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Functional and Pasting Characteristics of Fermented Maize and Nile Tilapia (*Oreochromis niloticus*) Flour Diet

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Abstract: The proximate composition, pasting characteristics, Water Absorption Capacities (WAC), Oil Absorption Capacities (OAC), bulk densities (packed and loosed), Least Gelation Concentrations (LGC) swelling capacity, solubility, and viscosity of fermented and unfermented maize-tilapia mixes namely -MUF_1, MUF_2, MFF_3 and MFF_4 was investigated. WAC, OAC, PBD, LBD and LGC obtained are 271.7%; 176.0%; 0.570gmL^{-1}; 0.468g/ml; 10% (w/v) and 253.3-300%; 150.0-246.7%;0 355-0.468gmL^{-1}; 0. 513-0.610gmL^{-1}; 4.0-8.0% (w/v) respectively. Solubility and swelling power increased with increase in temperature. Viscosity increased with increase in the cold paste concentration and temperature. Peak viscosity of MF was 300RVA and 253.83-270.33 RVA in the formulated maize-tilapia mixes.

Key words: Functional properties, pasting properties, fermented maize flour, tilapia flour

Introduction

In developing countries malnutrition persist as a principal health problem among children below the age of five in Nigeria (UNICEF, 1996). Most traditional weaning foods in developing countries are made from cereals, starchy fruits, roots and tubers. Such foods are often of poor protein quality and have high paste properties (Desikachar, 1979). Efforts to improve the nutritional value of these staples have been based on fortification with legumes to provide the deficient amino acids (Bressani and Elias, 1983). The protein quality is synergistically improved in cereal-legume blends and is of variable organoleptic properties and poor digestibility; which is attributed to the low solubility of plant proteins in legumes (Okeiyi and Futrell, 1983). Fish is among the first natural resources to be exploited by man and supplies over 50% of the total animal protein consumed in developing countries and less so in developed countries (FAO, 2000). Nile Tilapia (*Oreochromis niloticus*) is a widely cultured species of fish in Africa having a worldwide harvest of over 800,000 metric tonnes (Popma and Masser, 1999). They are often discarded in fish farm due to their tendency to over populate the pond, because of their high fecundity, which results in stunted growth, they are bony and fail to command good market price.

These results in high post harvest loss of these species of fish especially in the riverine areas of developing countries. Fasasi *et al.* (2005) reported the development of highly digestible proteinous cereal mix using the underutilized tilapia. Functional properties are very important in determining the level of utilization in ingredient formulation and food product development (Tasneem *et al.,* 1982). Past research efforts on functional properties has focused on proteinous oil seeds and beans (Lawhon and Carter, 1971; Lin, *et al.*, 1974; Oshodi and Fagbemi, 1992) and some carbohydrate foods (Tagodoe and Nip, 1994; Osundahunsi *et al.*, 2003). This study is aimed at investigating the effect of Nile tilapia inclusion on some functional and pasting properties of fermented maize flour in order to enhance its commercial utilization.

Materials and Methods

Nile tilapia samples were obtained from a government fish farm in Ibadan, Nigeria. The fish was transported in frozen blocks to Food Science and Technology laboratory, Federal University of Technology, Akure, Nigeria. Fresh tilapias were descaled, degutted and washed in clean water; they were steamed for 15 min and minced. The minced tilapia was divided into two parts: one portion was oven-dried at 60°C, milled and sieved with a 200 µm mesh sieve to obtain Unfermented Fish flour (UF). The second portion was subjected to natural fermentation by spreading on a tray for 24 h at room temperature (30±2°C). Samples were oven-dried at 60°C for 24 h and milled to obtain the fermented Fish Flour (FF). Yellow maize *(Zea mays*) grains were purchased from Oja-Oba in Akure, Nigeria; and processed into "Ogi" using an improved method with greater protein recovery (Akingbala *et al.*, 1987). The fresh "Ogi" was oven-dried at 60°C, milled into flour, and sieved in 200 µm mesh sieve to obtain the fermented Maize Flour (MF). The resultant flour samples- MF, UF and FF were packaged in airtight polythene sachets and stored at 4°C until used.

