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EFFECT OF PRE-TREATMENT AND DRYING TEMPERATURE ON MINERAL COMPOSITION, MICROBIAL ANALYSES, SENSORY SCORES AND LIPID STABILITY OF DRIED TILAPIA FISH (*OREOCHROMIS NILOTICUS*)

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ABSTRACT

This research work was carried out to evaluate the effect of preliminary processing and drying temperature on the mineral, microbial, sensory property and lipid stability of dried Tilipia fish *Oreochromis niloticus*). Two hundred and fifty (250) grammes of Tilapia fish samples were descaled, eviscerated and cleaned before application of different treatments (control, blanching, salting, sugaring and a mixture of salt and sugar), and coded as FWT, FBL, FST, FSU and FSS. The samples were dried at varying temperatures of 60^{o}C, 70^{o}C and 80^{o}C. This was done to study the rates of drying of the different samples. Thereafter, mineral, microbial, sensory, and lipid stability analyses were carried out using standard methods. The mineral content indicated that sample FSU had the highest values for magnesium (0.0246 ppm), sample FST had highest value for sodium (2.6110 ppm) while sample FSS had the highest (1.4010 ppm) calcium content. Microbial analysis of the fish samples during storage showed that sample FBL had the highest microbial counts. Results for sensory scored showed that Sample FSU and FSS had the highest values for colour, taste, aroma, mouth-feel and general acceptability while sample FWT was the least accepted. For sensory scores after storage, sample FST, FWT and FBL were most accepted. The values for peroxide values indicated sample FSS was the highest (3.04 meq/kg) while sample FST and

FSU (2.76 and 2.72 meq/kg) was the lowest. Highest values for TBA was recorded in sample FSS (0.98 mg/100g) and sample FSU (0.58 mg/100g) had the lowest values. The values for TMA indicated that sample FSS (18.20 mg/100g) had the highest values while sample FWT (10.50 mg/100g) had the least values.

KEYWORDS: Pre-treatment, drying temperature, mineral contents, microbial and sensory property.

1.0 INTRODUCTION

Fish are the most successful vertebrates in aquatic habitats and also make up more than half of all living vertebrates in the world. Fish species number roughly 28,000, of which about 1000 have cartilage (sharks, Skates and rays), 108 have no jaws (hagfishes, lampreys), and the remaining 26,000 are bony fishes. In almost every aquatic habitat, from high mountain streams to the abysmal and even hadal depths of the sea, fish can be found. They are very diverse in species than any other group of vertebrates (Helfman *et al*., 2009). Fish are an important source of food especially protein to humans and are considered sea-foods or marine foods. Fresh Fish is said to contain 70 -84 % water, 15-24 % protein, 0.1-22% fat and 1-2 % minerals and 0.1- 1% carbohydrate (Bereket *et al.*, 2018). In Nigeria, the predominant fishes farmed are catfish and tilapia fish. Nigeria has the resources (12 million ha inland water and aquaculture) to produce 2.4 million metric tonnes of fish annually, however, the predicted demand is now greater than the supply of 1.4 million metric tonnes (Abba, 2007). Tilapia (*Oreochromis niloticus*) is a type of bony fish, covered in scales. It is primarily a freshwater fish that lives in shallow streams, ponds, rivers and lakes but are barely found in brackish water (Rathnayake *et al.*, 2021). Tilapia is low in fat and saturated fat, omega-3 fatty acids, calories, carbohydrates, and sodium however; it is a rich source of protein, phosphorus, potassium, selenium, niacin and vitamin B-12 (ARS, 2009). Tilapia possess three main species namely; Nile tilapia, Mozambique tilapia and blue tilapia. Tilapia, though scaly, is inexpensive and eaten in different forms in Nigeria. It can be boiled, fried, roasted, grilled, sautéed, baked and served with other side dishes (Sheeran, 2021). According to Ghaly *et al.* (2010), about 25 % of main agricultural and fishery products are lost annually due to chemical and microbiological degradation. Changes in physical traits including colour, odour, texture, eye colour, gill colour, softness of the muscle and so forth are frequently associated with spoilage (Prabjeet *et al.*, 2021). Freshly caught fish's shelf life is difficult to predict due to many factors including variances in species' tissue composition, the impact of the season

on composition, differences between freshwater and salt water fish, unhygienic handling and more (Norman and Joseph, 2006). Traditionally, fish has been preserved by sun drying, smoking, salting, smoke-drying, fermenting, grilling and frying. However, recent methods of preserving fish are by use of chemical preservatives (such as benzoate or sorbic acid) irradiation, refrigeration, freezing, freeze drying and canning (Norman and Joseph, 2006). New techniques have emerged to replace sun drying using equipment such as oven, drum dryers, solar dryers etc. to achieve effective and efficient drying and produce wholesome product fit for consumption. Drying or dehydration helps to reduce the amount of moisture available in the foods, thereby reducing water activity, concentrating nutrients and preventing microbial spoilage and increasing the shelf life (Sabina *et al.,* 2011). Fresh fish can be dried to a moisture level of 25 %, which will inhibit bacterial development and lessen autolytic activity. Water activity in fishes, can be regulated by drying, chemical treatment or a combination of the two. To bind the free water molecules and produce an osmotic imbalance that inhibits cell growth, scientists have utilized sugars and sodium chloride (Ray, 2004). This technique has been extensively investigated as a practical way to enhance the economics of the dehydration process and is excellent for partially removing water from foods (Minh *et al*., 2013). The use of sugars, sodium chloride and other acids to lower water activity in fish (foods) has been reported in many studies. In depth research on the autolytic activity of endogenous proteinases in Indian anchovy was reported by Siringan *et al.* (2006). They discovered a 48 % reduction in autolytic activity when 25 % (w/w) sodium chloride (NaCl) was added. Sen (2005) proposed blanching shrimp for five minutes at 80 °C in a 10 % solution of sodium chloride inactivated the autolytic enzyme. Jasmina *et al.* (2014) also reported using three osmotic solutions to reduce water activity of fish (*Crassus gibelio)*, R_1: sugar beet molasses, R_2: NaCl + sucrose, R_3: (NaCl + sucrose+ sugar beet molasses). Fresh fish tissue is more perishable than other animal tissues even under conditions of refrigeration and frozen storage as deterioration sets in as soon as fish is caught and removed from water and these results to loss of quality. Drying of fish is one of the methods most commonly used in preserving fish. In Nigeria, dried fish are faced with the problems of insect infestation, microbial proliferation, loss in quality and lower shelf life during storage. This could be due to inefficient drying, making moisture available for chemical interactions and microbial proliferation. Drying temperature/time regime for efficient enhancement of fish quality and shelf life has been studied, but the effect of pre-treatments on these conditions (temperature and time) has not been well studied. Therefore, there is need to investigate the effect of pre-treatment and drying temperatures on the quality, drying rate and shelf life of tilapia fish.

