Acta Aquatica Turcica

Home Page: https://dergipark.org.tr/actaquatr
E-ISSN: 2651-5474
21(2): 089-099, 2025
DOI: 10.22392/actaquatr.1560683

Research Article
Araştırma Makalesi

# Effect of Drying Medium on Proximate and Mineral Composition of Croaker Fish peculiar to the Coastline of Akwa Ibom State, Nigeria

# Kurutma Ortamının Nijerya'nın Akwa Ibom Eyaleti Kıyı Şeridine Özgü Çiroz Balığının Organik Madde ve Mineral Bileşimi Üzerine Etkisi

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**Received:** 05.10.2024 **Accepted:** 18.12.2024 **Published:** 01.06.2025

**How to Cite:** Etim, P., Edet, B., Udo, U. & Udo, A. (2025). Effect of drying medium on proximate and mineral composition of Croaker Fish peculiar to the coastline of Akwa Ibom State, Nigeria. *Acta Aquatica Turcica, 21*(2), 089-099. https://doi.org/10.22392/actaquatr.1560683

**Abstract:** The present study investigated the nutritional composition of dried croaker (*Pseudotolithus typus*) fish from the coastline of Eastern Obolo, Ibeno, Ikot Abasi, and Mkpat Enin Local Government Areas of Akwa Ibom State, in Southern Nigeria. The quality of the products dried using a designed active solar dryer was compared to that of the same products dried using a traditional roadside dryer commonly used by local fish vendors. The result revealed a significant difference ($p < 0.05$) in the proximate properties of the products from the two drying mediums. The ash content, crude fiber, and lipid were higher in products from the conventional dryer than products from the solar dryer. The protein content was slightly higher in the products from the active solar dryer (47.67±0.17 %) than in those from the conventional dryer (43.33±0.19 %). These findings suggest that the products from the active solar dryer were more suitable for consumption. Carbohydrate content was higher in the products from the conventional roadside dryer (4.13±0.02 %) than in the products from the solar dryer (3.74±0.03 %). The energy level was also higher in the solar-dried products (467.17±0.39 Kcal) as compared to those from the conventional dryer (430.33±0.34 Kcal). These differences were attributed to factors such as exposure of the product to impurities and the nature of the drying medium. The study confirmed the presence of higher concentration of macro elements (Sodium, Potassium, Calcium, Magnesium, and Sulphur) in products from the conventional dryer than in those from the active solar dryer. The mineral composition of the products from the two methods also exhibited significant differences ($p < 0.05$). The study recommends the consumption of products dried from the active solar dryer based on low levels of arsenic, chlorine and iodine, which were less than the 0.010 Mg/kg prescribed by the World Health Organization.

**Keywords**
- Solar drying
- Fish processing
- Proximate properties
- Mineral elements
- Southern Nigeria

**Özet:** Bu çalışmada, Güney Nijerya'daki Akwa Ibom Eyaleti'nin Doğu Obolo, Ibeno, İkot Abasi ve Mkpat Enin Yerel Yönetim Bölgelerinin kıyı şeridinden kurutulmuş kraker (Pseudotolithus typus) balığının besin bileşimi araştırılmıştır. Tasarlanan aktif solar kurutucu kullanılarak kurutulan ürünlerin kalitesi, yerel balık satıcıları tarafından yaygın olarak kullanılan geleneksel yol kenarı kurutucusu kullanılarak kurutulan aynı ürünlerin kalitesiyle karşılaştırılmıştır. Sonuçlar, iki kurutma ortamından elde edilen ürünlerin yakın özelliklerinde önemli farklılıklar ($p < 0.05$) olduğunu ortaya koymuştur. Kül içeriği, ham lif ve lipid, geleneksel kurutucudan elde edilen ürünlerde güneş enerjili kurutucudan elde edilen ürünlerden daha yüksekti. Protein içeriği aktif solar kurutucudan elde edilen ürünlerde (%47,67±0,17) konvansiyonel kurutucudan