Mix Formulation: The flours were blended in ratios obtained via linear programming using Corel Quatro pro 8. Protein (16%) and fat (9%) were used as constraints (targets) in the formulation. The blends obtained were-M: UF_1, M: UF_2, M: FF_3, M: FF_4 in ratios obtained via linear programming. MF is the control. Maize-tilapia mixes obtained were packaged in airtight polythene sachets and stored at 4°C prior to further analyses.

Keys:
MF-Fermented maize flour (control)
UF-Unfermented fish flour.
FF-Fermented fish flour.
M: UF_1-Mixes of fermented maize flour and unfermented tilapia flour at ratio 6.25: 1.
M:UF_2-Mixes of fermented maize flour and unfermented tilapia flour at ratio 8.87: 1
M: FF_3-Mixes of fermented maize flour and fermented tilapia flour at ratio 6.25: 1
M: FF_4-Mixes of fermented maize flour and fermented tilapia flour at ratio 9.30: 1

Determination of proximate composition of maize-tilapia mixes: Moisture, crude protein (Kjeldahl, N x 6.25), fat (solvent extraction), ash were determined in triplicate according to AOAC (1990) methods. The digestible carbohydrates (NFE) was calculated by difference.

Determination of functional properties: The Water and Oil Absorption Capacities (WAC and OAC) was determined as described by Sathe *et al.* (1982a). Packed Bulk Density (PBD) and Loose Bulk Density (LBD) was determined as described by Akpapunam and Markakis (1981). Least Gelation Concentration (LGC) was determined with slight modification of Coffman and Garcia (1977) method described by Desphande *et al.* (1982). Swelling capacity and Solubility was determined as described by Leach *et al.* (1959). Viscosity was determined as described by Beuchat (1977); Tagodoe and Nip (1994), at varied concentrations and temperatures using a rotatory viscometer (VEB MLW PRUFGERATE-WERK TYP RN Model Germany).

Visco-elastic properties: Visco-elastic properties were determined with the Rapid Visco-analyzer (RVA) at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Results and Discussion

Proximate composition: The proximate composition of mixes containing Unfermented Tilapia (UF) and fermented tilapia is shown in Table 1. The crude protein ranged between 15.68-16.09%, for Maize-tilapia mixes. The protein content of mixes was significantly higher at $p\leq0.05$ when compared to 7.63% for fermented Maize Flour (MF). The protein content conforms to the set target of 16%. Results obtained are comparable with the minimum FAO/WHO pattern for weaning foods of protein $\leq$16.00% (Mitzner *et al.*, 1994). Inclusion of fermented and unfermented tilapia into fermented Maize Flour (MF) resulted in a significant increase ($p\leq0.05$) in the fat content of mixes (6.20-6.40%).
The gross energy value for maize- tilapia mixes ranged between 1611.79 and 1677.48Kjg^{-1} . FAO/ WHO/ UNU (1985) reported the daily energy requirement for an adult to be 10,500-12,600 KJ depending on his physiological state while that of infants is 3094.68KJ. This implies that an adult man may require between 6.5-7.5g of maize-tilapia mixes and an infant would require between 0.24-0.29g to meet the daily energy requirement.

Water- and oil- absorption capacity: The results of the functional properties are as shown in Table 2. The Water Absorption Capacity (WAC) varies from 271.1% in fermented Maize Flour (MF) to 300% in fermented maize-tilapia mix (M:FF3). The OAC varies from 176% in fermented Maize Flour (MF) to 246.7% in maize-fermented tilapia mix (M:FF_4) Results show that the addition of fermented tilapia to fermented Maize Flour (MF) significantly increased the WAC and OAC. This observation is consistent with the reports of Sefa-Dedeh *et al.* (2002), who reported increase in WAC and OAC of a nixtamilized product with the addition of cowpea. The WAC values obtained for the maize-tilapia mixes (M:UF_1, M:UF_2, M:FF_3, M:FF_4) are higher than 180%, 166%,150% reported for red, white and nive taro flours (Tagodoe and Nip, 1994), 85% for fluted pumpkin seed flour (Fagbemi,and Oshodi, 1991), 24%, and 26% for red and white sweet potatoes flour (Osundahunsi *et al.*, 2003). The OAC of mixes are higher than OAC of taro flours 190%, as reported by Tagodoe and Nip (1994), 10-12% for sweet potatoes flour (red and white) as reported by Osundahunsi *et al.* (2003) and 167% for lupin seed flour (Sathe *et al.*, 1982a). The improved WAC and OAC

