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Effect of oven drying and smoking on the nutritional composition of Atlantic mackerel (*Scomber scombrus*)

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ABSTRACT: Fish is a vital source of essential nutrients, offering a healthier protein due to its lower saturated fat and higher omega-3 fatty acid content. The study evaluates the effect of oven drying and smoking as processing techniques on the nutritional composition of Atlantic mackerel (*Scomber scombrus*), specifically, the moisture, crude protein, crude fat, ash, carbohydrate content and energy. Proximate analysis revealed significant differences ($p<0.05$) between the two methods. Oven-dried fish had a higher dry matter content (90.97%) compared to smoked fish (88.51%), while moisture content was significantly lower in oven-dried fish (9.03%) than in smoked fish (11.49%). Crude protein (35.37%), crude fat (35.37%), and carbohydrate content (30.22%) were significantly higher in smoked fish than in oven-dried fish (31.22%, 31.22%, and 27.08%, respectively). Conversely, oven drying resulted in significantly higher crude fibre (2.43%), ether extract (29.63%), and ash content (0.61%) compared to smoking (1.46%, 21.21%, and 0.25%, respectively). The energy content was also higher in oven-dried fish (499.86 kcal) than in smoked fish (453.27 kcal). The study concluded that both processing techniques preserve nutrients with different advantages. Oven drying is more effective in retaining dry matter, fibre, ether extract, ash, and energy, making it suitable for prolonged storage. While smoking better preserves protein and fat, enhancing flavour and making it ideal for immediate consumption. Selection of the appropriate processing method should therefore align with the intended use of the fish. Future studies should explore the impact of these techniques on sensory attributes, storage stability, and consumer preferences.

Keywords*:* Fish, mackerel, smoking, oven dried, processing, proximate.

INTRODUCTION

Fish is a staple diet in developing nations like Nigeria. Because of its abundance in nutritional qualities, such as its high protein, unsaturated fatty acid, carbohydrate, and mineral levels, it is accessible in both urban and rural locations and is reasonably priced (Saba *et al*., 2024). Due to its great nutritional value and low cholesterol level in comparison to meat, it is accepted globally and is frequently advised for eating, particularly by adults (Eyo, 2001; Sanni *et al*., 2023).

Products made from seafood contain a variety of vital elements for a balanced diet. One of the main sources of fats and proteins is fish (Bouriga *et al*., 2010). According to Varlik *et al*. (2004) and Erkan *et al*. (2010), it offers a significant quantity of necessary amino acids, vitamins, minerals, and polyunsaturated fatty acids (PUFAs). This fish has long muscles and easily digested flesh. Its oil is a rich source of polyunsaturated fatty acids (PUFAs), primarily those of the n-3 family, such as docosapentaenoic acid (DPA or 22:5 n-3), eicosapentaenoic acid (EPA or 20:5 n-3), and docosahexaenoic acid (DHA or 22:6 n-3), which may have some positive effects on cancer and cardio-vascular diseases (Marchioli, 2001; Luzia *et al*., 2003).

Atlantic mackerel (*Scomber scombrus*), locally known as *Kote*, is the most predominant fishery species in various markets and is well consumed among the Nigerian populace. *Scomber scombrus* is known for its high protein and fat content (Ackman, 1990).

Proximate analysis or nutritional evaluation of fish indicates the percentage composition of essential nutrients or constituents such as proteins, crude fats, and other minerals in fish products. The chemical constituents are naturally used as a pointer to the nutritional value found in fish (Moghaddam *et al*., 2007; Aberoumand, 2011). Fish generally differ from species to species. The differences can result from seasonal variation, feeding habits, or sex (Islam and Tanaka, 2004). Understanding the proximate composition is crucial when preparing fish. For efficient use, data on the oil (after it is described as fat/ether extract), protein, ash, and moisture content of fish are required. The makeup of the fish that they eat directly affects the processor, dietitian, and consumer (Olusola *et al*., 2011). The chemical constituents are actually utilised as a pointer to the wholesome esteem found in fish (Aberoumand, 2011). Fish generally differ from species to species. The contrasts can result from regular variety, nourishing propensities, or sex (Ferno *et al.*, 2020). Therefore, this work evaluates the influence of processing techniques on the nutritional value of Atlantic mackerel (*Scomber scombrus*).