Fish is an important source of protein in the human diet. It provides essential nutrients required for health. Tilapia contains phosphorus, potassium, selenium, niacin, and vitamin B-12, required for various functions. This research work if successful will provide information on the best pre-treatment method among brining, blanching and sugaring to be used to achieve efficient drying and also increase shelf life of stored fish and also reduce post-harvest losses. It will also help to produce a hygienic product as salt and blanching has been reported to have tendency of reducing microbial load on fish samples, helps in increasing drying rates, reduce water activity, serves as a preservative and also improve texture and flavour of the dried fish.

1.1 Broad Objective

The broad objective of this study was to evaluate the effect of pre-treatment and drying temperature on mineral, microbial, sensory property and lipid stability of dried Tilapia fish (*Oreochromis niloticus)*

2.0 MATERIALS AND METHODS

2.1 Sources of Raw Materials

Two hundred and fifty (250) grammes of Tilapia Fish were purchased from the Federal University Dutsin-Ma Fish Farm in Katsina State. Table Salt and table sugar were purchased from a local market in Dutsin-Ma Local Government of Katsina State and taken to the Department of Food Science and Technology Laboratory for processing and further analysis.

2.1.1 Sample Preparation

The fish samples were descaled, eviscerated, carefully washed and weighed before pre-treatment. The brine solution was prepared by mixing 15g of salt into 1litre of water while the solution of salt and sugar was prepared by mixing in 10 g of salt and 10 g of sugar into 1litre of water. For blanching, the water was boiled to 100 °C.

2.1.3 Application of Pre-Treatment

The fish samples was pre-treated by dipping the fish samples into the brine solution for 15 minutes then removed and placed on gauze, for 30 minutes to allow removal of surface water before drying in an oven, it was dipped into the prepared solution of salt and sugar for 15 minutes then placed in gauze to drain the surface water, poured boiled water over the fish to blanch and then placed on gauze to allow removal of surface water before drying and submerged into the prepared sugar solution for 15 minutes and was drained to remove surface water**.** For the control sample it was placed on gauze without pre-treatment to drain the

surface water before placing in an oven for drying.

2.14 Drying Procedure of the Tilapia Fish

The oven was preheated to the desired temperature of 60 °C, 70 °C and 80 °C before placing the fish samples to be dried. The samples were weighed at interval until constant moisture content is achieved. The moisture content of the samples at interval was calculated using the standard drying formula;

$M.C(\text{d.b}) = \frac{\text{Mi}-\text{Mf}}{\text{Mf}}$ ..... (i) While the drying rate was calculated using the formula;

$$R = \frac{dM}{dt} = \frac{Mi - Mf}{t} = -\frac{M}{A}\frac{dM}{dt} \quad \text{.....(ii)}$$

where: M.C= moisture content, Mi. = initial moisture content Mf = final moisture content T = time, R = drying rate

dM = change in moisture content dt = change in time. $\frac{M}{A}$= constant.

2.1.5 Storage Period

After drying, the quality parameters of the Tilapia fish samples was analysed and packaged in paper boards. The samples were stored at ambient temperature in the food science laboratory for 6 months and examined monthly for microbial infection.

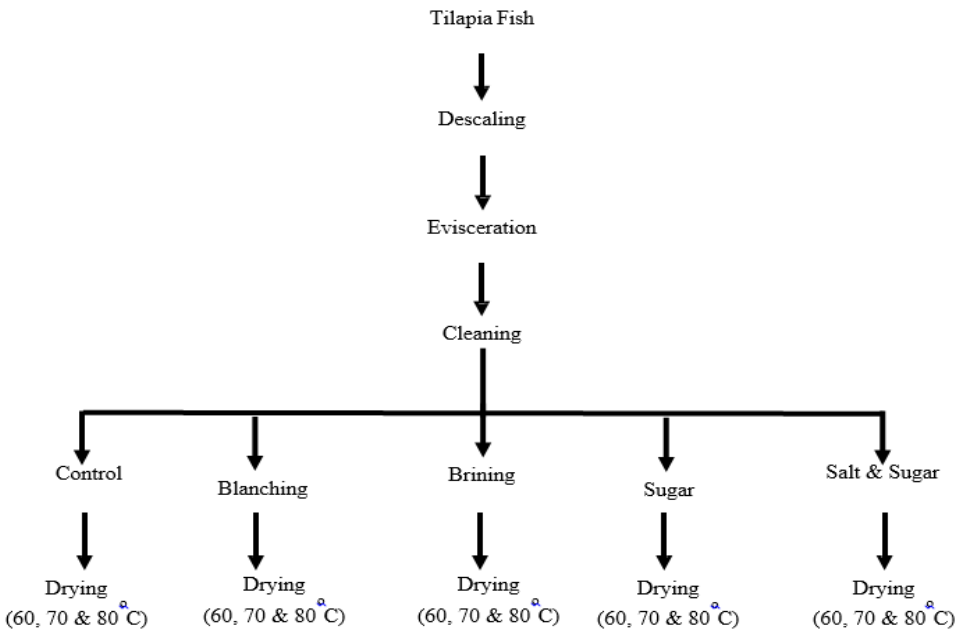

Figure 1: Flow Chart for Tilapia Processing.

Source: Ndife *et al.*
(2018) modified

2.2 Analyses

2.2.1 Mineral Analysis of the Tilapia Fish

Fish samples were analysed for calcium, magnesium and sodium using the method of AOAC (2012). The sample was weighed in a crucible (10 g) and then placed in a muffle furnace for ashing at a temperature of 500 °C for 2 hours. To the ashed sample, 10 ml of 6 M Nitric acid (HNO_3) was added and agitated until a uniform solution was obtained. This was filtered and distilled water (10 ml) added. The elemental contents of the digest were determined using Atomic Absorption Spectrophotometer (AAS) for Calcium, Sodium and Magnesium.

2.2.2 Determination of Calcium (Ca). Five millilitres (5) of the digested sample previously prepared in 3.7 was pipetted into a test tube in triplicate. Then 5 ml of calcium working reagent was added, the absorbance was read at 512 nm against the blank.