Table 1: Proximate composition (g $100g^{-1}$ DM) of maize flour and maize-tilapia mixes

Components	MF	M:UF_1	M:UF_2	M:FF_3	M:FF_4
Moisture	11.69±0.03^a	9.55±0.02^b	5.90±0.01^d	5.99±0.05^d	7.61±0.03^c
Crude protein	7.63±0.02^d	16.0±0.03^a	15.72±0.01^b	15.68±0.02^b	14.09±0.01^c
Fat	4.00±0.04^c	6.24±0.00^b	6.40±0.03^a	6.38±0.01^a	6.20±0.02^b
Ash	1.62±0.02^b	2.30±0.05^a	2.25±0.01^a	2.26±0.04^a	2.27±0.01^a
Carbohydrate	86.74±0.05^a	65.91±0.01^b	69.73±0.00^a	69.78±0.01^a	69.83±0.02^a
Gross Energy (Kjg^{-1})	1736.62	1611.79	1677.48	1676.89	1644.89

Mean±SD of at least three determinations. Values in a row denoted by different lower case letters differ significantly at $p<0.05$.

Table 2: Physicochemical properties of the samples

Samples	WAC (%)	OAC (%)	Bulk Density (g mL^{-1}) Loose	Packed	Least Gelation Concentration (%)
MF	271.7±0.6	176 .0±0.5	0.5±1.7E-03	0.6±5.8E-03	10 .0±0.0
M:UF_1	260.0±0.1	230.0±0.3	0.4±6.5E-03	0.5±1.86E-03	8.0±0.4
M:UF_2	253.3±0.3	150.0±0.8	0.4±3.1E-03	0.6±5.8E-03	6.0±0.3
M:FF_3	300 .0±0.7	153.3±0.3	0.4±2.9E-03	0.5±2.9E-03	6.0±0.4
M:FF_4	266.7±0.7	246.7±0.9	0.4±4.4E-03	0.6±5.8E-0	34.0±0.3

Mean±SE of at least three determinations

Table 3: Regression equations showing relationship between solubility (Y) and swelling power (Y_1) and temperature (X) of maize-tilapia mixes

Samples	Linear Equations	R^2	Quadratic Equations	R^2
MF	Y = 0.213X - 6	0.8977	Y = 0.0058X^2 – 0.4813X +13.671	0.9904
M:UF_1	Y= 0.3016 X – 9.404	0.8797	Y = 0.0085X^2 - 0.7167X +19.447	0.9772
M:UF_2	Y= 0.2745X-7.374	0.9216	Y = 0.0038X^2- 0.1824X +5.5703	0.9464
M:FF_3	Y= 0.3563X-10.884	0.7687	Y = 0.0085X^2-0.7167X +19.447	0.9772
M:FF_4	Y = 0.2019X-3.972	0.8588	Y = 0.0053X^2-0.4298X+13.927	0.9405
MF	Y_1= 0.246x- 4.22	0.9451	Y = -0.0019X^2+0.4689X-10.534	0.9526
M:UF_1	Y_1= 0.274x- 7.2	0.9466	Y = -0.0016X^2+0.4626X-12.543	0.9509
M:UF_2	Y_1`= 0.321x- 9	0.9751	Y = -0.0033X^2+0.7063X-20.171	0.9903
M:FF_3	Y_1= 0.289x-9.54	0.9309	Y = 0.005X^2+0.229X-7.84	0.9313
M:FF_4	Y_1= 0.276x-8.92	0.9143	Y = -0.0017X^2+0.4817X-14.749	0.9193

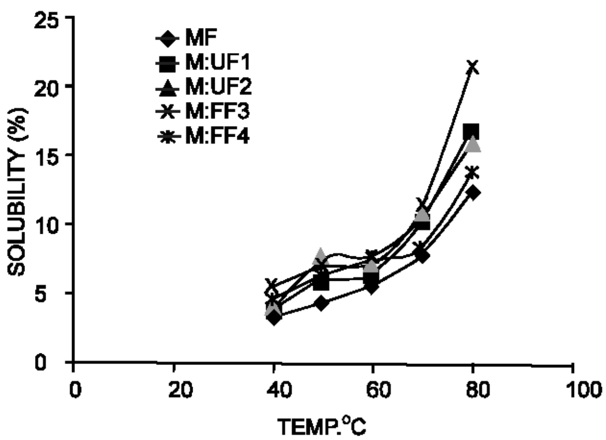

Fig. 1: Effect of temperature on solubility of maize-tilapia mixes.