**Anahtar kelimeler**
- Güneşte kurutma
- Balık işleme
- Organik özellikler
- Mineral elementler
- Güney Nijerya

elde edilenlere göre (%43,33±0,19) biraz daha yüksekti. Bu bulgular, aktif solar kurutucudan elde edilen ürünlerin daha sağlıklı olduğunu göstermektedir. Karbonhidrat içeriği geleneksel yol kenarı kurutucusundan elde edilen ürünlerde (%4,13±0,02) solar kurutucudan elde edilen ürünlere (%3,74±0,03) kıyasla daha yüksekti. Enerji seviyesi de güneşte kurutulan ürünlerde (467,17±0,39 Kcal) geleneksel kurutucudan elde edilenlere (430,33±0,34 Kcal) kıyasla daha yüksekti. Bu farklılıklar, ürünün yabancı maddelere maruz kalması ve kurutma ortamının niteliği gibi faktörlere bağlanmıştır. Çalışma, geleneksel kurutucudan elde edilen ürünlerde aktif solar kurutucudan elde edilenlere kıyasla yüksek konsantrasyonda makro elementlerin (Sodyum, Potasyum, Kalsiyum, Magnezyum ve Kükürt) varlığını doğrulamıştır. İki yöntemle elde edilen ürünlerin mineral bileşimi de önemli farklılıklar göstermiştir ($p < 0.05$). Çalışma, Dünya Sağlık Örgütü tarafından öngörülen 0.010 Mg/kg değerinden daha düşük olan düşük arsenik, klor ve iyot seviyelerine dayanarak aktif solar kurutucudan kurutulan ürünlerin tüketimini önermektedir.

# 1.INTRODUCTION

Drying fish and preserving the dried product for an extended period is a significant challenge faced by fish processors in Akwa Ibom State, Southern Nigeria. Some of the methods used for drying these products are outdated and the hygienic state of some are questionable. Roadside fish vendors in Southern Nigeria are grappling with the difficulties of maintaining the product's quality and understanding the changes in the nutritional and chemical properties of the products (Edet et al, 2024). These challenges have led to a decline in interest for their services. According to Ahmed et al. (2022), the nutritional content of dried fish products could influence consumer preference for these products. Drying technique could influence the physical, chemical, nutritional and sensory properties of the product. These properties are relevant in defining the general acceptability of such products by consumers. This assertion was further corroborated by Alahmad et al. (2021) in their study of the influence of drying techniques on the physicochemical, nutritional and morphological properties of bighead carp (*Hypophthalmichthys nobilis*) fillets. Rusal et al. (2021) also shared a similar view when they studied the effect of drying methods on the physico-chemical, microbiological and sensory properties of torpedo scad (*Megalaspis cordyla*).

The proximate composition of dried fish products has been thoroughly examined by multiple authors to determine their shelf life and quality (Siddiky et al., 2017; Avila et al., 2022; Balavinayagamani et al., 2020; Moshood et al., 2014; Bolowa et al., 2011; Fitri et al., 2022; Rasul et al., 2021). In a study by Ezugwu (2021), the proximate composition of four different fish species (croaker, mackerel, catfish, and tilapia) showed significant variation in their properties. Protein content across all species ranged from 46.09 to 67.71%, with croaker having the highest lipid content at 32.11%, compared to 8.32% for catfish and 8.68% for tilapia. Kim et al. (2020) studied the effect of various drying methods on the physicochemical characteristics and textural features of croaker. They reported that crude protein increased from 19.03 to 31.32 % after drying of the product in a hot air oven. Abraham-Olukayode (2013) investigated the changes in the proximate composition of certain fish species subjected to various processing methods in Southern Nigeria. The study found that processed croaker fish samples had higher nutritional value than the fresh samples based on experimental data, with moisture, ash, lipid, and protein content differing significantly between the fresh and oven-dried samples.

Abimbola (2016) conducted a study on the proximate and mineral composition of two species of croaker fish from a Lagoon in Lagos. The study found that the *Pseudotolithus senegalensis species* had higher moisture and ash content when compared to the *P. typus species*. However, fresh samples of *P. typus species* had higher fat (0.86 %), fiber (2.01 %), and carbohydrate content (5.05 %). A similar study by Metha & Nayak (2017) revealed that the crude protein content in *Johnius dussumieri* species of croaker fish was slightly lower (15.40 %) than what was reported by Metha et al. (2014) for fresh *P. typus*. The high moisture content and low-fat content classified the fish as lean. Njinkoue et al. (2016) also analyzed the proximate composition and mineral elements of two marine fish samples from the Cameroon coastline that were subjected to drying. They described the products as rich in protein and low-fat content of less than 0.5 %.

