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NUTRITIONAL ASSESSMENT OF SMOKED DRIED FISH PRE-TREATED WITH NATURAL SPICES

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***Abstract*—This study is examined the effect of using different pretreatment methods on the quality of smoke-dried sardine fish. The fish samples were pretreated using salt, and some natural spices (cloves, nutmeg and yaji) prior to smoke drying. The proximate composition, minerals, physicochemical properties and microbial analysis of the fish samples were analyzed using standard analytical methods and data obtained were analyzed using ANOVA and significance accepted for P< 0.05. Result of proximate analysis showed a moisture range of 10.46 -37.20%, ash 13.81-17.57%, fat 5.81-9.24%, protein 37-46.31% and carbohydrate 5.57-26.74%. Mineral compositions (mg/100g) were in the range of 2.00 – 2.11 Mg, 25.25-25.85Ca, 14.40-14.55 potassium, 10.29-10.72 Na and iron ranged from 1.59-1.71. Low pH and TBA values obtained are indication that rancidity will not occur during storage. Bacteria and fungi count were 2.0 x 108 and 2.4 x 108 CFU/g respectively. The fish treated with Yaji and Brine was mostly preferred in all the sensory attributes. However, all samples differed with respect to overall acceptability.**

***Keywords*—Kiln drying; antioxidant; organic; preservation**

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I. INTRODUCTION

Fish is an excellent source of animal protein due to its high nutritional value, good quality proteins which contains most of the essential amino acids and important minerals such as phosphorus, calcium and magnesium [1]. Fish are often prone to spoilage because of its high nutrient content value which supports the growth of pathogens. According to [2] proper handling and good storage facilities will enhance keeping quality of smoked fish in Africa. The impact of fish as a food product in developing countries (such as Nigeria) cannot be neglected; as it is one of the major sources of food and income to many people. Freshly harvested fish may have up to 80% moisture of the total weight; the proportion of other nutrients may vary from 15 - 25% for protein, and 1-2% mineral matter [2]. Small fishes which are often consumed together with its bones are cheap source of highly bioavailability calcium. The nutrient composition of fish species varies from one habitat to another, of which feed intake plays the major role in fish nutrient composition.

The broad objective of processing and preservation of fish is to reduce most of the biochemical processes (such as enzymatic, microbial and chemical reactions) that aids in fresh fish deterioration [3], which will its availability during season and off-season [4]. Consumers' acceptability of fish is greatly affected by lipids oxidation and microbial proliferation which reduces its nutritional qualities as well as impacting offensive odour on the product [5].

Some traditional processing and preservation methods (such as smoking, drying, salting, frying, fermentation and or combination of these) have been used in attempt to preserve and process fish and improve its shelf stability. Smoke-drying of fish is the most widely practice method of fish preservation in Nigeria, accounting for 70-80% of domestic marine and fresh water catch. Smoking prolongs shelf life, enhances flavor, reduces postharvest losses in fishes as well as improves protein availability [6]. In the

light of the aforementioned, the aim of this research was to evaluate some nutritional qualities of smoked fish pre-treated using local spices.

II. MATERIALS AND METHODS

A. Procurement of raw materials

Fish (sardine fish) for this work and other ingredients used were bought from Ndioru market in Umudike, Ikwuano LGA of Abia State Nigeria. Other materials and equipment used were obtained from Food Science and Technology Department, Michael Okpara University of Agriculture, Umudike Nigeria.

B. Sample preparation

The ingredients used for pretreatment comprised of local spices (cloves and African nutmeg) and other ingredients such salt, yaji (a local mixed spices) and water were formulated as shown in **Table 1.**

Fish preparation: Three hundred grams (300g) of raw sardine fish was weighed fish was thawed, filleted and eviscerated to remove all internal organs. The filleted fish was smoked- dried using a smoking kiln. Each of the ingredients was ground into powder. The brining process was carried using 50 g of salt to 500 ml of water. The raw fish was submerged into brine mixed with spice for about 20 minutes, after which it was removed and placed in a tray, then placed in a smoking kiln at a temperature of 60-80oC for 7 hours and was cooled, packed and labeled sample A. Another sample was pre-treated with 50 g of dry salt (Sample B), sample C was pre-treated using mixture of 100 g African nutmeg and 50 g dry salt, sample D was pre-treated using mixture of 100 g of clove and brine and sample E was pre-treated with yaji and brine. The finished products were allowed to cool at room temperature and weighed 50 g after drying.