2.2.3 Determination of Magnesium (Mg): Five (5) millilitres of the digested sample previously prepared in 3.7 was pipetted into a test tube in triplicate. Then 1 ml of 0.67 N sulphuric acids (H_2SO_4) was added and 1ml of 0.05 % titan yellow was also added. Then 1ml of 0.01 % gum acacia and 2 ml of 10% sodium hydroxide (NaOH) was included. The solution is mixed and absorbance read at 520 nm using AAS.

2.2.4 Determination of Sodium (Na): Five (5) millilitres of the digested sample previously prepared in 3.7 was measured into a test tube in triplicate of which 5 ml of ammonia is added. Metals were extracted from this mixture by adding consecutively 5 ml portions of ditizone extraction solution 1 until ditizone becomes green. Time per extraction is 1 minute and after each addition of the solution, the upper part was transferred into another dry test tube. After the extraction, the supernatant is separated from the residue and discarded while the residue was allowed to settle and centrifuged for 15 minutes. The absorbance was taken at 520 nm against the blank.

2.3 Microbial Analysis of the processed Tilapia Fish

This was carried out on the fish samples after drying and during the periods of storage for the first five (5) months. Microbial analysis was carried out as total bacterial and total fungi counts determined using the method described by APHA (1976) and Difco- Manual (1984).

2.3.1 Total Bacterial Count: All glass wares to be used were sterilized. The agar (the media nutrient agar) was prepared by weighing seven (7) grammes and was dissolved in 250 ml of

distilled water; it was then sterilized and was allowed to cool to 45 °C. The serial dilution of the five fish samples was carried out by pipetting 1ml of each of sample to already measured 9ml distilled water into the test tubes labelled as 10^1 to 10^5 and was covered with non-absorbent cotton wool to avoid contamination. One (1) millilitre each from 10^1 and10^5 serial dilution was aseptically transferred into a sterile Petri dish. The plate was covered immediately after transferring the sample. Twenty (20) millilitres of the cooled nutrient agar was poured into the Petri dish and rotated gently for thorough distribution of the inocula through out of the medium and it was allowed to solidify, the plate was inverted and incubated at 30 °C for 48 hours.

2.3.2 Total Fungal Count: Total Fungal Count (TFC) was enumerated using potato dextrose agar. Ten (10) grammes of fish samples was weighed aseptically and homogenised with 9.0 ml of physiological saline solution. Appropriate dilutions were made from the 9.0 ml physiological saline and plated onto Potato dextrose agar plate containing antibiotics or tartaric acid solution. The plates were incubated at room temperature for four days and all colonies counted and the data collected was reported as Colony Forming Units CFU/gG1.

2.4 Sensory Scores of the tilapia fish

Sensory evaluation was carried out using a 30 untrained panelists made up of staff and students of the Department of Food Science and Technology, Federal University, Dutsin-Ma, Katsina State as described by Ochelle et al. (2025) to assess the sensory property.

2.4 Lipid Stability of the Stored Tilapia Fish

Determination of free fatty acids, peroxide value test, thiobarbituric acid test and trimethylamine test (TMA) were carried out to test the level of rancidity in the stored fish samples. This was done using the method as described by Onwuka (2018).

2.4.1 Determination of Acid Value/ Free Fatty Acids (FFA)

Twenty-five millilitres (25) of diethyl ether was mixed with 25 ml ethanol, 1 ml of phenolphthalein solution (1 %) and neutralised with 0.1 M sodium hydroxide. Five (5) grammes of the oil from the fish was dissolved in the mixed neutral solvent and titrated with aqueous 0.1M sodium hydroxide shaking constantly until a pink colour which persisted for 15 second is obtained. Acid value = titration (ml)/weight of sample used x 5.61. The FFA value was calculated as oleic acid, where 1ml of 0.1 M sodium hydroxide = 0.0282 g of oleic acid, in which case the acid value = 2 x FFA.

2.4.2 Peroxide Value

A 100 ml of round bottomed flask with a ground glass joint was attached to a plain reflux tube, long 9 mm internal diameter the upper 15 cm of which was cooled by a water jacket. 10

ml of chloroform and 10 ml of glacial acetic acid was added to the flask and, using a micro gas flame close to the flask, the mixture was boiled to top of the tube where it condenses by the water jacket. One gram (1) of potassium iodide dissolved in 1.3 ml was poured slowly down the condenser when the mixture was boiling steadily so that the refluxing was not interrupted; 0.3 ml water was added to dissolve any precipitated iodide. One (1) gram of the fish oil was added down the condenser without interrupting the refluxing and condenser water was turned off so that the entire sample is washed into the flask. The mixture was boiled for more 4 minutes; the flask then removed, and cooled rapidly. Fifty (50) millilitres of water was added and the liberated iodine titrated against 0.01M sodium thiosulphate.

2.4.1 Thiobarbituric Acid (TBA) Value

Ten grammes (10) of fish was macerated with 50 ml of water for 2 minutes and washed into a distillation flask with 47.5 ml water. Then 2.5 ml of 4 M hydrochloric acid was added to bring the pH to 1.5 followed by an anti-foaming preparation and a few glass beads. The flask was heated by means of an electric mantle so that 50 ml distillate was collected in 10 minutes from the time boiling commenced. Five (5) millilitres of distillate was pipetted into a glass stoppered tube; 5 ml of TBA reagent (0.2883 g/100 ml of 90 % glacial acetic acid) will be added stoppered, shaken and heated in boiling water for 35 minutes. A blank was prepared similarly using 5 ml of water.

2.4.2 Trimethylamine (TMA) value

One (1) gram of the sample was weighed into a conical flask containing four (4) grammes magnesium oxide and 24 ml distilled water. The flask was connected to a distillation unit and steam distilled into a flask containing 2 % boric acid into which 2 drops of methyl red indicator was added. The distillate was titrated against 0.1N H_2SO_4 and the TMA was calculated as follows:

TMA mg/100g = Volume of acid used x 14

2.5 Statistical Analysis

Tilapia fish products were analysed in triplicates. All the data obtained were subjected to one way analysis of variance (ANOVA) at 5 % level of significance using SPSS (Statistical Package for the social sciences) version 20.0 and the results presented as mean ± standard deviation. Duncan Multiple Range Test was used to compare the means.