Ezugwu (2021) confirmed the presence of both macro and micro mineral elements, including calcium, potassium, sodium, phosphorus, manganese, iron, zinc, and magnesium, in croaker fish. He underscored the significance of these elements in promoting healthy nutrition. Chukwu (2009) reported that drying methods influence the nutritional properties of fish and aquatic related products. The study revealed that potassium content in Tilapia increased from 0.00012 (in its raw state) to 0.00058 % (after drying). Phosphorus content also increased from 0.00012 to 0.00042 % after drying the product. Abimbola (2016) also verified the existence of these mineral elements while examining two species of croaker fish, with the *P. typus* variety containing 22.64 mg/kg of calcium and 22.04 mg/kg for *P. senegalensis*. Manganese had the lowest composition of less than 2.00 mg/100g for both varieties. Moreover, various authors have highlighted the presence of macro and micro elements in different fish species, emphasizing their critical role in defining the edibility of such products (Ahmed et al., 2017; Gong et al., 2019; Simpson & Uche, 2019; Moses, 2019; Dou et al., 2020; Namaga et al., 2020; Ayebusi, 2021; Umamageshawari et al., 2022).

There is limited information available regarding studies on the proximate and mineral composition of croaker fish dried using an active solar drying system, despite the increasing demand for the product in Southern Nigeria. Availability of such information could help in safeguarding the health of consumers and the choices they make with respect to medium of drying the product. This study aimed to investigate how drying mediums affect the proximate and mineral content of croaker fish peculiar to the long coastline of Akwa Ibom State, South South Nigeria.

The present article is structured in four sections. The first section gives an overview of the research, highlights research gaps and captures the objectives of the study. The second section highlights the materials and methods used to achieve the objectives of the research, while the results from the experiments are discussed in the third section. The fourth section concludes the research and highlights recommendations which could help in optimizing drying and preservation techniques for croaker fish and related products in the coastal zone of Akwa Ibom State.

## 2.MATERIALS AND METHODS

### 2.1.Material for Experiment

Fourty samples of net weight of 10 kg were bought from a local fish vendor along the coastline connecting Eastern Obolo, Ibeno, and Ikot Abasi as well as Mkpat Enin Local Government Areas of Akwa Ibom State, Nigeria, in February 2024. The average weight of each individual product was 255 g, while the average length was 30.4 cm. These values were consistent with the typical measurements obtainable for the products in the study area. The samples were promptly placed in an iced container and transported to the Agricultural Products Processing and Storage Laboratory of the Department of Agricultural Engineering, Akwa Ibom State University, Ikot Akpaden, Mkpat Enin.

### 2.2.Sample Preparation and Experimental Set Up

The products were carefully washed, cleaned, and sliced with a sterilized steel knife. Removal of the gills ensured that the bitter taste of the section did not affect the edible part while also eliminating bacterial agents in the process. The samples were subjected to drying in an active indirect solar dryer, while the conventional roadside dryer served as a control experiment. The conventional dryer was a regular charcoal fired dryer used by fish vendors, whose drying tray takes between five to ten products depending on the size of the products. The product had direct contact with the fuel source (Charcoal). The solar powered dryer was an enclosed dryer which had a 5-blade axial blower which was powered by the solar PV system. The blower was placed in the basement of the dryer to ensure air was trapped efficiently to the drying chamber to burn the charcoal at a high intensity for drying of the product. A heat exchange medium was used as an intermediary between the fuel source and the drying chamber. This wasn’t the case for the conventional dryer as the drying was dependent on ambient factors such as temperature, wind speed and relative humidity. The wind speed for an average drying day ranged from 0.5 to 2.5 m/s. The relative humidity ranged from 40 to 85 %, while the air temperature was between 27 and 36 °C. The factors contributed immensely to the performance of the conventional dryer.