MATERIALS AND METHODS

Study area

The research was conducted at the Department of Zoology, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

Experimental animals

A total of seventy-two (72) pieces of frozen *Scomber scombrus*, were purchased at a cold room store located in Umuahia main market, Abia State, Nigeria. The samples were then transported to the Department of Zoology, Michael Okpara University of Agriculture, Umudike, for identification. Thereafter, the samples were moved to the Biochemistry Department of the same school for analysis.

Fish preparation

The samples were prepared by washing, sorting, cutting, drying, and milling in order to achieve the goal of the study.

Smoking process

The fish samples were gutted and washed thoroughly with distilled water; thereafter, the samples were kept on a wire above the firewood. The smoking of the fish was carried out for 4 hours. Thereafter, smoked products were milled separately into fine powder using a manual grinder and sieved with a 0.5μm mesh size to achieve uniformity in particle size, and then packed in a transparent polythene bag and sealed to reduce microbial infestation.

Oven dried-process

After washing the fish samples, they were wrapped with aluminium foil and put in the electric oven at a temperature of 50°C for 2 days; thereafter, the fish were removed and milled with an electric blender to obtain a powdered form of the fish sample.

Proximate analysis

The proximate analyses (dry matter, moisture content, carbohydrate, energy, ether extract, crude protein, fat, ash and crude fibre) were analysed by adopting the methods described in AOAC (2005). The carbohydrate content was calculated by subtracting the sum of moisture, protein, fat, fibre, and ash from the total weight of the sample.

Fat content determination

Cleaned and fat-free filter paper was weighed initially (W_1). 5 grams of the fish sample was added to the filter paper and weighed (W_2). The weighed fish sample was dropped into the Soxhlet apparatus's thimble after being knotted with a piece of thread. The device's round-bottom flask was filled with 250 millilitres of petroleum ether. The Soxhlet was placed on the heating mantle, and the solvent was used to extract the fat for four hours. The thimble was taken out, the condenser was disconnected, and petroleum ether was siphoned over the barrel. A clean, dried Petri dish was carefully filled with the solvent extract (lipid) mixture, which was then placed in a fume cupboard for two hours. As the solvent vanished, it left behind the extracted fat. The filter paper containing the residue was dropped into a beaker and transferred into an oven at 50°C. It was then dried to a constant weight and cooled in a desiccator, and reweighed (W_3). The percentage of fat was calculated.

$$\%\, Fat\ content = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Moisture content determination

Weight loss was used to determine the moisture content using a drying process. Using a weighing balance, the weight of a dry, clean crucible was measured and recorded (W_1). After adding samples to the empty crucible, the weight of each sample was noted (W_2). The sample-containing crucible was placed in the oven, kept there at 105°C, and allowed to dry for four hours. After an hour of cooling in a desiccator, the dish was reweighed (W_3). The percentage moisture content was calculated.

$$Moisture\ content\ = \frac{W_{2-W_3}}{W_{2-W_1}} \times 100$$

Ash content

The weight of an ash-free crucible was measured and noted (W_1). After being weighed, 2 g of the sample was put into the crucible (W_2) and placed into the muffle furnace. After that, the muffle furnace was fired for approximately four hours at 600°C until a grayish-white material was produced. After cooling in a desiccator, the crucible was reweighed (W_3). The percentage ash content was calculated.

$$\%\ Ash\ content\ = \frac{W_{2-W_3}}{W_3\ -\ W_1} \times 100$$

Crude-fibre content determination

A 2500 ml conical flask and 5 g of the defatted material was weighed (W_1). 200 millilitres of H_2SO_4 at 1.25% were added. After 30 minutes of heating, the fluid was chilled and suctioned through poplin fabric with a Bunchier funnel. After being scraped back into a flask, the residue was washed in hot, distilled water. After adding 200 millilitres of 1.25% NaOH, the mixture was heated for half an hour. It was chilled, filtered, and rinsed twice with methylated spirit, once with hot distilled water, once with 10% HCL, and four times with hot water. After being drained, the residue was put in a crucible and dried at 105°C in an oven. It was weighed (W_2) after being dried in an oven and cooled in a desiccator. The crucible containing the residue was placed in a muffle furnace at 300°C for 30 minutes, placed in a desiccator to cool to room temperature, and weighed (W_3).