3.0 RESULTS AND DISCUSSION

3.1 Effect of Pre-treatments on the Mineral Composition of Dried Tilapia Fish

The mineral content of tilapia fish samples presented in Table 1 shows the values for magnesium, calcium and sodium. The values for magnesium ranged from 0.0192 to 0.0246 Mg/Kg. Low values for magnesium were observed in sample FWT (the control sample) when compared to the pre-treated samples. This could be attributed to the pre- treatment used which include salting and sugaring. This observation is in line with Chien-Te et al. (2014) who reported that animal that fed on high salt diet had increased magnesium, calcium and sodium excretion. Magnesium helps in regulating muscle and nerve function, blood sugar level and blood pressure while sodium (contained in table salt) helps in nerves and muscle functions and in maintaining balance of body fluids. The values for calcium were significantly different ($p < 0.05$) as the values ranged from 1.0900 to 1.4010 Mg/Kg. Samples FSS (sugared + salted samples) and FST (salted sample) had high calcium content this could be due to the pre-treatment used. Calcium is stored in bones and teeth and helps to release hormones. The values for sodium content ranged from1.8830 to 2.6110 Mg/Kg as the samples differs significantly ($p < 0.05$). The sodium content of the salted Tilapia fish samples (FST) was higher than other samples; this could be due to the salt added during the pre-treatment as sodium is a component of common salt (sodium chloride). This observation is in line with that reported by Nursyah *et al.* (2022) that salt added to fish during drying process, contributes to the sodium content and minerals found in the fish fish in concentrations up to 40%. Minerals are vital to the body and are those elements on the earth and in foods that our bodies need to develop and function normally. According to Nursyah *et al.* (2022), different minerals were found in dried fish but at varying quantities depending on the fish type. Paul *et al*. (2018) also proposed that the discrepancies in the mineral content of fish is linked to and depends on its location, species, and pre-treatment given to the fish. It may also depend on the availability of the mineral in their environment, followed by the diet absorptive proficiency and preferential accumulation of minerals by the fish (Rasul *et al.*, 2021).

Table 1: Mineral composition of the pre-treated dried tilapia fish.

SAMPLE	Mg (Mg/Kg)	Ca (Mg/Kg)	Na (Mg/Kg)
FWT	0.0192 ± 0.0003^{c}	1.1240 ± 0.0003^{c}	2.2810 ± 0.0003^{c}
FBL	0.0241 ± 0.0006^{a}	1.0900 ± 0.0001^{d}	2.1640 ± 0.0001^{d}
FST	0.0233 ± 0.0005^{a}	1.2620 ± 0.2992^{b}	2.6110 ± 0.2992^{a}
FSU	0.0246 ± 0.0009^{a}	1.1130 ± 0.0042^{c}	2.4020 ± 0.0042^{b}
FSS	0.0200 ± 0.0040^{b}	1.4010 ± 0.0007^{a}	1.8830 ± 0.0007^{e}

Values are expressed as means ±SD of three different determinations. Means with different superscripts in the same column indicate significant differences (P< 0.05).

Key: FWT =Fish without treatment (control) FBL=Fish Blanched, FST= Fish Salted FSU= Fish Sugared, FSS= Fish sugared+ salted

3.2 Microbial Analysis of the Dried Tilapia Fish During Storage

The result of microbial examination from Figure 2 indicates the values of total bacterial count carried out immediately after drying, the values ranged from 2.0 to 7.0 cfu/g in the first serial dilution (10^1) with sample FWT (the control) having the lowest value (2.0 cfu/g) while sample FST (salted sample) had the highest values (7.0×10^1 cfu/g) than other samples. The high bacterial load seen in sample FST (salted sample) could be attributed to residual moisture from the samples which might have caused the increase in bacterial number and also the presence of halophilic bacteria since sample FST was treated with salt. Similar report was given by Mustafa (2019), that halophilic bacteria were isolated and identified in the salted fish (*Hout-kasef*) samples. According to CIFT (2020), halophilic bacteria present in fish can be associated to the presence of salt and thrive best at 36 °C. As the storage proceeds there was an increase in the bacterial count which later decreased as shown in Figure 3 and Figure 4. This decrease may be due to low moisture content during storage as there was continuous moisture loss from the product. According to Holley and Patel (2005), deteriorative activities of enzymes, yeast and bacteria are arrested at low moisture levels (less 10 %). Many factors are responsible for increased bacteria load in fish this includes; initial bacterial load, contaminated water, ingested contaminated feed, handling during processing (Novoslavskij *et al.*, 2016). The result for Fungal count, carried out immediately after drying, showed that there was also a high fungal count in sample FST (salted sample) (51×10^1 cfu/g), this followed thesame pattern as the bacterial count. The moisture content of samples FST (51×10^1 cfu/g) and sample FWT (10×10^5 cfu/g) (control) could have been responsible for the high fungal growth. According to CIFT (2020), Fungus also grows well on salted and unsalted dried fish which usually have high moisture content and moulds grow at relative humidity above 75 %. The increase in the fungal count could be caused by halophilic mould *Sporendonema epizoum*, whose optimum temperature for growth is 30 – 35ºC (CIFT, 2020). However, there was no visible mould growth on the samples during the storage period and also after the storage period which lasted for 6 months. This could also be attributed to the moisture loss during the storage period. This support the report by Ezeama (2007) that the susceptibility of a product to undergo microbial spoilage depends on the moisture contents

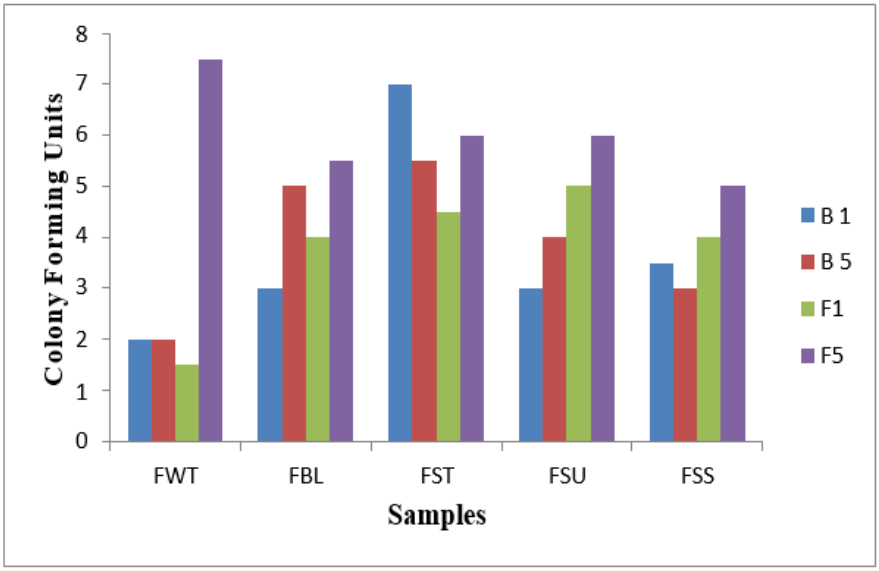

Figure 2: Microbial evaluation of dried pre-treated tilapia fish before storage.