Compressed air into the dryer averaged 2.0 m/s in terms of speed during a typical drying experiment. The temperature inside the chamber of the solar enclosed dryer ranged between 40 to 60 ℃ during a drying experiment. This high temperature range and speed of the blower aided faster drying of the product in the solar enclosed system.

## 2.3.Drying Time and Temperature

The products were arranged in the drying chamber of the respective mediums equidistant from each other. It took 85 minutes for samples in the conventional dryer to attain a constant weight, while samples in the active solar dryer reached an equilibrium weight in 135 minutes. The temperature range for the active solar dryer was between 35 to 60 ℃. After the drying experiment, the samples from the two mediums were allowed to cool before being subjected to proximate and mineral analyses. The dried products from the experiments were not similar in appearance as shown in Figure 1 (Conventional Dryer) and Figure 2 (Active Solar Dryer) respectively, as observed after the experiment.

**Figure 1:** Dried Products in the Conventional roadside dryer.

**Figure 2:** Dried Products in the Active solar dryer.

## 2.4.Proximate Properties

The chemical composition of the dried samples was determined using the standard set by the Association of Official Chemists (AOAC, 2020). The properties analyzed included crude protein, crude lipid, carbohydrate, moisture, and ash contents. After the drying experiment, the samples were carefully wrapped in a foil to prevent rewetting and contamination. The moisture content was determined using a hot air oven (Model DHG-9101-2SA) manufactured by Jiangsu Instruments Technology Limited, China. The temperature of the oven was set at 105 °C. The crude protein was determined using an automatic Kjeldahl Protein Analyzer (Model ZDDN-11) manufactured by WINCOM Company Limited, China. For lipid content, 2 g of the sample was placed in an extraction thimble and refluxed in an extraction flask filled with petroleum ether for six hours. A rotary evaporator (Model F250 - manufactured by Julabo Instruments, United Kingdom), was used to evaporate ether, and the weight loss was recorded as the crude lipid. The crude fiber was obtained by infusing 200 ml of N-hexane for 2 hours in a 250 ml conical flask. 5 ml of sulfuric acid was added to the flask, and the mixture was boiled and refluxed for half an hour. The hot solution was then filtered through suction. The total ash was obtained by igniting a previously dried sample (2.00 g) in a muffle furnace at 500 °C for 4 hours. The carbohydrate content was obtained by subtracting the total lipid, protein, fiber, ash, and moisture from 100. Each experiment was replicated three times for samples from each medium.

## 2.5.Mineral Composition

The mineral composition of the dried samples was determined using standard procedures. The minerals considered included Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Copper (Cu), Zinc (Zn), Iron (Fe), Manganese (Mn), Silicon (Si), Arsenic (As), Phosphorus (P), Sulphur (S), Chlorine ($Cl_2$), and Iodine ($I_2$). The dried products were crushed and sieved before digestion. An Atomic Absorption Spectrophotometer (Spectrum Lab 752 Pro Model) manufactured by Shenyang Ebetter Optics Company Limited, China, was used to analyze the samples for metal concentration. The principle of Beer and Lambert's law was applied. All standards were prepared in 1000 mg/L, which was equivalent to 1000 PPM stock standard, except for Sodium and Potassium. Five grams (5 g) of the crushed sample were placed into a digestion bottle. 50 ml of $HNO_3$ was added to the sample and dried for 2 hours at 110 °C. After two hours, the samples were removed from the oven and allowed to cool for an hour before they were filtered and analyzed using the Spectrophotometer. The results of the experiments were obtained in mg/L and multiplied by the Digestion Factor to obtain solid sample values in mg/kg.

The samples were analyzed for nitrogen and potassium using a flame photometer (FP640NC model) manufactured by WINCOM Company Limited, China. Before being introduced to the flame, the samples were nebulized to ensure a fine spray for efficient atomization. As the samples entered the flame, the solvent evaporated, leaving behind dissolved elements in the form of atoms. The high temperature of the flame excited the atoms, causing them to emit light at specific wavelengths characteristic of the elements in the sample. A monochromator was used to select the desired wavelength of light emitted by the sample while blocking undesired wavelengths. The detector captured the appropriate wavelength and converted it into an electrical signal. The signal processor then measured the intensity of the signal, providing insight into the concentration of the element in the sample. The measured signal was further compared to calibration curves (standards) to quantitatively determine the concentration of the elements. This method was also used by Njikoue et al. (2016) for a similar product.