$$\%\ Crude\ fibre\ = \frac{w_{2-W_3}}{w_1} \times 100$$

Determination of protein content

Kjeldahl catalyst tablet was used to add 12.5 ml of concentrated H_2SO_4 to 2 g of sample that had been weighed into a 50 ml Kjeldahl flask. The flask was heated for approximately fifteen minutes on low heat, thirty minutes on medium heat, and then until it was digested, on high heat. To guarantee full digestion, the flask was heated for a few minutes after being spun periodically until the digest was transparent. After letting the flask cool, the sample residue was cleaned and filtered to bring the digest's volume up to 50 millilitres (V_1). Following the completion of the digestion, three drops of the mixed indicator were added to five millilitres of 2% boric acid (H_3BO_3) in a 100-millilitre conical flask. The receiving flask was placed so that the tip of the condenser tube was below the surface of the boric acid. 5 ml of the digest (V_2) was pipetted into the distillation tube, and 10 ml of 40% NaOH was added. The heater was turned on, and the distillation continued until approximately 50 ml of distillate was collected into the receiving flask. The distillate was titrated with 0.01M HCl, and the blank was titrated with the acid.

$$\%N\ = \frac{M\ \times T\ \times 0.014}{W} \times \frac{V_1}{V_2} \times 100$$

$\%\ protein$ = % $N\ x$ 6.25

Determination of carbohydrate

The carbohydrate content of a food can be determined by calculating the percent remaining after all the other components have been measured, as per the formula below.

%Carbohydrates = 100 − %moisture − %protein − %fat - %ash - %fibre

Statistical analysis

The data collected were subjected to statistical analysis using the Statistical Package for Social Sciences Version 18 (SPSS, Inc., USA). An independent t-test analysis was done to determine significant differences at ($p < 0.05$). The means were separated using the Least Significant Difference (LSD). The mean, standard deviation and standard errors were calculated according to Andrade (2020).

RESULTS AND DISCUSSION

The result presented in Table 1 shows that both methods significantly reduced the moisture content (11.49% for smoked fish and 9.03% for oven-dried fish), with oven drying showing a greater reduction compared to smoking, by 23.977%, thereby enhancing shelf stability (Tan *et al.*, 2023).

Conversely, a decrease in moisture content resulted in a corresponding higher quantity of dry matter in oven-dried *Scomber scombrus* compared to smoked dried Atlantic mackerel by 2.741%, illustrating the inverse relationship between dry matter and moisture content. The results obtained from this study for moisture content were lower than the value of 56.5% reported by Olusola *et al*. (2011), but higher than the values of 5.28% and 5.48% by Aremu *et al*. (2014) and Adeyi *et al*. (2010), respectively. The

Table 1. Proximate composition of Atlantic mackerel.

Parameters	Smoked fish	Oven-dried fish	Percentage difference
Dry matter (%)	88.51±0.22[b]	90.97±0.02[a]	2.741%
Moisture content (%)	11.49±0.21[a]	9.03±0.02[b]	23.977%
Crude fat (%)	35.37±0.12[a]	31.22±0.01[b]	33.124 %
Crude protein (%)	35.37±0.12[a]	31.22±0.01[b]	12.352%
Crude fibre (%)	1.46±0.01[b]	2.43±0.07[a]	49.871%.
Ether extract (%)	21.21±0.01[b]	29.63±0.01[a]	33.124%
Ash content (%)	0.25±0.01[b]	0.61±0.01[a]	83.721%
Carbohydrate (%)	30.22±0.30[a]	27.08±0.06[b]	10.968%
Energy (kcal)	453.27±0.88[b]	499.86±0.20[a]	9.776%

[ab]Means on the same row with different superscripts are significantly different at ($p<0.05$).