TABLE I

INGREDIENT FORMULATION

Ingredients	Weights (g)
Curry powder	10
Defatted groundnut	200
Ginger	10
Dried pepper	30
Salt	50
Guinea pepper	10
African nutmeg	100
Clove	100

C. Determination of Proximate Composition

Proximate compositions (moisture, crude fiber, crude fat, crude protein and ash content) were determined using methods described by [7] while carbohydrate was calculated by difference.

D. Mineral Analysis

Calcium, Iron, Potassium, Magnesium, Sodium by Atomic Absorption Spectrophotometer according to method of [8]. About a gram of the sample was digested with 20 ml of acid mixture containing 650 ml of conc. HNO3; 80 ml Perchloric acid PCA 20 ml conc. H2SO4) and small quantity of the diluted clear digest was used for atomic absorption spectrophotometer using the filters that match the different elements.

Sample preparation

A gram of the sample was weighed into a digestion flask together with 20 ml of the acid mixture.The flask was heated until a clear digest was obtained. The digest was diluted with distilled water to the 500 ml mark. Appropriate dilutions were then made for each element.

For the determination of calcium and magnesium, enough SrCl2 solution containing 10,000 mg/ml was added to yield a 1,500 mg/ml of Sr2+ in the final solution.

For the determination of potassium and sodium, 91.0% w/v lithium chloride was added such that the final solution would be 1.0%. Calibration curves were prepared for each element using standard solution [8].

E. Determination of Physico-Chemical Compositions

Peroxide Value

Two grams (2.0g) of the oil was weighed into a clean dry flask and 22 ml of a mixture of 12 ml of chloroform and 10 ml of acetic acid was added. This was followed by the addition of 0.5 ml of potassium iodide. The flask was covered and allowed to stay with constant shaking for 1 minute. After which 30 ml of distilled water was then added and titrated against 0.1 M of sodium thiosulphate (Na2S2O3) solution until an initial yellow color disappeared and a faint blue color appeared. 0.5 ml of starch indicator was added quickly with continuous titration until there was a sudden disappearance of the blue color which signifies the end point. The peroxide value was obtained by the use of the following expression;

$$Peroxide\ Value\ (mERqH2O2/100g) = \frac{(S-B)\times M\times 1000}{W\times 100} \quad (1)$$

Where: S = sample titre value (cm), B = Blank titre value (cm), M = Molarity of Na2S203 solution (mEq/cm), 1000 = Conversion of unit (g/kg), W= Weight of oil sample

Thiobarbituric acid (TBA)

Thiobarbituric acid value was determined using the method reported by [7]. Ten grams of samples was macerated in 50 ml of distillation flask with 47.5 ml distilled water. About 2.5 ml of 4 M hydrochloric acid was added to bring the pH to 1.5. The flask was

heated until 50 ml distillate was collected from the time boiling commenced. Five milliliters of thiobarbituric acid reagent was added. It was shaken and heated in boiling water for 35 min. A blank was prepared using 5 ml of reagent. The tubes were cooled in water for 10 min and the absorbance was measured against the blank at 538 nm.

The TBA number was calculated as:

$$TBA = 7.8 \times D \quad (2)$$

Where: D = absorbance reading

PH Measurement

The pH of the food samples was measured with a pH meter (model: Mettler Delta 350) according to themethod described by [7]. The Sample was prepared by blending 10 g sample in 100 ml of deionized water. The mixture was filtered and the pH of the filtrate was measured with a pH meter in triplicate.

Microbial Analysis

The microbial analysis was determined using method described by [9]. Five grams of the sample was dissolved in 45 ml of distilled water.1ml of the sample suspension was diluted using a ten-fold serial dilution inoculating them on a nutrient agar, MacConkey agar and potato dextrose Agar respectively. The dilution used was 106. The organisms inoculated on nutrient agar were incubated for 24 hr. at 37oC. The plates were observed for growth after been incubated and were purified and the microbial load counted and calculated. The purified cultures were then transferred onto MacConkey agar (a selective media) and incubated for 24 hr at 37oC. The samples were equally plated on potato dextrose agar (PDA) for isolation of fungi. Thereafter the organisms (bacteria) were characterized biochemically while fungi isolated were characterized with the microscope and with reference to mycological manuals

$$\text{Microbial loads} = \frac{CFU}{Volume\ used}\ X \quad \text{dilution} \quad (3)$$

F. Sensory Analysis

Taste panel evaluation was carried out using 20 semi-trained panelists according [10]. These panelists are randomly allocated to the five treatments of the fish. The panelists are made to rate each of the 5 replicates of the meat product. Equal bite size samples from the five treatments was coded and served on a plate to each of the panelists. Each sample was evaluated independent of the other. The panelist rated the samples on a 9-point hedonic scale for flavor, and overall acceptability.