Key: FWT =Fish without treatment (control) FBL=Fish Blanched, FST= Fish Salted FSU= Fish Sugared, FSS= Fish sugared+ salted, B1 = first bacterial serial dilution ($\times 10^1$), B5 = fifth bacterial serial dilution ($\times 10^5$), F1 = first fungal serial dilution ($\times 10^1$) F5= fifth fungal serial dilution ($\times 10^5$)

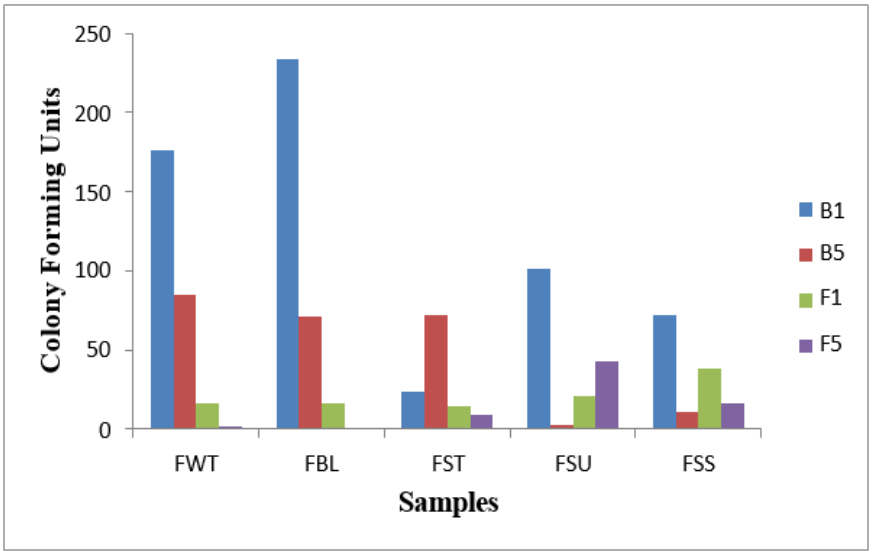

Figure 3: Microbial Evaluation of dried pre-treated tilapia fish after 1 month of storage.

Key: FWT =Fish without treatment (control) FBL=Fish Blanched, FST= Fish Salted FSU= Fish Sugared, FSS= Fish sugared+ salted, B1 = first bacterial serial dilution ($\times 10^1$), B5 = fifth bacterial serial dilution ($\times 10^5$), F1 = first fungal serial dilution ($\times 10^1$) F5= fifth fungal serial dilution ($\times 10^5$)

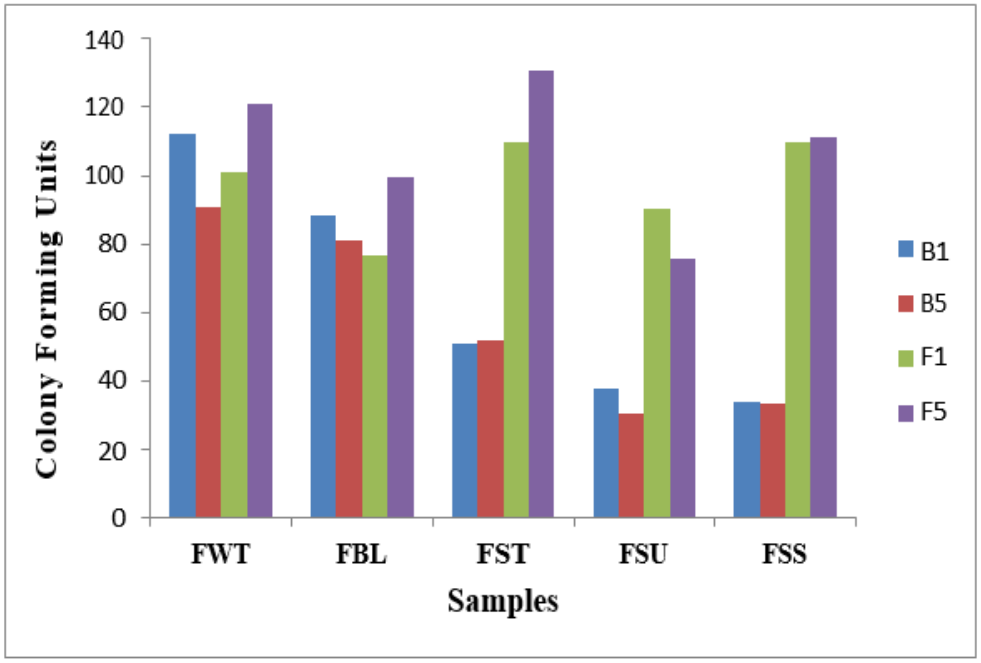

Figure 4: Microbial Evaluation of dried pre-treated tilapia fish after 2 months of storage.

Key: FWT =Fish without treatment (control) FBL=Fish Blanched, FST= Fish Salted FSU= Fish Sugared, FSS= Fish sugared+ salted, B1 = first bacterial serial dilution ($\times 10^1$), B5 = fifth bacterial serial dilution ($\times 10^5$), F1 = first fungal serial dilution ($\times 10^1$) F5= fifth fungal serial dilution ($\times 10^5$)