variations in moisture content obtained in this study when compare to other reports maybe attributed to differences in the type of environment in which the samples were collected or the season in which the fish was collected (Sanni *et al*., 2023), it may also be due to the method used in drying or smoking the fish. Aremu *et al*. (2014) dried the fish using an electric oven, whereas Adeyi *et al*. (2010) used coconut husk for heat treatment. Similarly, in this study, an electric oven and firewood were used as heat sources. Oven drying removes moisture more efficiently than smoking, resulting in a higher dry matter content. This might be attributed to the higher temperature to which the fish were exposed in the oven and the duration of the processing. Oven-dry method contributes to improved textural stability and reduced water activity, creating an environment less conducive to microbial growth and enzymatic activity. As a result, food preservation is extended, leading to enhanced food security, reduced food waste, and significant economic benefits, including increased shelf life, reduced storage costs, and availability of fish at all seasons.

Proteins and fats are known to be the major nutrients found in fish. Considering the various species, there are variations depending on age, sex, and environment. The variations help to determine their nutritional status (Aberoumad and Pourshafi, 2010). The crude protein obtained for smoked fish was 35.37%. This was slightly higher than the value obtained from oven-dried fish, which was 31.22%. This value was found to be lower when compared to 57.80% obtained from *Scomber scombrus* reported when the sample was smoked with an electric oven (Aremu *et al*., 2014); lower compared with the 70.24% for melon husk heat treatment reported (Aremu *et al*., 2014); 62.14% for *Clarias gariepinus* as observed by Kumolu-Johnson *et al*. (2010); and higher than 26.25% reported for *Scomber scombrus* by Agu and Bhandary (2005). Crude proteins are made up of amino acids, which are building blocks, regulating various metabolic processes, and influencing nutritional status, with their nutritional values and functions extending beyond protein synthesis to impact overall well-being (Wu, 2009). Post-processing analysis of crude proteins showed a significantly higher level in smoked fish than in oven-dried ones by 12.352%, implying that the smoking method preserved these nutritive values more than oven drying. This is particularly important for children who need them for growth and development. The Dietary Reference Intakes for protein indicate that children 4–13 years and 14–18 years require 0.95 and 0.85 $g \cdot kg^{-1} \cdot day^{-1}$, though recently, Hudson *et al*. (2021) suggested it to be ~1.55 $g \cdot kg^{-1} \cdot day^{-1}$ for children 6–10 years and an average sedentary adult, 0.8 grams per kilogram of body weight are recommended as dietary allowance to prevent deficiency (Wu, 2016).

The value of the crude fat of smoked fish was observed to be 35.37%, while that of oven-dried fish was recorded to be 31.22%. The values of crude fat for both smoked and oven-dried were higher than the range of crude fat for *Scomber scombrus*, ranging between 7.41 and 17.51% using different heat sources, as reported by Aremu *et al*. (2014). Fat contents were higher in oven-dried Atlantic mackerel than in smoked fish by 33.124 %, denoting that the oven drying method offers a better taste to food and better preservation of the health benefits mentioned above. Besides taste and health advantages provided by lipids, they also aid in the transportation of fat-soluble vitamins, insulate and protect internal organs.

The ash content of smoked fish was 0.25%, and that of oven-dried fish was 0.61%. This shows that oven-dried fish has a higher ash content compared to smoked fish. The values obtained in this study were lower than the values of 5.20% obtained from *Scomber scombrus* using an electric oven as reported by Sanni *et al*. (2023), and also lower than the ash content of 5.70% obtained for heat treatment using sawdust by Aremu *et al*. (2014) and 6.01% reported for mackerel fish by Agu and Bhandary (2005).

Energy from fish is derived from carbohydrates, fats and proteins. Lipids yield more energy than carbohydrates. Energy derived from both oven-dry and smoked fish was above 20% of the daily energy required; this makes consumption of Atlantic mackerel a great advantage, especially in developing countries where malnutrition is not primarily linked to protein deficiency but to insufficient energy (Okweche *et al.*, 2024). Oven-dried fish yielded more energy than smoked fish by 9.776%, though the percentage was not big, the difference was nevertheless statistically significant, making oven-dried fish a superior method.