### 2.6.Analysis of Data

The experiments for the proximate properties and mineral composition were replicated five times, and the mean value ± standard deviation was used as a reference. To determine significant differences between the data for the dried products from the two mediums, a one-way ANOVA was performed at a 5 % level of significance ($p < 0.05$). Statistical analysis was done using Minitab statistical software version 20.0.

## 3.RESULTS AND DISCUSSION

### 3.1.Proximate Properties

Table 1 highlights the proximate properties of the dried products from the active solar dryer and the conventional roadside dryer. The initial moisture content of the fresh samples was 74.50±0.32 % (dry basis) in the active indirect solar dryer and 74.74±0.18 % (dry basis) for fresh samples in the conventional dryer. The final moisture content was higher for samples in the active solar dryer (7.75±0.12 % - dry basis) than for samples dried using the conventional roadside dryer (7.43±0.12 % - dry basis). The difference between the products from the two methods was found statistically significant ($p < 0.05$) as shown in Table 2. The t-value of 5.13 obtained from the experimental data indicates the distinction between the pooled standard error and the difference in the value of moisture content of the products from the two mediums. The moisture content values for the products from the two methods align with the study by Ezugwu (2021), who reported 5.56 % (dry basis). The moisture level of the product is responsible for limiting microbial activities in the dried product and enhancing the shelf life of the product after drying. Most seafood vendors in the study area have abandoned the trade due to the consistent challenge of breaking even, due to the high rate of losses.

**Table 1:** Proximate properties of the dried products from the different mediums.

| Proximate Property | Solar Dryer | Conventional Dryer |
|---|---|---|
| Moisture Content (%) | 7.75±0.12 | 7.43±0.07 |
| Ash (%) | 4.14±0.03 | 4.19±0.01 |
| Crude Fiber (%) | 30.73±0.28 | 34.53±0.26 |
| Lipid (%) | 6.25±0.03 | 6.30±0.01 |
| Protein (%) | 47.67±0.17 | 43.33±0.19 |
| Carbohydrate (%) | 3.74±0.03 | 4.13±0.02 |
| Energy Level (Kcal) | 467.17±0.39 | 430.33±0.34 |

* n, number of replications = 5.

The ash content in the product from the conventional roadside dryer was higher (4.19±0.01 %) than the ash content in products dried using the active solar dryer (4.14±0.03 %). There was significant difference ($p<0.05$) in ash content for products dried using the different methods. This result contrasts with the study of Njikoune et al. (2016), which reported 7.28 ± 0.25 % ash content for the fresh edible part of *P. typus* and 1.28 % for smoked products (Amusan et al., 2018). These values were closer to the 5.90 % reported by Bolawa et al. (2011) for a similar product obtained in the riverine area of Lagos, Nigeria. These values were also higher than those obtained by Tang et al. (2009) for the

*Pseudosciaena crocea R*. (2.5±0.12 %) species. The ash content signifies low toxicity level for the product, good texture, taste and nutritional properties of the dried product.

Crude fiber content of samples dried in the conventional dryer (34.53±0.26 %) was higher than that of samples dried using the active solar dryer (30.73±0.28 %). This attribute is crucial for ensuring better absorption and digestion of the dried product. Additionally, there was significant difference ($p < 0.05$) in the values obtained from the different drying methods, which contradicted the findings of Bolawa et al. (2011) and Ibe (2021).

The lipid content was observed to be higher in the samples dried in the conventional dryer (6.30 ± 0.01 %) compared to those dried in the active solar dryer (6.25±0.03 %). There was significant difference ($p < 0.05$) in the lipid content between the samples from the two different mediums. These values closely align with the 6.6 % obtained by Abraham-Olukayode (2013) for the same product dried in the open sun, but were higher than 1.48 % obtained by Amusan et al. (2018). This property is essential for defining the energy characteristics of the dried products and for preventing cardiovascular and heart diseases.

