be balanced with preservatives or proper packaging (Ezeocha *et al*., 2023; Ogunjemilusi *et al*., 2023).

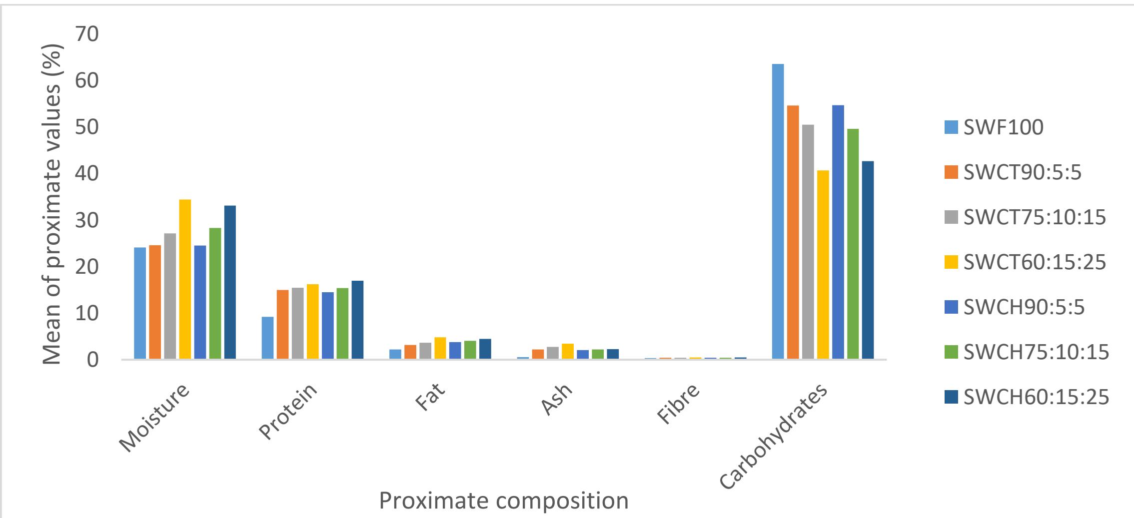

Figure 1: Proximate Composition of Bread Samples

The protein content of the composite bread samples ranged from 14.49 % (SWCH90:5:5) to 16.94 % (SWCH60:15:25). The protein content of SWF100 (9.24 %) was lower than that of the composite bread samples (14.49 % to 16.94 %) and there was an increase in the protein content of the bread samples with increased inclusion of carrot, tilapia, and herring fish flour. Mulak *et al.* (2020) also reported an increase in protein content (6.14 % to 10.23 %) for bread prepared from wheat, almond seed, and carrot flour. Furthermore, the protein content observed in this study is comparable to the protein content (10.60 % to 14.25 %) reported by Cavenaghi & Fonseca (2024) for bread prepared from wheat, corn, cassava, and fish finger flour. The gradual increase in protein content with increased inclusion of carrot, tilapia, and herring fish flours into wheat flour could be attributed to the high protein content of tilapia and herring fish flours (Yahaya *et al*., 2018). Carrot contributes minimally to protein content (Ronda *et al.,* 2005). The higher protein content of the composite bread samples can improve the nutritional profile and may appeal to protein-conscious consumers and populations with protein-deficiency risks (Masresha *et al*., 2023), but excessive substitution may reduce gluten strength, thereby affecting loaf structure (AOAC, 2019).

The fat content of the composite bread samples ranged from 3.17 % (SWCT90:5:5) to 4.83 % (SWCT60:15:25). The fat content of SWF100 (2.17 %) was lower than that of the composite bread samples (3.17 % to 4.83 %) and there was an increase in the fat content of the composite bread samples with increased inclusion of carrot, tilapia, and herring fish flour. The result observed in this study for fat content is similar to the fat content range of 2.90 % to 5.30 % reported by Bastos *et al*. (2024) for wheat-fish-based bread. The increase in the fat content of composite bread samples with increased substitution of carrot flour and particularly tilapia and herring fish flours could be attributed mainly to the healthy fat content of the fish flours, particularly omega-3 fatty acids, as carrot flour has negligible fat, so the rise in fat is primarily due to the fish flours (Bastos *et al*., 2024). The higher fat content of the composite bread samples can enhance energy density and nutritional quality; however, higher fat content may reduce shelf-life if not properly preserved due to lipid oxidation (Samuel *et al*., 2024; Ibidapo *et al*., 2017). Fat acts as a lubricating agent to improve the quality of bread in terms of texture and flavor. It also provides energy and is essential as it carries along fat-soluble vitamins.