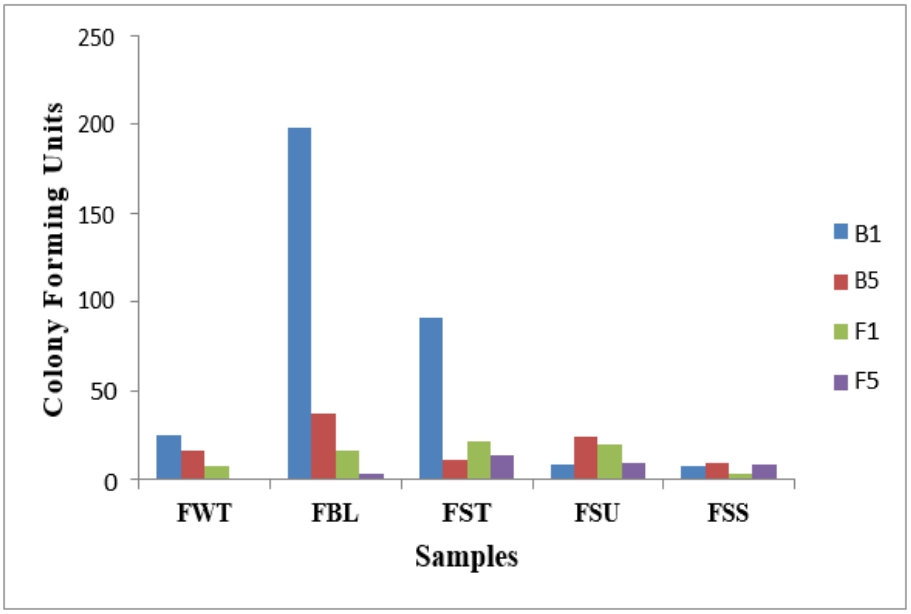

Figure 5: Microbial Evaluation of dried pre-treated tilapia fish after 3 months of storage.

Key: FWT =Fish without treatment (control) FBL=Fish Blanched, FST= Fish Salted FSU= Fish Sugared, FSS= Fish sugared+ salted, B1 = first bacterial serial dilution ($\times 10^1$), B5 = fifth bacterial serial dilution ($\times 10^5$), F1 = first fungal serial dilution ($\times 10^5$) F5= fifth fungal serial dilution ($\times 10^5$)

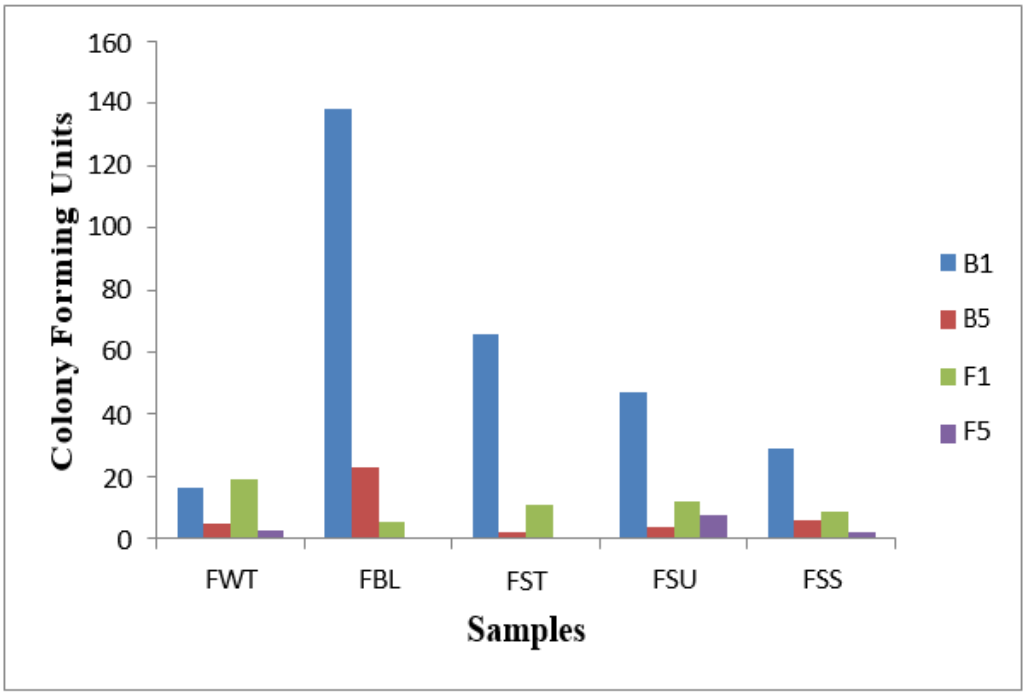

Figure 6: Microbial Evaluation of Dried Pre-Treated Tilapia Fish after 4 Months of Storage.

Key: FWT =Fish without treatment (control) FBL=Fish Blanched, FST= Fish Salted FSU= Fish Sugared, FSS= Fish sugared+ salted, B1 = first bacterial serial dilution ($\times 10^1$) B5 = fifth bacterial serial dilution ($\times 10^5$), F1 = first fungal serial dilution ($\times 10^1$) F5= fifth fungal serial dilution ($\times 10^5$)

3.3 Effect of Pre-treatments on the Sensory Properties of the Dried Tilapia Fish

Sensory Properties of Pre-treated Dried Tilapia Fish are presented in Table 2. Sensory evaluation is a science that measures, analyses and interprets the reactions of people to products as perceived by the sense organ (Danielle *et al.,* 2013; Fatemeh *et al.,* 2019). It gives the perception of people towards a particular food. The values for the sensory analysis in Table 4.3 showed that the colour of the sample varies from 6.30 to 7.75%, with sample FWT (the control sample) having the lowest value (6.30 %) while sample FSS (sugared + salted sample) had the highest value (7.75%). This shows that the colour of the pre-treated samples was preferred to that of the control. This may be attributed to the temperature and pre-

treatment used, as sugar caused the browning of the samples due to a caramelisation reaction, producing a product that is slightly brown and appealing to the eyes. According to Prasad (2019), caramelisation reaction involves the oxidation of carbohydrate or sugar, leading to the formation of brown pigments in foods heated at high temperature. The preference for Sample FBL (blanched samples) could be due to the blanching treatment it received, which retained the colour of the fish. Onwuka (2014) reported that food colour is a quality indicator of the appearance of foods and also helps to determine the degree of processing and is a pointer to the spoilage level. The values for the aroma of the dried tilapia fish ranged from 4.40 % to 7.60 %. The values for the pre-treated fish samples were significantly higher ($p < 0.05$) than those of the control sample (FWT). Sample FSU (sugared sample) and FSS (sugared + salted sample), which had no significant difference ($p < 0.05$), had the highest values for aroma. This could be attributed to the pre-treatment used. Sample FWT (control sample) was least preferred in its aroma; this may be because no pre-treatment was given, as certain enzymes weren't inactivated, or it may just be the panel's choice, since they were untrained panellists. The values for mouth-feel of the dried tilapia fish samples ranged from 3.80 to 7.50 %, showing a significant difference ($p < 0.05$) between the samples. Sample FSU (sugared sample) and sample FSS (sugared + salted sample) were highly preferred to other samples. This could be attributed to the low moisture content exhibited by the sample FSU (sugared sample) and FSS (sugared + salted sample), giving the sample a crisp texture. This is in accordance with the report by Ndife *et al.* (2019) that low moisture content of fish may lead to dryness and toughness, which might influence the texture of fish. The value for taste of the dried tilapia ranged from 3.95 to 8.10 %. The samples were significantly different ($p < 0.05$) from each other, and samples FSU (sugared sample) and FSS (sugared + salted sample) recorded high values. The preference for the taste of sample FSU and FSS could be because the pre-treatment used was sugaring and a combination of salt and sugar; however, the majority of the panellists were sweet-toothed and would prefer sweet foods. This report supports the report by FAO (2022) that variations among individuals in the response to the same level of stimuli can vary and can contribute to a non-conclusive answer to the test. For general acceptability, the values ranged from5.00 to 7.80 %, showing that all samples were accepted. Sample FSU (sugared samples) and FSS (sugared + salted samples) were still preferred, maybe because of their taste and colour. This proved that salt and sugar improved the acceptability of the dried tilapia fish sample. This was also suggested by Nursyah *et al*. (2022) that sugar beet molasses will be preferred if used in the pre-treatment of fish.