The protein content was found to be higher in products dried in the active solar dryer (47.67±0.17 %) compared to those dried in the conventional dryer (43.33±0.19 %). Significant difference ($p < 0.05$) was observed in the values obtained for the products in the two mediums. The recorded result surpassed the 39.22% obtained by Amusan et al. (2018) for smoked croaker from retail outlets in the Makoko environs of Lagos, Nigeria. However, it differed from the findings of Abraham-Olukayode et al. (2013) for the same product. The higher value obtained for the products dried using the active solar dryer could potentially enhance the amino acid content in the product, thereby helping to reduce the risk of high blood pressure and stroke.

The carbohydrate content was observed to be higher in samples dried in the conventional dryer (4.13±0.02 %) compared to those dried in the active solar dryer (3.74±0.03 %). These values were lower than the 2.49 % reported by Anene et al. (2013) for the *Pseudotolithus elongatus* species of croaker and the range of 0.20 to 0.49 % reported for fresh products by Ondo-Azi et al. (2013). However, they were closer to the 5.05 % obtained for the *P. senegalensis* species of the fish (Abimbola, 2016). There was a significant difference ($p < 0.05$) between the values obtained from the two drying methods as shown in Table 2. The low carbohydrate content is an indicator that the dried product will have a significant impact on blood sugar levels for persons that consume them.

The energy level was higher in products from the solar dryer (467.17±0.39 Kcal) than those from the conventional dryer (430.33±0.34 Kcal). The variation in the values of the proximate properties of the products from the different drying mediums was due to the airflow into the respective dryers, exposure of the products to the atmosphere, the interaction between the products and the fuel source (charcoal), and the quantity of heat and air circulation in the drying chamber.

**Table 2:** Tukey Simultaneous Tests for Differences of Means of Proximate Properties.

| Proximate Property | Difference of Dryer | Difference of Means | SE of Difference | Simultaneous 95% CI | T-Value | P-Value |
|---|---|---|---|---|---|---|
| Moisture Content | Solar Dryer - Conventional | 0.3220 | 0.063 | (0.177, 0.467) | 5.13 | 0.001* |
| Ash | Solar Dryer - Conventional | -0.050 | 0.015 | (-0.084, -0.016) | -3.43 | 0.009* |
| Crude Fiber | Solar Dryer - Conventional | -3.802 | 0.171 | (-4.196, -3.408) | -22.27 | 0.001* |
| Lipid | Solar Dryer - Conventional | -0.058 | 0.014 | (-0.091, -0.025) | -4.08 | 0.004* |
| Protein | Solar Dryer - Conventional | 4.344 | 0.113 | (4.083, 4.605) | 38.31 | 0.001* |
| Carbohydrate | Solar Dryer - Conventional | -0.396 | 0.016 | (-0.433, -0.359) | -25.05 | 0.001* |
| Energy Level | Solar Dryer - Conventional | 36.846 | 0.226 | (36.325, 37.367) | 163.14 | 0.001* |

*Significant difference between data from the two mediums; CI – Confidence Interval.

### 3.2.Mineral Composition

#### 3.2.1.Main Elements

Microelements such as sodium, potassium, calcium, and sulphur were higher in samples dried using the conventional dryer than in samples subjected to drying in the active solar dryer. Phosphorus was higher in the samples dried in the active solar dryer than in the conventional as shown in Table 3. There were significant differences in the values obtained for samples in both mediums ($p < 0.05$) represented in Table 4. The high sodium content (68.16 ± 0.26 mg/kg) in the conventional dryer means the product could subject consumers to threats of high blood pressure and cardiovascular diseases. The result was higher than the value of 64.27 ± 0.25 mg/kg obtained for products from the active solar dryer. These values obtained for the dried samples from both mediums were higher than 11.20 ± 0.09 mg/kg obtained by Adejonwo (2016), who studied the mineral composition *P. senegalensis* and *P. typus species*, and obtained an average of 9.89 ± 1.65 mg/kg.