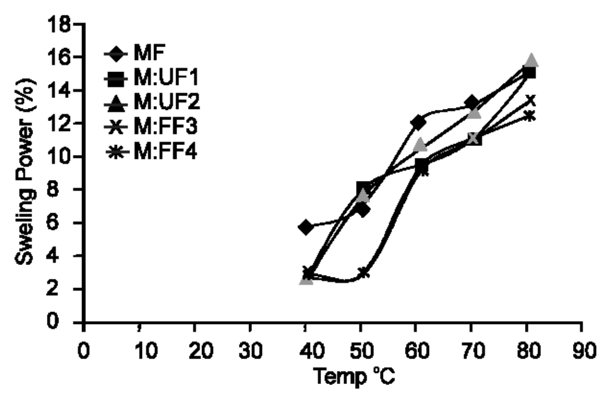

Fig 2: Effect of temperature on the swelling power of maize-tilapia mixes

indicate that the inclusion of tilapia especially the fermented tilapia improves the ability of the fermented maize flour to absorb water and oil. The improved WAC and OAC may be due to the increase observed in the crude protein after the addition of fermented and unfermented tilapia to fermented Maize Flour (MF). The % crude protein increase observed are: 110%, 106%, 106% and 85% for M: UF_1 M: UF_2 M: FF_3 and M: FF_4 (Table 3). The high protein content of the mixes might be responsible for high hydrogen bonding and high electrostatic repulsion, both conditions facilitating binding and entrapment of water (Sathe *et al.*, 1982b). WAC ranging from 149.1% to 471.5% are considered critical in viscous foods such as soups, gravies (Aletor *et al.*, 2002), hence the mixes may find use as functional ingredients in soups, gravies and baked products, it could also be used as a thickener in liquid and semi-liquids foods since the mixes has the ability to absorb water and swell for improved consistency in food.

The water and oil absorbing capacity is the ability of the flour mix protein to absorb and retain water / oil, which in turn influences the texture and mouth feel of food products like ground meat formulations, doughnuts, pancakes, baked goods and soups. Mixes of maize and tilapia may therefore be of good use for this purpose.

Loosed and packed bulk density: The Loose Bulk and Packed Bulk Densities (LBD and PBD) of maize-tilapia flour mixes are presented in Table 2. Result show that LBD ranged from 0.4 (maize-tilapia mixes)-0.5 gmL^{-1} (MF) while the PBD ranged from 0.5 (M:UF_1 and M:$FF_{3)}$- 0.6 g mL^{-1} (.M:$FF_{4,}$ M:$UF_{2,}$ MF). Tilapia incorporation had no significant effect on the bulk densities of the flour

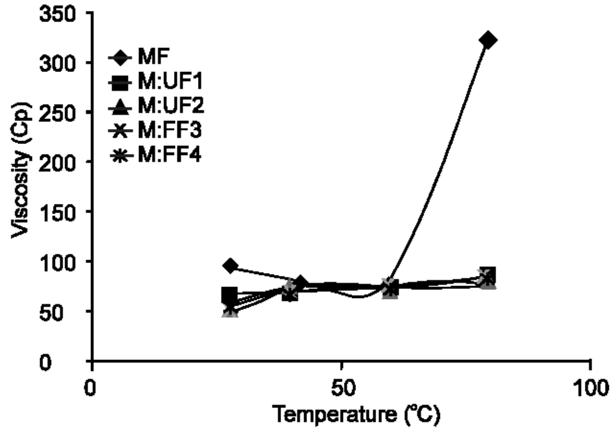

Fig. 3a: Effect of temperature on viscosity at 2% cold paste concentration.