Table 2: Sensory Properties of Pre-treated Dried Tilapia Fish.

SAMPLE	Colour	Aroma	Mouth feel	Taste	General Acceptability
FWT	6.30 ±2.56 [b]	4.40±2.19[b]	3.80±2.55[c]	3.95±2.28[c]	5.00±2.20[c]
FBL	6.80 ±1.36[ab]	5.30±1.26[b]	5.6±2.23[b]	5.75±1.77[b]	6.35±1.27[b]
FST	7.00 ±0.97[ab]	5.35±1.35[b]	5.8±1.47[b]	6.25±1.52[b]	6.40±1.10[b]
FSU	7.70 ±1.59 [a]	7.60±1.60[a]	7.5±1.73[a]	8.10±1.33[a]	7.80±1.64[a]
FSS	7.75 ±0.85 [a]	7.10±1.37[a]	7.25±1.62[a]	7.65±0.88[a]	7.70±1.03[a]
LSD	0.087	0.077	0.688	0.333	0.835

Values are expressed as means ±SD of three different determinations. Means with different superscripts in the same column indicate significant differences (P< 0.05).

Key: FWT =Fish without treatment (control) FBL=Fish Blanched, FST= Fish Salted FSU= Fish Sugared, FSS= Fish sugared+ salt

3.3.1 Effect of Storage on Sensory Properties of Dried Pre-treated Tilapia Fish

The sensory results of the sensory properties of the pre-treated dried tilapia fish are shown in Table 3. The results showed that the fish samples were still accepted even after storage. This might be due to the fact that the fish had a lower moisture content, which gave the fish a crispy texture and the fact that people accept dried fish. All the colours were, however, accepted by the panellists. For the aroma, the values were higher in sample FST (salted sample) and lower in samples FBL (blanched sample) and FSU (sugared sample). Samples FSS (sugared + salted sample) and FWT (control sample) were, however, not significantly different ($p < 0.05$) from each other. Before storage, the sugared sample and the sample with a mixture of both salt and sugar were more preferred to others when compared, but after storage, the aroma of FST (salted samples), FWT (control sample) and FSS (sugared + salted sample) were more preferred. This preference can also be related to a reduction in moisture content from the samples, as these samples had lower moisture content when compared to other samples. For mouth feel, the sample FST (salted sample) was highly preferred, followed by sample FBL (blanched sample), FSS (sugared + salted sample) and FWT (control sample). When comparing the sensory properties before storage to that after storage, we can see that before storage, sample FSU (sugared sample) and FSS (sugared + salted sample) were most preferred but after storage, sample FST (salted sample) and FBL (blanched sample) were preferred after storage. Here, the preference shifted from FSU (sugared fish) and FSS (sugared + salted sample) to FST (salted sample) and FWT control sample, then later FBL (blanched sample). The preference could be because of moisture loss

in the dried fish, giving it a tough texture. This is in accordance with the report by Ndife *et al.* (2019) that low moisture content of fish may lead to dryness and toughness, which might influence the texture of fish. However, the taste values was also higher to the values of that obtained before storage, but then the preference changed from sample FSU (sugared samples) and FSS (sugared + salted sample) before storage to sample FST (salted sample) and FWT (control sample) after storage, this maybe because of the taste of salt evident in sample FST which was treated with salt. The sugar taste of the sample FSU (sugared sample), which was preferred before storage, has degraded, leaving a bland taste. Generally, sample FST (salted sample), FWT (control) and FBL (blanched sample) were more accepted than sample FSU (sugared sample) and FSS (sugared + salted sample). These values were in contrast to those before storage, which shows FSU (sugared sample) and FSS (sugared + salted sample) as more accepted. This shows that storage has an effect on the acceptability of dried tilapia fish, and the pre-treatment applied also contributes to the acceptability of the fish before and after storage. According to FAO (2022), variations among individuals in the response to the same level of stimuli can vary and can contribute to a non-conclusive answer to the test.

Table 3: Sensory Properties of Stored Dried Pre-treated Tilapia Fish.

Sample	Colour	Aroma	Mouth feel	Taste	General Acceptability
FWT	7.30 ±1.03^{ab}	7.20±0.69^{ab}	7.05±0.51^{b}	7.50±0.51^{ab}	7.75±-0.85^{ab}
FBL	7.90±1.12^{a}	6.90±0.96^{b}	7.20±0.77^{b}	7.05±1.09^{b}	7.20±0.83^{bc}
FST	7.75 ±0.91^{a}	7.75±0.44^{a}	7.80±0.62^{a}	8.05±0.60^{a}	7.95±0.51^{a}
FSU	6.95±1.10^{b}	6.70±1.86^{b}	6.70±1.49^{b}	6.95±1.23^{b}	6.85±1.81^{c}
FSS	7.50 ±0.88^{ab}	7.10±1.07^{ab}	7.10±1.62^{b}	7.25±1.45^{b}	6.80±1.11^{c}
LSD	0.090	0.085	0.051	0.099	0.121

Values are expressed as means ±SD of three different determinations. Means with different superscripts in the same column indicate significant differences (P< 0.05).