The potassium content (33.05 ± 0.05 mg/kg) in products dried using the active solar dryer was lower than that in products dried using the conventional dryer (35.15 ± 0.04 mg/kg). This suggest that consuming products dried using the solar dryer may reduce the risk of kidney disease in humans. These values were closer to what was obtained by Abimbola (2016) in a similar study (30.39 mg/kg) for croaker.

The calcium content from samples in the active solar dryer (32.18 ± 0.13 mg/kg) was lower than what was obtained for products dried in the conventional dryer (34.45 ± 0.33 mg/kg). The high calcium content indicates the presence of vitamin D in the product, which can contribute to building strong bones and teeth. The calcium content aligns with the findings of Chen et al. (2022). They opined that calcium content less than 40 mg/kg promotes suitability of croaker fish for consumption by humans.

The samples from both drying mediums exhibited high magnesium content, indicating that the products were nutritious. The low phosphorus content in the solar-dried samples (2.65 ± 0.03 mg/kg) and the conventional dryer samples (2.42 ± 0.03 mg/kg) suggested that the products possessed high antioxidant properties. These results slightly exceeded the values obtained by Adejonwo (2016), which were 1.84 ± 0.16 and 1.68 ± 0.23 mg/kg, respectively. The flavour of the dried products from both methods was appealing, implying low sulphur content, similar to the description of Petricorena (2014).

**Table 3:** Mineral composition of the dried products from the different mediums.

| Type | Mineral Component (Mg/Kg) | Solar Dryer | Conventional Dryer |
|---|---|---|---|
| Macro Elements | Sodium | 64.27 ± 0.25 | 68.16 ± 0.26 |
| | Potassium | 33.05 ± 0.05 | 35.15 ± 0.04 |
| | Calcium | 32.18 ± 0.13 | 34.45 ± 0.33 |
| | Magnesium | 14.32 ± 0.35 | 16.15 ± 0.33 |
| | Phosphorus | 2.65 ± 0.03 | 2.42 ± 0.03 |
| | Sulphur | 0.02 ± 0.00 | 0.04 ± 0.01 |
| Micro Elements | Copper | 3.13 ± 0.03 | 2.82 ± 0.02 |
| | Zinc | 18.57 ± 0.08 | 23.22 ± 0.27 |
| | Manganese | 2.16 ± 0.02 | 2.46 ± 0.02 |
| | Silicon | 0.82 ± 0.02 | 0.67 ± 0.01 |

* n, number of replications = 5.

#### 3.2.2.Micro Elements

The levels of copper and silicon were higher in the samples dried in the active solar dryer than the conventional dryer as shown in Table 3. The concentration of Zinc and Manganese were higher in samples from the conventional dryer than the products from the solar dryer. These findings did not agree with the studies conducted by Ogundira et al. (2012) and Njikuoe et al. (2016). The duo obtained separate values for the edible part and bone for the product. Manganese content was higher than what Adejonwo (2016) obtained in his study of similar product from a Lagoon in Lagos, Southern Nigeria.

In comparison with the standards of the Food and Agricultural Organization and the World Health Organization (FAO, 2001), the trace elements were in range and not higher in concentration, making the products from both mediums fit for consumption. Similarly, the levels of Arsenic, Iodine and Chlorine in samples from both drying mediums were less than 0.01 mg/kg, indicating that the samples were less toxic, but also with enhanced shelf life and reduced risk of poisoning and obesity for persons that consume the dried product. These values were lower than the WHO standards for acceptable levels of arsenic, iodine and chlorine (0.01 mg/kg), posing the product as fit for consumption (FAO, 2001).