G. *Statstical Analysis*

Data generated from this work was subjected to analysis of variance (ANOVA) and results were presented as means ± standard deviation of duplicate determinations, while means were separated using Duncan multiple range test and significance was established for $p \leq 0.05$.

III. RESULTS AND DISCUSSION

A. Proximate Composition Of Smoked-Dried Fish

Table 2 shows percentage proximate composition result of smoked-dried.

Moisture content of the smoked-dried fish ranged between 10.46% (Sample B) to 37.20% (Sample A). There was significant ($p<0.05$) difference among the samples, however, samples C and D (Ehuru + Dry salt and Clove + brine treatments) were not significantly different ($p>0.05$) from each other. The reduction in moisture content of the pretreated smoked-dried fish is in agreement with the findings of [11] which stated that the use of salt together with either sun drying or smoking could significantly reduce moisture as well as spoilage of fish from the action of enzymes and bacteria. While high moisture content provides enabling environment for spoilage by microbes in fish [12]. The lower moisture content recorded in smoked-dried fish samples entails a longer shelf life of the fish. Moisture content is an important attribute in food processing and preservation because many biochemical and physiological changes depends very much on it [7].

Percentage ash content in smoked-dried fish was maximum (17.57%) in clove + brine treated smoked-dried fish (Sample D) while minimum value (14.50) was recorded in sample E. The higher ash value in the smoked-dried fish may be due to moisture loss during heat processing. [13] reported that smoking significantly increased ash in dagga fish. An increase in ash content by a combination of pretreatment methods involving smoking can also be attributed to protein denaturation due to a reduction in moisture and consequently loss of water holding capacity of the protein in the samples.

The fat content of the smoked-dried fish samples ranged between 5.81 to 9.24%. Highest fat content value (9.24%) was recorded in sample treated with Yaji and Brine, while lest value (5.81%) was recorded for the control sample. It has been reported that fat increases with heat processing and reduction in moisture content [14; 1; 12]. Result in this study was higher than the raw fish sample and in conformity to increasing fat content due to heat processing. However, fat levels reported in this study were lower than those reported for other processed fish species, [1] reported 28.0% while [14] reported 21.2% fat for Kiln dried Tilapia (Oreochromis niloticus) and cat fish (Clarias gariepinus) respectively. Fish species with more than 20% fat content are considered fatty. Increased fat in human diet provides and sustains energy in the body [16]. Fat is also important for normal functioning of the brain which is made up of nearly 60% fat [17].

The percentage protein content ranged between 37.61% (Control) to 46.31% (Sample E). There were significant ($p<0.05$) differences among the samples. High protein (49.5%) was reported for whole fish by [18]. High levels of protein in smoked-dried fish as recorded in this study have been reported [19; 20]. It is widely reported that smoke drying increases protein, attributing this to dehydration in the proteins resulting into its aggregation [21]. Protein levels reported in this study are nevertheless, relatively lower than those reported for other species such as Tilapia [22; 23]. The carbohydrate content of fish ranged from 5.57% (Control) to 26.74% (Sample B salting). There was significant different ($p<0.05$) in all the fish products.