Oven-dry processed *Scomber scombrus* had a higher crude fibre content compared to smoked fish by 49.871%. Fibre is very low in mackerel (Data from the USDA shows that one 3.5-ounce serving (100 grams) of raw Atlantic mackerel provides 205 calories, 13.9 g of fat, 90 mg of sodium, 19 g of protein, and no carbohydrates, fibre, or sugar) (USDA, 2024). Crude fibre plays a vital role in the body, offering several key benefits, including the prevention of diverticulitis, enhanced mineral absorption in the gastrointestinal tract, and efficient elimination of undigested food residues from the intestine (Das *et al.*, 2024). Reynolds *et al.* (2022) in their meta-analysis concluded that consuming high fibre foods could be a valuable strategy for managing cardiovascular disease and hypertension, leading to improved overall health and reduced risk of premature death.

Carbohydrate is an important macromolecule present in fish, but is often neglected. Fishes are usually valued only for their rich protein content, yet some contain reasonable amounts of carbohydrates like *Cirrhinus Mrigala* (Tidame *et al.*, 2021). Atlantic mackerel has a high amount of carbohydrates, though the specific carbohydrates are yet to be identified. The amount of carbohydrates coupled with the fat content can justify why the fish is a high-calorie meal, yielding so much energy. The smoked fish had a higher amount than the oven-dried fish by 10.968%, making smoking a better method to preserve carbohydrates over oven oven-drying method.

Conclusion

The study revealed that both processing techniques enhance nutrient preservation, oven drying is more effective for long-term storage due to its higher retention of dry matter, fibre, ether extract, ash, and energy, whereas smoking better preserves protein and fat, making it ideal for immediate consumption; therefore, it is recommended that the choice of processing method be guided by the intended use of the fish, with further research needed to assess their effects on sensory attributes, storage stability, and consumer preference.

COMPETING INTEREST

The authors have no conflict of interest to declare.

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REFERENCES

Aberoumad, A., & Pourshafi, K. (2010). Chemical and proximate composition properties of different fish species obtained from Iran. *World Journal of Fish and Marine Sciences*, *2*(3), 237-239.

Aberoumand, A. (2011). Nutritive aspects of two food plants: a preliminary comparative study. *Electronic Journal of Environmental, Agricultural & Food Chemistry*, *10*(3), 2019-2025.

Ackman, R. G. (1990). Seafood lipids and fatty acids. *Food Reviews International*, *6*(4), 617-646.

Adeyi, O. (2010). Proximate composition of some agricultural wastes in Nigeria and their potential use in activated carbon production. *Journal of Applied Sciences and Environmental Management*, *14*(1), 55-58.

Agu, H. O., & Bhandary, C. S. (2005). Effect of smoking time on keeping quality of smoked mackerel (*Scomboromorus scombrus*). *Nigerian Food Journal*, *23*(1), 114-120.

Andrade, C. (2020). Understanding the difference between standard deviation and standard error of the mean, and knowing when to use which. *Indian Journal of Psychological Medicine*, *42*(4), 409-410.

AOAC (2005). Official Methods of Analysis (18th edition). Association of Official Analytical Chemists, Washington D. C., USA.

Aremu, M. O., Namo, B. S., Oko, O. J., Adelagun, R. O. A., & Yebpella, G. G. (2014). Compositional evaluation of local smoked Nigerian mackerel (*Scomber scombrus*). *Food Science and Quality Management*, *24*, 42-50.

biochemical composition of some fishes. *International Journal of Fisheries and Aquatic Studies*, *9*(6), 7-12.

Bouriga, N., Selmi, S., Faure, E., & Trabelsi, M. (2010). Biochemical composition of three Tunisian silverside (fish) populations caught in open sea, lagoon and island coasts. *African Journal of Biotechnology*, *9*(26), 4114-4119.

Das, A. K., Kashyap, K., Bhardwaj, A. K., Biswas, S., Roymahapatra, G., Bhattacharyya, S., & Hait, M. (2024). Proximate analysis, and mineral content determination of Delonix regia flower. *ES Food & Agroforestry*, *17*, 1132.

Erkan, N., Selçuk, A., & Özden, Ö. (2010). Amino acid and vitamin composition of raw and cooked horse mackerel. *Food Analytical Methods*, *3*, 269-275.

Eyo, A. A. (2001). *Fish processing technology in the tropics*. National Institute for Freshwater Fisheries Research (NIFFR). Pp. New Bussa, 37-39.