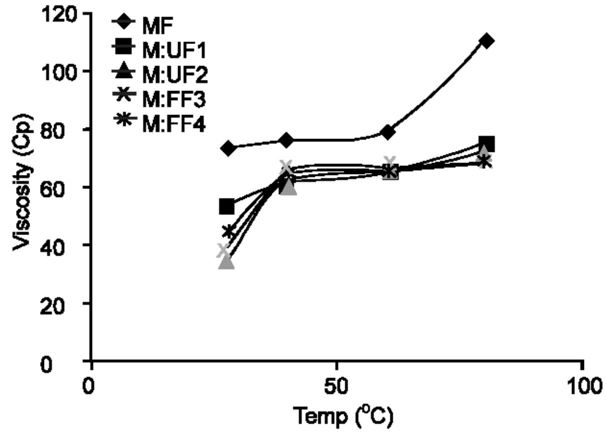

Fig. 3c: Effect of temperature on viscosity at 6% cold paste concentration.

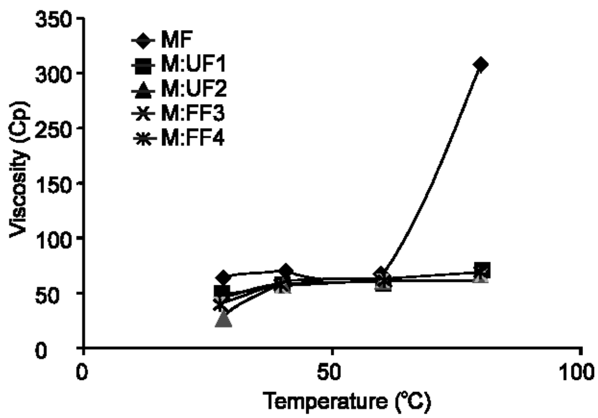

Fig. 3b: Effect of temperature on viscosity at 4% cold paste concentration.

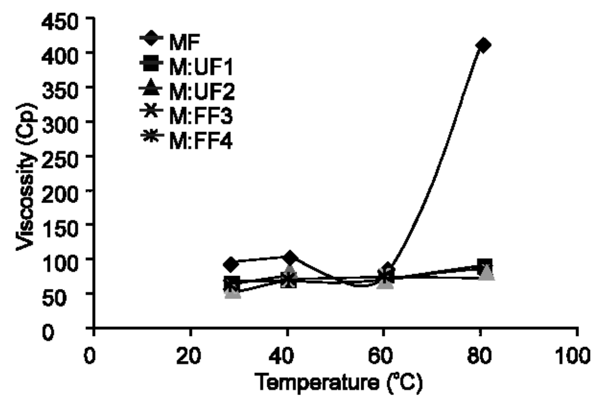

Fig. 3d: Effect of temperature on viscosity at 8% cold paste concentration.

mixes. However, Edema *et al.* (2005) reported a decrease in the bulk density of maize with increasing soy supplementation. This may be due to variation in the nature of protein sources and supplementation level. Supplementation level is between 9.71-13.79% in the mixes studied in this work and 20% soybean in the reports of Edema *et al.* (2005). The difference between the loose and packed bulk densities of flour mixes range between 20% and 40%. High PBD as reported is important in view of the packaging advantages it offers to flour products (Bencini, 1986) The packed bulk densities of maize-tilapia mixes are lower compared to 0.80-0.82 gmL^{-1} for durum wheat blends (Amarjeet *et al.*, 1993) thereby making the mix suitable for use in the formulation of high nutrient-dense weaning food.

Least gelation concentration: The LGC of maize-tilapia flour mixes are presented in Table 2. The values ranged between 4% (M:FF_4) -8% (M:UF_1), while the MF has an LGC of 10%. The results indicate that the addition of tilapia flour to fermented maize flour improved its gelling ability. The LGC of the maize-tilapia flour mixes is less than values reported for lupin, pigeon pea and cowpea flours: 14,12 and 16% respectively (Sathe and Salunkhe, 1981; Oshodi and Ekperigin 1989; Abbey and Ibeh 1988). Gelling ability is a function of the ability of the flour to absorb water and swell. A relationship therefore exists between WAC and LGC; and by extension protein content. The variations in LGC could be attributed to the relative ratios of different constituent proteins, carbohydrates and lipids in the flour samples. Sathe,Desphande *et al.* (1982) reported that interactions between protein, carbohydrate and lipid play a significant role in the functional properties.

Maize-tilapia flour blends, especially M:FF_4, with the least LGC, may serve as a good binder and provide consistency in food preparations such as semi-solid beverages like Kunun zaki (Adeyemi and Umar, 1994).