TABLE II

PROXIMATE COMPOSITION OF SMOKED-DRIED FISH

SAMPLE	Moisture (%)	ASH (%)	Fat (%)	Protein (%)	CHO (%)
A	37.20b ± 0.28	13.81e ± 0.02	5.81e ± 0.02	37.61f ± 0.04	5.57e ± 0.04
B	10.46e ± 0.08	16.16c ± 0.01	6.38d ± 0.04	40.26e ± 0.01	26.74a ± 0.02
C	11.14d ± 0.02	17.21b ± 0.01	7.17c ± 0.02	42.21d ± 0.01	22.27b ± 0.03
D	11.38d ± 0.004	17.57a ± 0.02	8.13b ± 0.04	44.15c ± 0.07	18.77c ± 0.02
E	12.14c ± 00.2	14.50d ± 0.01	9.24a ± 0.02	46.31a ± 0.01	17.80d ± 0.03

Reported values are mean ± standard deviation of determination in duplicate. a-b means with different superscript in the column are significantly different ($p<0.05$). Key = A = Control, B = Dry Salting, C = Ehuru + Dry salt, D = Clove + Brine, E = Yaji + Brine

B. Mineral Composition Of Smoked-Dried Fish Samples

Table 3 shows the result of mineral composition of smoked-dried. From the result, magnesium content ranged from 2.00 mg/100g (Control) to 2.11 mg/100 g (Sample D from clove + brine). There were significant ($p<0.05$) differences in the Mg+ content of the smoke-dried fishes. [24] reported higher values for dried fishes. Calcium content was observed to be highest in sample B (fish pre-treated by dry salting) while lowest value was recorded in sample E (fish pre-treated with Yaji + brine) with values ranging between 25.25 and 25.85 mg/100g. [24] reported calcium content higher than values recorded in this study. Calcium is an important element in most physiological functional integrity, involving optimum functioning of heart muscles, the skeletal system and cell membrane; which is also important in proper blood clotting, nerve signal transmission and regulation of enzymes and hormones [25].

Potassium content value ranged between 14.10 to 14.55 mg/100g. Highest value (14.55 mg/100 g) was recorded in dry salted sample (sample B) while Lowest value (14.10 mg/100 g) was obtained in sample C (Ehuru + brine). There was significant ($p<0.05$) differences in potassium content of the smoke-dried fishes. Highest sodium content was recorded in sample E (Yaji + brine) while sample A (control) had the lowest value. Values ranges from 10.29 to 1072 mg/100 g. All smoked-dried fish samples were significantly different ($p<0.05$) from each other. Sodium/potassium ratio in the body helps to maintain fluid and blood volume to function normally. However, consuming too little potassium and much sodium can raise the blood pressure [25]. Increase intake of potassium can lower blood pressure and evidence indicates that it may help prevent strokes. However, extremely high sodium intake has been associated with fluid retention, leading to hypertension, heart failure and instant death [25].

Iron content value ranged between 1.56 to 1.71 mg/100g. Highest value was recorded in sample E (Yaji + brine) while sample C (Ehuru + brine) recorded the lowest value. There was no observed significant ($p<0.05$) difference in sample B and D as well as between sample A and C. Generally, most of the mineral analyzed are within the [26] recommended limit (5 mg/kg for Fe). It is evident from the result, that the pretreated smoked-dried fish recorded higher level of these minerals compared to the un-pretreated fish (Control sample). The high concentrations of these elements can be attributed to the additives added to the fish prior to smoking.

TABLE III

MINERAL COMPOSITION (MG/100G) OF SMOKED-DRIED FISH SAMPLES

SAMPLE	Mg	Ca	K	Na	Fe
A	2.00c ± 0.01	25.45a ± 0.07	14.45a ± 0.07	10.29b ± 0.01	1.59a ± 0.01
B	2.10ab ± 0.03	25.85a ± 0.07	14.55a ± 0.07	10.33b ± 0.01	1.64a ± 0.01
C	2.08ab ± 0.01	25.60a ± 0.14	14.10b ± 0.14	10.36b ± 0.01	1.56a ± 0.01
D	2.11a ± 0.01	25.40b ± 0.14	14.40b ± 0.14	10.58a ± 0.07	1.65a ± 0.01
E	2.07b ± 0.01	25.25b ± 0.07	14.55a ± 0.07	10.72a ± 0.01	1.71a ± 0.01

Reported values are mean ± standard deviation of determination in duplicate. a-b means with different superscript in the column are significantly different (p<0.05). Key = A = Control, B = Dry Salting, C = Ehuru + Dry salt, D = Clove + Brine, E = Yaji + Brine