**Table 4:** Tukey Simultaneous Tests for Differences of Means of Mineral components.

| Mineral Component (Mg/Kg) | Difference of Dryer | Difference of Means | SE of Difference | Simultaneous 95 % CI | T-Value | P-Value |
|---|---|---|---|---|---|---|
| Sodium | Solar Dryer - Conventional | -3.893 | 0.210 | (-4.475, -3.312) | -18.58 | 0.001* |
| Potassium | Solar Dryer - Conventional | -2.107 | 0.038 | (-2.211, -2.002) | -55.86 | 0.001* |
| Calcium | Solar Dryer - Conventional | -2.267 | 0.203 | (-2.831, -1.703) | -11.16 | 0.001* |
| Magnesium | Solar Dryer - Conventional | -1.830 | 0.277 | (-2.599, -1.061) | -6.60 | 0.003* |
| Copper | Solar Dryer - Conventional | -0.313 | 0.021 | (-0.372, -0.255) | -14.86 | 0.001* |
| Zinc | Solar Dryer - Conventional | -3.750 | 0.159 | (-4.192, -3.308) | -23.53 | 0.001* |
| Magnesium | Solar Dryer - Conventional | -0.297 | 0.013 | (-0.334, -0.259) | -22.25 | 0.001* |
| Silicon | Solar Dryer - Conventional | 0.157 | 0.011 | (0.127, 0.186) | 14.86 | 0.001* |
| Phosphorus | Solar Dryer - Conventional | 0.230 | 0.023 | (0.167, 0.293) | 10.06 | 0.001* |
| Sulphur | Solar Dryer - Conventional | -0.017 | 0.003 | (-0.026, -0.007) | -5.00 | 0.007* |

* Significant difference between data from the two mediums; CI – Confidence Interval.

## 4.CONCLUSIONS

This research examined croaker fish from the coastal area of Akwa Ibom State based on their chemical composition and mineral content after undergoing drying experiments. The study concluded that the appearance of dried *P. typus* is a function of the medium used for drying the product. Results of the proximate analysis showed significant differences in the proximate properties (moisture content, ash content, crude fiber, protein and lipid). Moisture content was higher in the solar dried samples, than the conventional dryer, but the reverse was the case for ash content. Protein content was slightly higher in products from the active solar dryer (47.67±0.17 %) as against the conventional dryer (43.33±0.19 %). The result suggests that products from the active solar dryer could help reduce the risk of high blood pressure and promote healthy dieting. Carbohydrate level was higher in products from the conventional dryer (4.13±0.02 %) than in products from the solar dryer (3.74±0.03 %). The energy level was higher in solar-dried samples (3.74±0.03 %) than in those from the conventional dryer (430.33±0.34 Kcal). The difference in the values of the chemical properties of the products from the drying mediums was attributed to factors such as airflow into the respective dryers, exposure of the products to the atmosphere, and interaction between the products and the fuel source (charcoal), and the quantity of heat and air circulation in the drying chamber. Air flow into the dryer was through a force convective means. A blower linked to a solar PV cell was attached at the basement of the dryer which enhanced circulation of air to burn the charcoal with much intensity and further produced the much-desired hot air to heat up the drying chamber for faster drying of the product. However, this wasn't the case for the conventional dryer as no blower was attached to the dryer to accelerate flow of hot air in the drying chamber. The drying process was dependent on ambient conditions and time of the day. The macro elements found in samples from both dryers were Sodium, Potassium, Calcium, Sulphur, Magnesium, and Phosphorus. The results showed that Sodium, Potassium, Calcium, Magnesium, and Sulphur were of higher concentration in products dried using the conventional dryer than in products from the active solar dryer, with Phosphorus higher in the solar-dried samples. However, there was a significant difference for the samples in both mediums. The concentration of trace elements identified in the samples from both drying methods was within the standards prescribed by the World Health Organization, confirming the fitness of the products for consumption and low toxicity level (< 0.01 mg/kg). The study recommends an active solar dryer for drying the products to promote healthy dieting based on reduced interaction with impurities and environmental factors.

## ACKNOWLEDGEMENTS

The authors appreciate Akwa Ibom State University and the University of Uyo, both in Nigeria, for allowing their facilities to be used for this study.

## DECLARATION OF FUNDING

This study did not receive any financial support.

## CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## AUTHOR CONTRIBUTIONS

Conceptualization: PE; Literature: PE; Methodology: PE, BE, UU, AU; Experiment: PE, BE, UU, AU; Data analysis: PE; Manuscript writing: PE, UU; Supervision: PE

All authors approved the final draft.

## ETHICAL APPROVAL:

Local Ethics Committee Approval was not obtained because experimental animals were not used in this study.

## DATA AVAILABILITY

Data supporting the findings of the present study are available from the corresponding author upon reasonable request.

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