Effect of temperature on solubility and swelling power: The effect of temperature on the solubility of the maize-tilapia flour mixes is shown in Fig. 1. The solubility of the

Table 4: Visco-elastic properties (RVU) of the maize-tilapia flour mixes

	MF	M:UF_1	M:UF_2	M:FF_3	M:FF_4
Peak 1 (Peak viscosity)	300	266.75	266.25	253.83	270.33
Trough 1	97.74	94.58	83	79.42	89.42
Breakdown	120	166.33	179.83	173.17	175.42
Final viscosity	250	135	123.25	87.33	134.67
Set back	55.20	40.92	40.25	47.92	45.25
Peak time	4.05	3.85	3.88	3.94	3.84
pasting temperature	57.35	64.7	64.25	64.85	64.85

maize-tilapia mixes increased with increase in temperature. The relationships between solubility (Y), swelling power (Y_1) and temperature (X) can be fully described using regression equations in Table 4. High R^2 values obtained for quadratic models suggest that they would be better for describing the observed relationship. Thus it becomes easier to predict the solubility and swelling power of maize-tilapia mixes over wider temperature range. According to Schoch and Maywald (1968) the degree of swelling and amount of soluble components depends on the type and species of starch in the flour samples. This implies that high temperature weakens the starch granules of flour leading to improved solubility; the incorporation or addition of tilapia flour to fermented maize (MF) increased the solubility of maize-tilapia flour compared to MF.

The effect of temperature on the swelling power of the maize-tilapia flour mixes is shown in Fig. 2. The swelling power of the maize-tilapia flour mixes increased with increase in temperature.

Adebowale *et al.* (2005) reported similar increase in swelling power with corresponding in temperature for red sorghum flour. Significant increase in swelling power was observed between 60°C and 90°C, similar to the observation of Hoover and Sosulski (1991) in some legume starches. This implies that 60°C might be the gelatinization temperature of maize-tilapia flour mixes.

Effect of temperature on viscosity: The effects of temperature variation on the viscosity of maize-tilapia flour mixes, at different concentrations are shown on Fig. 3a, b, c and d, at different concentrations. The viscosity of maize-tilapia mixes increased as temperature increased, thereby showing temperature dependence on viscosity. Factors that affect the viscosity of material or solution include: concentration, shear rate, type of solute (polymer vs low molecular weight solutes), solvent type, ionic strength, type of instrument and instrument setting. At 28°C and 2% flour concentration, the viscosity of the products ranged from 34.36 centipoise (Cp) in M: UF_2 (maize-unfermented tilapia) to 63.84 Cp in M: UF_1 (maize–unfermented tilapia) flour while the viscosity of MF range from 73.66 Cp at 2% flour concentration to 93.29 Cp at 8% flour concentration. At 80°C and 2% flour concentration, the viscosity of the products ranged from 67.5 Cp (M: FF_4) to 85.8 Cp (M: UF_1) while the viscosity of MF at the same temperature range from 110 Cp at 2% flour concentration to 412.5 Cp at 8% flour concentration. This trend was the same in all temperatures (28°, 40°, 60° and 80°) showing an increase in viscosity with corresponding increase in temperature The low viscosity recorded in M: UF and M: FF samples is nutritionally beneficial in infant nutrition, similar low viscosity was reported in Ogi supplemented with 30% soy tempe flour Egounlety and Syarief (1992). The set back is an index of retrogradation (re-ordering of the starch molecules), it ranges from 40.25-47.92 RVU, in fortified samples. Maize-tilapia flour mixes with low set back viscosity values will eliminate the need for dilution before feeding . As the mixture is cooled, re-association between starch molecules occurs resulting in the formation of gel micellar regions and increase in index of retrogradation, making entrapped water more prone to expression (syneresis). The retrogradation in the maize-tilapia flours may be advantageous nutritionally since it enhances the production of nutrient-dense product that may not require the addition of water during child infant feeding. The pasting temperature provides an indication of the minimum temperature required for cooking the various mixes, this have implication on the stability of other components in the mixes and also indicate energy costs.

Conclusion: This study has shown that, the functional properties of fermented maize flour can be enhanced through fish (fermented and unfermented) supplementation .The maize-tilapia flour mix could be of value in optimizing the utilization of Nile tilapia in developing countries where excesses are found and discarded. The maize-tilapia flour mixes developed may be used as cereal gruel in breakfast food by vulnerable groups , it could also be incorporated effectively in to food systems.

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