C. Physico-Chemical Composition of Smoked-Dried Fish Samples

Table 4 shows the result of physicochemical compositions of the smoked-dried fish. Thiobarbituric acid (TBA) values was lowest in sample D (fish treated with Yaji + brine) (2.07 mg MDA/kg) and highest in control sample (2.53 mg MDA/kg). There was significant (p<0.05) difference in the TBA content of the fish samples. Thiobarbituric acid measures secondary lipid oxidation compounds formed during drying [3].The high Thiobarbituric acid value obtained for the control sample could as a result of combined effect of temperature and exposure time; and the formation of secondary oxidation compounds has proved to be an interesting tool to assess the chemical changes produced as a result of the drying process [27]. [28] reported similar increase in Thiobarbituric value of smoked-dried and sun-dried flesh of two fish species. According to [27] exposure time during drying plays significant role in formation of secondary lipid oxidation compounds in dried fishes from 40 to 60 0C. Thiobarbituric values above 3-4 mg MDA/kg indicates a loss of product quality [29]. The values obtained for Thiobarbituric acid for pretreated smoked-dried fishes in the study were within the limit (3-4 mg MDA/kg) acceptability.

Peroxide value (PV) was highest (2.33 meq of O2 /kg of fat) in sample E (fish pre-treated with Yaji + brine) and lowest in sample A (control) (2.25 meq of O2 /kg of fat). There was no significant (p>0.05%) in peroxide values of the smoke-dried fishes. Peroxide value is an indication of initial stage of the oxidative changes in products; [30] identified peroxide value was a poor indicator for heat treatment. Increased peroxide value in the pretreated smoked-dried fish samples may be due to the increased exposure of fish to oxygen. Prolonged exposure to light and air during initial drying has resulted in oxidation of fatty acids [31]. A peroxide value of 10-15 meq of O2 /kg of lipid indicates rancidity [32]. The peroxide values recorded in this study were within the acceptable limit indicating that the products will keep well during storage.

pH value ranged from 6.15 sample E to 6.40 (sample C). There was significant (p<0.05) difference in pH of the products. [33] reported a decrease in pH in dried salted beef. According to [34] high pH values are associated with the development of basic components induced by the growth of bacteria.

TABLE IV
PHYSICO-CHEMICAL COMPOSITION OF SMOKED-DRIED FISH SAMPLES

SAMPLE	TBA (mg/AA/g)	PV (meq/g)	pH
A	2.53a ± 0.01	2.25a ± 0.01	6.35a ± 0.07
B	2.44b ± 0.01	2.28a ± 0.01	6.35a ± 0.07
C	2.45ab ± 0.01	2.30a ± 0.01	6.40a ± 0.00
D	2.48ab ± 0.01	2.26a ± 0.01	6.25b ± 0.07
E	2.51a ± 0.01	2.33a ± 0.01	6.15bc ± 0.07

Reported values are mean ± standard deviation of determination in duplicate. a-b means with different superscript in the column are significantly different (p<0.05). Key = A = Control, B = Dry Salting, C = Ehuru + Dry salt, D = Clove + Brine, E = Yaji + Brine

D. Microbial Analysis of Smoked-Dried Fish Samples

Table 5 presents the result of Microbial analysis of smoked-dried fishes.

The results of microbial analysis of smoked-dried fish pretreated with some selected natural preservatives showed reduced total viable bacteria count. The control sample (sample A) had the highest bacteria count (2.4 x 108 cfu/g) while sample D (fish pre-treated with Yaji + Brine) had the lowest bacteria count (1.4 x 108 cfu/g). However, sample B (dry salting) and sample C (Ehuru + dry salt) showed no presence of bacteria which could be attributed to the actions of salt and natural spices used to pretreat them. The microbial populations for the entire treated smoked-dried fish samples observed in this study are within the recommended safe limits (5x105) for good quality fish product according to [35].

Molds have been implicated in the spoilage of fish by producing mycotoxins; and can grow in salt concentrations between 5 and 26% [36]. Total fungal count ranged from 1.5 X 108 cfu/g in Sample D (Clove + Brine) to 2.0x 108 cfu/g min control sample. Sample B, C and E (dry salting, Ehuru + Drysalt and Yaji + Brine respectively) had no fungal count. [37] reported the production of aflatoxin in dried and smoked fishes.