The ash content of the composite bread samples ranged from 2.10 % (SWCH90:5:5) to 3.41 % (SWCT60:15:25) and was higher than that of SWF100 (0.57 %). There was an increase in the ash content of the composite bread samples with increased inclusion of carrot, tilapia, and herring fish flour. The ash content of a product gives a rough estimate of its mineral content (Adelekan *et al*., 2019). Minerals are essential nutrients that serve a variety of essential functions in metabolism and are among the parts of biomolecules such as hemoglobin, deoxyribonucleic acid (DNA), and adenosine triphosphate (ATP) (Awuchi, 2019). The increase in ash content of the bread samples with increased substitution of carrot, tilapia, and herring fish flour corresponds with the report of Mulak *et al*. (2020), who reported an increase in ash content (1.62 % to 2.72 %) of bread produced from wheat, almond seed, and carrot bread. The values also corroborated with the results of Zebib *et al*. (2020) for wheat-fish composite bread. It was observed that both carrot and fish flours contributed significantly to the ash content of the composite bread samples, as tilapia and herring fish are particularly rich in calcium, phosphorus, and other trace elements (Adelekan *et al*., 2019), and carrot flour also contains some minerals. The improved mineral content of the composite bread samples supports bone health and metabolism, and it is valuable for nutritionally enriched bakery products (Mulak *et al*. 2020).

The fibre content of the composite bread samples ranged from 0.40 % (SWCH90:5:5) to 0.50 % (SWCT60:15:25) compared to SWF100 (100 % wheat bread) with a fibre content of 0.33 %. There was an increase in the fibre content of the composite bread samples with increased inclusion of tilapia, herring fish flour, and particularly carrot flour, as carrot is a good source of dietary fiber, particularly insoluble fiber (Arise *et al*., 2018). Fibre in food products is essential owing to its bulk addition to food and prevention of many gastrointestinal diseases. Crude fiber, which is comprised of indigestible carbohydrates such as cellulose, hemicellulose, pectin, and lignin, reduces the rate of release of glucose into the bloodstream and also reduces inter-colonic pressure, thereby reducing the risk of colon cancer (Awuchi, 2019). The increase in fibre content of the composite bread samples with increased inclusion of carrot, tilapia, and herring fish flour is in line with the report of Zebib *et al.* (2020), who reported an increase in fibre content of wheat-fish-based bread with increased fish substitution. The fibre content of the bread samples in this current report is within the range of fibre content (0.36 to 0.97 %) reported by Mulak *et al.* (2020) for bread prepared from wheat, almond seed, and carrot. The high crude fibre content of the composite bread samples is beneficial for digestive health, but too much fiber may toughen the texture (Awuchi, 2019). The high fibre content also helps with satiety and bowel movement regulation, thereby enhancing the functional appeal of the bread (Ayo *et al*., 2007).

The carbohydrate content of the composite bread samples ranged from 40.67 % (SWCT60:15:25) to 54.71 % (SWCH90:5:5). The carbohydrate content of SWF100 (63.56 %) was higher than that of the composite bread samples, and there was a decrease in the carbohydrate content of the bread samples with increased inclusion of carrot, tilapia, and herring fish flour. This decrease is because wheat is primarily carbohydrate-based; therefore, as it is substituted with protein and mineral-rich flours, the carbohydrate percentage falls (Adeyemi & Idowu, 2020). Zebib *et al*. (2020) also reported a decrease in total carbohydrate of bread from 72.02 % to 64.40 % on substitution of wheat flour with fish flour and suggested that this might be due to the effect of starch dilution through the incorporation of the fish flour. The reduced carbohydrate content of the composite bread samples is desirable for diabetic or low-carbohydrate diet patients. However, too low a carbohydrate level may reduce the bread's fluffiness and structure since carbohydrate (starch) gelatinizes during baking (Elkhalifa *et al*., 2005).