Ferno, A., Bjelland, O., & Kristiansen, T. S. (2020). *The diverse world of fishes*. Springer Nature. Pp. 43-72.

Hudson, J. L., Baum, J. I., Diaz, E. C., & Børsheim, E. (2021). Dietary protein requirements in children: methods for consideration. *Nutrients*, *13*(5), 1554.

Islam, M. S., & Tanaka, M. (2004). Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: A review and synthesis. *Marine Pollution Bulletin*, *48*(7-8), 624-649.

Kumolu-Johnson, C. A., Aladetohun, N. F., & Ndimele, P. E. (2010). The effects of smoking on the nutritional qualities and shelf-life of *Clarias gariepinus* (Burchell 1822). *African Journal of Biotechnology*, *9*(1),73-76.

Luzia, L. A., Sampaio, G. R., Castellucci, C. M., & Torres, E. A. (2003). The influence of season on the lipid profiles of five commercially important species of Brazilian fish. *Food chemistry*, *83*(1), 93-97.

Marchioli, R. (2001). Treatment with n-3 polyunsaturated fatty acids after myocardial infarction: results of GISSI-Prevenzione Trial. *European Heart Journal Supplements*, *3*(suppl_D), D85-D97.

Moghaddam, H. N., Mesgaran, M. D., Najafabadi, H. J., & Najafabadi, R. J. (2007). Determination of chemical composition, mineral contents, and protein quality of Iranian kilka fish meal. *International Journal of Poultry Science*, *6*(5), 354-361.

Okweche, S. I., Ugwu, Q. O., & Nwaogu, C. (2024). Nutritional composition of cricket, Brachytrupes membranaceus (Drury, 1770), and selected animal source foods in Cross River State, Nigeria. *International Journal of Tropical Insect Science*, *44*(3), 1271-1278.

Olusola, A. O., Ezekiel M. O., Akande, G. R., Salaudeen, M. M., Adeyemi, R. S. & Babalola, A. F. (2011). Technological properties and proximate composition of two imported fish species in Nigeria. *Electronic Journal of Environmental & Agricultural, Food Chemistry*, *10*(6), 2398-2403.

Reynolds, A. N., Akerman, A., Kumar, S., Diep Pham, H. T., Coffey, S., & Mann, J. (2022). Dietary fibre in hypertension and cardiovascular disease management: systematic review and meta-analyses. *BMC Medicine*, *20*(1), 139.

Saba, A. O., Eyo, V. O., Elegbede, O. I., Fakoya, K. A., Ojewole, A. E., Dawodu, F. O., Adewale, R. A. & Amal, M. N. A. (2024). Sustaining the blue bounty: Fish food and nutrition security in Nigeria's evolving blue economy. *AIMS Agriculture and Food*, *9*(2), 500-530.

Sanni, J., Sanni, G., Awoniyi, R., Remi, V. O., & Richards, Y. E. (2023). Proximate and Mineral Composition of Atlantic Mackerel (*Scomber scombrus*) and Atlantic Horse Mackerel (*Trachurus trachurus*). *Biology Medicine & Natural Product Chemistry*, *122*, 457-461.

Tan, K., Huang, L., Tan, K., Lim, L., Peng, Y., & Cheong, K. L. (2023). Effects of culinary treatments on the lipid nutritional quality of fish and shellfish. *Food Chemistry: X*, *19*, 100856.

Tidame, A., Kakulte, V., Yasmeen, S., Tidame, S., & Gangurde, J. (2021). An assessment of the

USDA (2024). FoodData Central. Mackerel, Atlantic, raw. Retrieved from https://fdc.nal.usda.gov/fdc-app.html#/food-details/175119/nutrients.

Varlik, C., Erkan, A., Ozden, O., Mol, S. & Baygar, T. (2004). *Processing Technology of Seafood*. Istanbul University. Seafood Faculty Publisher, Istanbul, p. 491.

Wu, G. (2009). Amino acids: Metabolism, functions, and nutrition. *Amino Acids*, *37*, 1-17.

Wu, G. (2016). Dietary protein intake and human health. *Food & Function*, *7*(3), 1251-1265.