It is evident from the results of microbial analysis obtained in this study that the different pre-treatment of smoked-dried fish seems sufficient to have destroyed microbes and the absence of viable mold mass indicates the effectiveness of the applied pretreatments as anti-fungal agents. This agrees with the reports of [38] and [39 that spices extract was effective in reducing microbial load in the stored fish. [40] showed that Piper guineensis, Myristica monodora and Xylophia aethiopicum had chemical preservative and antioxidant properties which have effective preservation potential for smoked-dried fish during storage by retarding growth of microorganism

and could improve shelf stability of smoked fish. These antioxidants could be part of the reason for low or no microbial count of smoked-dried fish in this study which makes the fish to remain within the acceptable limit (5x105 cfu/g) recorded by International Commission on Microbiology Safety for Food and for good fish product [35]. Similarly, [4] reported that microbial analysis of fish Samples (Clarias gariepinus) treated with 3 spices shows that total viable counts as well as bacteria species were not detected in the fish samples after smoking. This corroborates the result of this study further.

TABLE V
MICROBIAL LOAD (CFU/G) OF SMOKED-DRIED FISH SAMPLES

Sample	Bacteria Colony count	Fungal Colony count
A	2.4 x 108	2.0 x 108
B	Nil	Nil
C	Nil	Nil
D	1.4 x 108	1.5 x 108
E	1.8 x 108	Nil

Key = A = Control, B = Dry Salting, C = Ehuru + Dry salt, D = Clove + Brine, E = Yaji + Brine

E. Sensory Composition of Smoked-Dried Fishes

Table 6 shows result of sensory evaluation of smoked-dried fish products.

The appearance attribute of the smoke-dried fishes ranged from 7.05 (control) to 7.95 (sample E). The appearance of the control sample and Sample B (containing only salt) were the least preferred by the panelists with mean scores of 7.05 and 7.33 respectively which translates to "Like moderately" on the Hedonic scale. Samples C, D and E recorded significant ($p<0.05$) better sensory scores compared to control sample and Sample B. However, appearance of all the products was in the liked range of the Hedonic scale. Physical appearance is an important feature of food samples [41]; [42] hence this is crucial in quality evaluation.

The best rates in terms of taste and aroma was sample E (Yaji + brine) with a sensory score of 8.05 and 7.90 for taste and aroma respectively which translates to 'like very much on the sensory Hedonic scale". The control (sample A) was least preferred by the panelists with a sensory score of 6.14 and 6.24 for taste and aroma, respectively. Other pretreated smoked-dried fish samples (sample B, C and D) were all not significantly different ($p>0.05$). Aroma is reported to be perceived as volatile odours diffusing from the food which are taken up the nose and detected by the olfactory receptors therein [43]. From this result (Table 6) the best smoked-dried fish sample with respect to general acceptability was sample E (Yaji + brine) with recorded mean sensory score of 8.33. This was closely followed by sample D (Ehuru+ brine) while the least preferred is sample A (control) with a sensory score of 7.05. However, all the smoke-dried products were liked very much by the panelists in terms of general acceptability, except for the control sample which was liked moderately with sensory mean score of 7.05.

TABLE VI
SENSORY SCORES OF SMOKED-DRIED FISH SAMPLES

SAMPLE	Appearance	Taste	Aroma	General Acceptability
A	7.05c ± 1.75	6.14c ± 1.59	6.24c ± 1.26	7.05b ± 1.02
B	7.33b ± 1.20	7.24b ± 0.83	7.38b ± 0.74	7.62a ± 0.86
C	7.71a ± 0.72	7.57a ± 0.75	7.19b ± 1.08	7.71a ± 0.72
D	7.67a ± 0.97	7.05b ± 0.80	7.48ab ± 0.87	7.86a ± 0.79
E	7.95a ± 0.97	8.05a ± 0.86	7.90a ± 1.09	8.33a ± 1.02

Reported values are mean ± standard deviation of determination in duplicate. a-b means with different superscript in the column are significantly different ($p<0.05$). Key = A = Control, B = Dry Salting, C = Ehuru + Dry salt, D = Clove + Brine, E = Yaji + Brine

IV. CONCLUSION

The study demonstrated the effectiveness of different pretreatment methods in improving consumer's acceptability and control of microbial population in fish processing. The study showed that application of these natural spices to fish prior to smoking helped retained most of the nutrients as evaluated and will keep well during storage owing to the low TBA and Peroxide values recorded. Consume acceptance of the fish products increased significantly and differed in terms of overall acceptability. It is therefore, recommended to pretreat fish with these natural spices before smoke-drying to improve and preserve nutrients in them for increased keep-ability and consumers acceptability.

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