Physical Properties of Bread Samples

The results for the physical properties of the bread samples are presented in Figure 2. The result showed that the physical properties of the bread samples are significantly different at $p \leq 0.05$. Physical properties of bread are critical in assessing the volume, structure, appearance, and consumer perception of bread, and these properties reflect how ingredient substitutions affect dough development, oven spring, and final product dimensions (Chinma & Gernah, 2007).

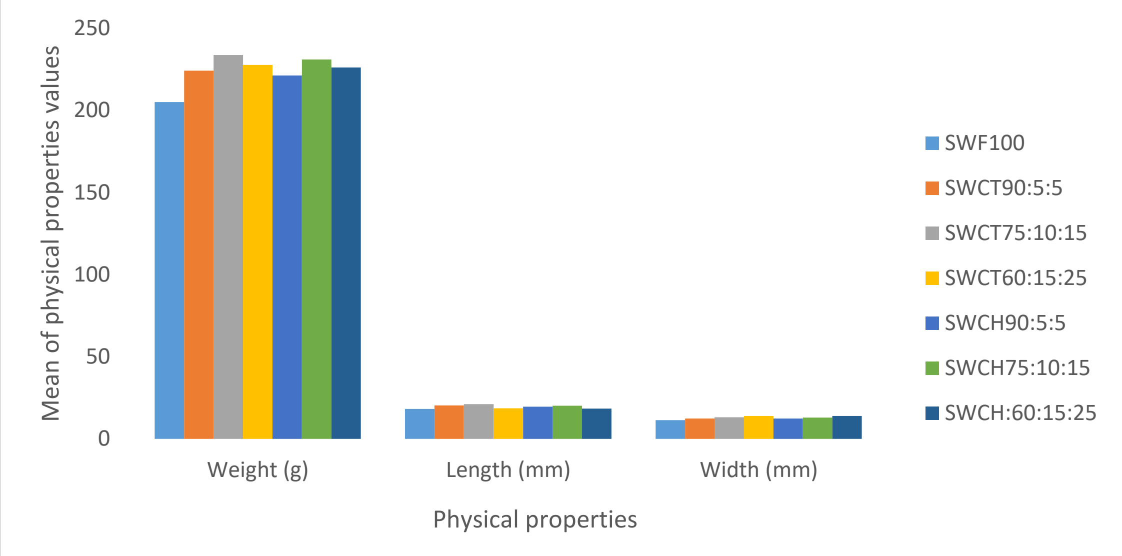

Figure 2: Physical Properties of Bread Samples

The weight of the composite bread samples ranged from 221.27g (SWCH90:5:5) to 233.70g (SWCT75:10:15). The result showed an increase in weight with carrot, tilapia, and herring fish flour, peaking in SWCT75:10:15, but a slight drop was observed in SWCT60:15:25 and SWCH60:15:25 possibly due to structure collapse or moisture loss during baking (Okereke *et al.,* 2021). Bread weight refers to the final mass of a baked loaf after it has been removed from the oven and allowed to cool, and it is an important physical property used to assess product yield, moisture retention, and formulation efficiency in bread making (Onwuka, 2018; Okereke *et al.,* 2021). The heavier composite bread samples indicate higher nutrient density, which may appeal to health-conscious consumers; however, the increased weight must not compromise loaf volume or softness (Olaoye *et al*., 2022). It could also be attributed to the denser nature of carrot, tilapia, and herring fish flour and their higher water absorption capacity (WAC), which leads to increased dough hydration and hence heavier loaves (Onwuka, 2018; Ndife *et al*., 2011). Adeleke & Odedeji (2010) found that bread weight increased with fish flour substitution, due to the enhanced water-binding ability of fish proteins.

The length of the composite bread samples ranged from 18.50mm (SWCH60:15:25) to 21.17mm (SWCT75:10:15) compared to SWF100 with a length of 18.20mm. The result showed a slight increase in length with increased substitution of carrot, tilapia, and herring fish flour. This could be attributed to increased moisture content and dough spread during baking due to weakened gluten matrix (Asaam *et al*., 2018). Additionally, bread may expand laterally rather than rise, especially with high water content and weaker structural integrity (Asaam *et al*., 2018). Bread length refers to the horizontal measurement of a baked loaf from end to end, and it can offer insight into the dough spread and structural stability during proofing and baking (Adebowale *et al*., 2005). Bread length is also directly related to the gluten strength, gas retention, and ingredient composition of the dough (Ndife *et al*., 2011). The length of the bread samples observed in this study may affect uniformity and cutting/slicing consistency (Onwuka, 2018). On the other hand, Siddiq *et al*. (2010) reported that high levels of non-gluten flour substitution reduce dough extensibility and expansion, resulting in smaller loaf dimensions. Also, Okoye & Ene (2019) found that increasing soy flour levels in wheat bread led to significantly shorter loaves due to gluten dilution.