Hedonic scale 1-9 (where 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)

Key: FWT =Fish without treatment (control) FBL=Fish Blanched, FST= Fish Salted FSU= Fish Sugared, FSS= Fish sugared+ salted

3.4 Effect of Storage on the Lipid Stability of the Dried Pre-treated Tilapia Fish

Table 4 shows the result of the lipid stability of the stored dried pre-treated tilapia fish free fatty acid value, peroxide value, thiobarbituric acid test and trimethylamine values for all samples analysed. The values for free fatty acids ranged from 0.36 to 0.61 %. There was a significant difference ($p < 0.05$) between the samples. The values for free fatty acids were low. The low value for free fatty acids indicates that deterioration in the dried tilapia was minimal, and the fish was still edible. According to Sook (2020), oils are still good for consumption and show high quality if the free fatty acid value does not exceed 5%. The free fatty acid (FFA) is a tertiary product of rancidity. It is a measure of hydrolytic rancidity, the extent of lipid hydrolysis by lipase action. In most fish oils, rancidity is noticeable when the values for free fatty acid calculated as oleic acid are between 0.5 1.5 % (Daramola *et al*., 2007). The values for peroxide value, as shown in Table 4.5, ranged from 2.72 to 3.04 meq/kg. The samples were significantly different ($p < 0.05$) from each other, although sample FSS (sugared + salted sample) had the highest values of PV, followed by sample FWT (control sample), then FBL (blanched sample). The values of PV in this research are within the acceptable range for good-quality food. According to Kong and Singh (2011), to avoid rancidity, peroxide value should not be above 10-20 meq/Kg of lipids. The peroxide value (PV) is a measure of the level of hydroperoxides in the samples. The peroxide value at which oxidation is detected as an off-flavour varies with different samples (Gordon, 2004). The lipid oxidation of dried fish increased steadily over time and can be accelerated during storage, especially at ambient temperature (Nursyah *et al*., 2022). The values for thiobarbituric acid ranged from 0.58 to 0.98 mg/100g. The samples differ significantly ($p < 0.05$) from each other. The value for TBA in this work was within that given for good-quality fish. According to Kong and Singh (2011), a food will have a rancid flavour if its TBA values are above 1-2µmol MDA Eq per gram fat. The thiobarbituric acid test (TBA), which is also referred to as thiobarbituric acid reactive substance (TBARS), is used to quantify the secondary oxidation products. It measures the concentration of malondialdehyde (MDA), a secondary reaction product and a reactive aldehyde (Kong and Singh, 2011). The Trimethylamine (TMA) values of the fish samples ranged from 10.50 to 18.20 mg/100g. The values for TMA of the pre-treated samples were significantly higher ($p < 0.05$) than those of the control sample. Sample FSS (sugared + salted sample) (18.20 mg/100g) and sample FSU (sugared sample) (16.10 mg/100g) were higher than other samples. While sample FWT (control sample) (10.50 mg/100g), sample FBL (blanched sample) (13.30 mg/100g) and sample FST (salted sample) (15.20 mg/100g) were all still within the acceptable range of

TMA. According to Prakash *et al.* (2011), the acceptable level of TMA in fish, which is recommended for consumption, is 10- 15 mg/100g. The formation of TMA is related to many factors such as differences in species, bacterial growth, processing methods and storage conditions (RodríguezVaquero *et al.,* 2013). Trimethylamine (TMA) is used widely as indicators of the freshness of marine fish. TMA is the main cause of fishy odour, and this increases as storage time increases and is produced from trimethylamine oxide, an osmosis-regulating substance in fish cells that functions by reduction reaction. As bacteria grow in fish, TMA increases and so does spoilage (FAO, 2022). TMA has an advantage over the enumeration of bacterial numbers, as it can be performed more quickly and often reflects the degree of spoilage than bacterial counts. But its disadvantage is that it does not reflect the earlier stages of spoilage and is reliable for certain types of fish species (FAO, 2022).Table 3: Lipid Stability of Stored Dried Pre-treated Tilapia fish

Table 4: Effect of Storage on the Lipid Stability of the Dried Pre-treated Tilapia Fish.

Samples	FFA (%)	Peroxide value (meq/kg)	TBA mg/100g	TMA Value Mg/100g
FWT	0.56 ± 0.003^{b}	2.9 ± 0.028^{b}	0.88 ± 0.006^{b}	10.50 ± 0.99^{d}
FBL	0.54 ± 0.006^{b}	2.84 ± 0.000^{b}	0.72 ± 0.003^{c}	13.30 ± 0.99^{c}
FST	0.48 ± 0.012^{c}	2.76 ± 0.000^{c}	0.61 ± 0.005^{d}	$15.20\pm0.28b^{c}$
FSU	0.36 ± 0.008^{d}	2.72 ± 0.000^{c}	0.58 ± 0.001^{e}	16.10 ± 0.99^{b}
FSS	0.61 ± 0.011^{a}	3.04 ± 0.057^{a}	0.98 ± 0.005^{a}	18.20 ± 0.00^{a}
LSD	0.072	0.087	1.000	0.058

Values are expressed as means ±SD of three different determinations. Means with different superscripts in the same column indicate significant differences ($P< 0.05$).

Key: FWT =Fish without treatment (control) FBL=Fish Blanched, FST= Fish Salted FSU= Fish Sugared, FSS= Fish sugared+ salt

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

In this study, pretreatment and drying temperatures influenced the mineral composition of dried Oreochromis niloticus, with notable variations in calcium, magnesium, iron, and zinc among treatments. The drying process preserved essential minerals, which support the nutritional value of the dried fish product. The pre-treated fish was stored for six months or more without visible growth of moulds. Microbial analysis of the fish samples during storage showed that halophilic organisms are responsible for microbial contamination in salted dried fish. Changes in the organoleptic properties of fish occurred due to increasing free fatty

acids, TMA values and peroxide values in the fish. The use of sugaring and a mixture of sugaring and salting increased the acceptability of the products due to the taste of sugar in the fish. However, after storage, the sugar degraded, leaving a bland taste and also reducing the salt in the sample treated with salt + sugar. For the lipid stability, the free-fatty acid of the fish samples did not exceed 5%. The values for peroxide values of the stored tilapia fish samples were within the acceptable range for good-quality food. Likewise, the thiobarbituric acid values were within that given for good quality fish, while the TMA values indicated that only sample FWT, FBL and FST were within the acceptable range of TMA in fish.

4.2 RECOMMENDATION

Based on the findings from this study, it is recommended that; further studies be carried out to ascertain other pre-treatment methods to store fish, proper enlightenment be given to the small scale off shore fish processors on how to handle and process fish products to avoid contamination of the fish and the storage period should not exceed 3 months to maintain its nutrient and organoleptic properties.

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