The width of the composite bread samples ranged from 12.33mm (SWCH90:5:5) to 14.00mm (SWCH60:15:25). SWF100 had a width of 11.33mm. It was observed that the width increased as the proportion of tilapia, herring fish, and carrot flours increased. This could be attributed to the report that bread tends to spread out rather than rise upwards in the absence of strong gluten networks. A wider loaf may be acceptable, but it may also indicate a weaker dough structure (Ndife *et al*., 2011). Bread width is the horizontal dimension of a bread loaf measured across its shorter side, perpendicular to the length, and it helps to assess the shape, spread, and uniformity of the bread after baking (Ndife *et al*., 2011). Bread width is also used to evaluate the expansion and shape of bread during baking, and it reflects how well the dough maintains its structure and spreads laterally in the baking pan, which is influenced by the type of flour, gluten development, and moisture content (Onwuka, 2018). Unlike length, width appears to be less sensitive to substitution levels, possibly due to pan confinement during baking (Oluwamukomi *et al*., 2011). Olaoye *et al*. (2022) indicated that width and variations in composite breads are largely influenced by the protein quality and baking pan geometry. Similar observations were also made by Adebowale *et al*. (2005) in their work with plantain and soy composite breads.

Sensory Scores of Bread Samples

The result for the sensory scores of the composite bread samples and SWF100 are presented in Figure 3. Sensory evaluation assesses the organoleptic qualities of food products, how they are perceived by the senses of sight, smell, taste, touch, and overall enjoyment, and it is also a critical tool in determining consumer acceptability and market success of novel food products (Saater *et al*., 2025; Roshana & Mahendran, 2019).

Figure 3: Sensory Properties of Bread Samples

The crust color of the composite bread samples ranged from 7.3 (SWCT60:15:25) to 7.8 (SWCT90:5:5 and SWCH90:5:5) compared to SWF100 with a crust color of 8.4. It was observed that the crust color of the composite bread samples decreased significantly with increasing levels of carrot, tilapia, and herring fish flour, and this suggests that the composite flours may reduce browning due to altered sugar and protein interactions and higher moisture content (Riaz *et al*., 2021). The incorporation of tilapia and herring fish flours may have contributed to a darker or uneven crust due to Maillard reactions involving fish proteins and reducing sugars (Mohammed *et al.,* 2022). Carrot flour, which is rich in carotenoids, may also have imparted the crust color that some panelists may find unfamiliar or less appealing (Mohammed *et al.,* 2022). It was also observed that the control sample A scored highest in crust color (8.40), and it may likely be due to the classic golden-brown crust from Maillard reactions in pure wheat bread (Obi, 2021). While the color reduction is minimal, darker or duller crusts might appear less attractive, and the inclusion of carrot (orange pigment) may also alter crust coloration, potentially leading to reddish or dull brown shades (Obi, 2021).

Appearance scores for the composite bread samples ranged from 7.00 (SWCT60:15:25) to 7.30 (SWCT90:5:5 and SWCH90:5:5). SWF100 had an appearance score of 7.95. The result showed a slight decrease in appearance scores of the composite bread samples with increasing substitution levels of carrot, tilapia, and herring fish flours. This suggests that the reduced loaf volume and flatter shapes in composite bread samples may be less visually appealing, and additionally, the uneven crumb structure from gluten dilution could also affect perception (Ajala & Taiwo, 2018). The high substitution levels of carrot, herring fish, and tilapia fish flours may have resulted in compact, less uniform loaves with rough surfaces (Adeleke & Odedeji, 2010). In addition, protein from tilapia fish flour and fiber from carrot may interfere with gluten network formation, causing reduced loaf symmetry and surface glossiness (Okoye & Ene, 2019). Appearance is important for marketability as visual cues are the first factor influencing purchase intent, and factors that can affect the appearance of the composite bread include the chemical composition of the flours, the drying temperature and duration, and the proportions or ratios of ingredients (Samuel *et al*., 2024).

Aroma scores ranged from 7.50 (SWCH90:5:5) to 7.70 (SWCH60:15:25). Although SWF100 was rated highest for aroma (7.85), the aroma scores were fairly stable across all samples. This could be attributed to the fact that wheat and carrot contribute to a sweet, pleasant aroma (Saater *et al*., 2025). Additionally, tilapia and herring fish flours may slightly influence aroma, but not strongly enough to cause rejection, especially at low levels (Ajala & Taiwo, 2018; Ndife *et al*., 2011). Aroma is very important in food as it influences the acceptance of food before they are consumed (Samuel *et al*., 2024).

The crumb texture of the bread samples ranged from 7.50 (SWCH90:5:5) to 7.96 (SWCT75:10:15). SWF100 had a crumb texture score of 8.15. It was observed that the crumb texture scores remained relatively high across all samples. The slight reduction from SWCT90:5:5 to SWCH60:15:25 may likely be due to gluten dilution (Ezeocha *et al*., 2023). Gluten helps to retain gas and create soft, elastic textures. However, tilapia, herring fish, and carrot flours lack gluten and introduce fiber and proteins, which can make the crumb coarser or denser, and despite nutritional benefits, a hard or crumbly crumb might reduce acceptability over time (Chinma & Gernah, 2007; Adebowale *et al*., 2005). In addition, the higher water absorption capacity and low viscoelasticity of the tilapia and herring fish flours contributed to a less cohesive crumb structure (Prada *et al*., 2020).

There was very minimal variation in the taste scores across the samples (7.50 to 7.71). Interestingly, samples SWCT90:5:5, SWCT75:10:15, SWCH90:5:5 and SWCH75:10:15 had slightly better taste scores than SWF100 (7.45) and composite samples SWCT60:15:25 and SWCH60:15:25. This observation could be attributed to the mild sweetness from carrot and umami richness from tilapia and herring fish flours which may have enhanced the taste perception and at higher levels (SWCT60:15:25 and SWCH60:15:25), any potential fishy or earthy aftertaste may start to appear, balancing out taste appeal (Chinma & Gernah, 2007). The taste score observed in this present study indicates that functional enrichment did not negatively impact flavor, which is a positive outcome for consumer acceptance (Olagunju, 2013).

Overall acceptability scores of the bread samples ranged from 7.10 (SWCH60:15:25) to 7.70 (SWCH90:5:5). SWF100 had an overall acceptability score of 7.95. All the bread samples had a mean overall acceptability score of 7.0 or above. Ndife *et al*. (2020) considered a product with an overall acceptability score of 7.0 and above as being accepted by the consumer. It was observed that the overall acceptability scores of the bread samples decreased as more wheat is replaced with carrot, tilapia and herring fish flours, especially in SWCT60:15:25 and SWCH60:15:25. The overall acceptability scores observed in this study suggests that consumers generally prefer traditional characteristics (SWF100), so a major deviation in color, structure, or texture can affect overall acceptability scores and also SWCT60:15:25 and SWCH60:15:25 may have been affected by high moisture, fish taste, or shape deformities (Kalu, 2023). Therefore, SWCT60:15:25 and SWCH60:15:25 may require formulation adjustment or masking strategies to improve acceptance (Samuel *et al*., 2024; Ndife *et al*., 2011).

CONCLUSION

This study successfully demonstrated the feasibility of producing nutritionally enriched functional bread by partially substituting wheat flour with carrot, tilapia, and herring fish flours. The inclusion of these nutrient-dense ingredients led to significant improvements in the protein, fat, ash (mineral), and fiber contents of the bread, highlighting their contribution to the functional value of the final product. Functional properties of the composite flours improved with increased substitution, particularly in terms of water absorption capacity, solubility. Sensory evaluation revealed that the composite bread samples achieved a good balance between nutritional quality and consumer acceptability. Although SWCT60:15:25 and SWCH60:15:25 had the highest nutritional profile, they showed slightly reduced sensory scores, particularly in overall acceptability and appearance. Therefore, the incorporation of carrot, tilapia, and herring fish flours at moderate levels can be a viable strategy for producing functional bread with enhanced nutritional quality without significantly compromising physical and sensory properties. Further research should be carried out on the microbial stability of the bread samples.

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