Effect of Stunning Methods on the Proximate Composition and Organoleptic Properties of Fresh and Smoke-Dried Catfish (*Clarias gariepinus*)

Ruth Chidinma OTI[1*]; Olalekan Rahman OGUNTADE[2]; Patrick Amaechi Okeke[3]; Chika Florence IKEOGU[4]; Chidimma Gift NWANKWO[5]

Department of Fisheries and Aquaculture Management, Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria
*Corresponding Author

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Abstract— *Stunning is a critical step in fish processing that immobilizes fish before slaughter. This study investigated the effect of different stunning methods on the proximate composition and organoleptic properties of fresh and smoke-dried catfish. A total number of 20 live catfish (Clarias gariepinus) with a mean weight of 0.84±0.03 kg were obtained from a fish farm and were stunned by salting, icing, hammering, and exsanguination methods. Proximate analysis was carried out on parts of the freshly stunned fish. The rest of the fish samples were smoked dried, and then subjected to proximate analysis and organoleptic properties evaluation. The result of the organoleptic properties evaluation revealed that fish stunned by Salting (9.4±0.52) were the most preferred, while those stunned by icing (8.8±0.79) were the least preferred with no significant difference in overall acceptability among the stunning methods. The proximate analysis of fish samples showed that stunning methods had varying impacts on the proximate composition of fresh and smoke-dried fish samples. Fresh fish samples stunned by icing had the highest protein content (33.95±0.49) with the lowest moisture content (39.48±3.97), while the hammering method had the lowest protein content (19.25±0.49) with the highest moisture content (51.11±0.77). Smoke-dried fish samples stunned by icing method had the highest protein content (64.23±0.74), fat content (17.91±3.01) with a moisture content of 4.01±0.55, while the Salting method had the lowest protein content (54.78±0.74), and highest fat content (19.44±3.08) with a moisture content of 4.21±0.66. This study revealed that smoke drying improved the nutritional composition of catfish across all stunning methods.*

Keywords— Stunning methods, Proximate composition, Organoleptic properties, Clarias gariepinus.

I. INTRODUCTION

Fish is consistently among the most used and cheap dietary sources of animal protein for most people worldwide (Allam *et al.*, 2020; Maulu *et al.*, 2020). It is a valuable source of essential nutrients, especially high-quality protein and fats (macronutrients), vitamins, and minerals (micronutrients) that make a vital contribution to the world's food and nutrition security (FAO, 2020). As a food product, fish is of greater importance in developing countries where it accounts for 75% of the daily animal protein, referred to as "rich and poor food" as an important companion (Willett *et al.*, 2019; Mansour, 2021). It is readily available even in poorer communities at a relatively cheaper price than other animal protein sources. Furthermore, fish production through aquaculture is considered sustainable and the most efficient way to produce high-quality proteins for human consumption (Ali *et al.*, 2021; Khalil *et al.*, 2021).

The African catfish (*Clarias gariepinus*) is a significant fish species cultured in Africa. It has also been introduced into aquaculture in different parts of the world. It is primarily freshwater fish that are well adapted to confined environments and are resistant to manipulation and disease. Catfish are highly nutritious, containing a high concentration of unsaturated fatty acids, vitamins, proteins, and minerals (Nelson *et al.*, 2016). Since dietary composition is a significant determinant of the nutritional quality of fish flesh, numerous reports are available on African catfish slaughter traits and fillet quality (Sándor *et al.*, 2022). Recently, farmed fish have been subjected to various stunning techniques while processing. Many of these methods are assumed to present welfare problems since they expose fish to prolonged suffering and pain before death (WOAH, 2022).

The physiological response to pain is to release oxidizing substances that negatively impact the quality of the flesh, not to mention the implications regarding animal welfare (Alves *et al.*, 2015).

For a slaughter method to be considered humane, effective stunning that lasts until death, as well as the reduction of pain and fear throughout all procedures, is essential. (Coelho *et al*., 2022). The stunning method was adequate if the fish had no movement or behavioral reaction to a painful stimulus. It was assumed that a fish in that condition would not be able to feel pain or would feel it less intensely. The severity of the stunning and slaughter stresses is recognized to affect many quality traits such as the fish and fillet appearance promoting physical injuries, flesh gaping and changes in colour, rigor evolution, texture (firmness, cohesiveness, elasticity), water holding capacity, sensorial freshness indicators and, finally, in the shelf life. To date, although several recommendations have been proposed to reduce stress before and during fish slaughtering (WOAH, 2022), no specific Regulations are available about the procedure to be adopted (Bermejo-Poza *et al*., 2021). Thus, this study aimed to examine the effect of stunning methods on the proximate composition and organoleptic properties of fresh and smoke-dried catfish samples.

II. MATERIAL AND METHODS

2.1 Sample Collection and Preparation:

Twenty mature *Clarias gariepinus* with a mean weight of 0.84±0.03 kg and a mean length of 32.91±0.77 cm were purchased from a commercial fish farm (HouseTully fish farm) in the Awka metropolis for this study. The fish were harvested from the same rearing tank and taken to the slaughter slab on the farm, where fish stunning and slaughtering processes took place. The pre-stunning procedures were the same for all the fish samples. The weight, length, and number of fish used for each stunning method were recorded before the stunning procedures.

2.2 Fish Stunning/Killing Procedures:

The fish stunning was carried out at the House Tully fish farm, where it was purchased. Immediately after the contemporary catch and pre-stunning procedure, the fish were subjected in parallel to the following stunning/killing methods:

a) **Salting:** Fish were placed in a bowl and sprinkled with salt (100 g of salt per 1kg), after which the bowl was covered to prevent the fish from escaping.

b) **Ice block:** Fish were placed in a cooler made from Polyethylene terephthalate (plastic) containing ice flakes and 3 liters of water.

c) **Hammering:** Fish were hit on its head using a small wooden hammer.

d) **Exsanguination without stunning method:** The fish were cut alive with a knife without allowing the fish to lose consciousness, and the fish bled to death.

2.3 Fish Processing Procedures:

The fish were taken to the processing house of the House Tully fish farm after stunning, where they were gutted, washed, and brined. The fish samples were cut into fillets before being subjected to smoking processing method. Fish smoking was done using a metallic oven smoking kiln with charcoal as its heat source. The fish were occasionally turned to achieve even drying and smoking of the fish lasted for about 2 days.

2.4 Physical and Organoleptic Analysis:

Sensory evaluation was performed by a 10 man-trained committee panel using a 9-point Hedonic scale. The following grades were allotted depending on the condition of the fish. 9-10 = very good, 7-8 = good, 5-6 = fair, 3-4 = bad and <2 = worst. Panelists were instructed to assess the fish by feeling and tasting it. Fish product samples were served in clean dishes alongside questionnaires to the panelists. The fish aroma, flavor/taste, appearance/color, acceptance, and texture were examined in a ranking test, a form of discriminating test aimed at evaluating specific attributes of the processed fish. The characteristics of the Smoke-dried fish products tested include taste, texture, aroma, and color acceptance. The questionnaires were returned and analyzed for each parameter.

2.5 Proximate Analysis:

The crude protein, moisture, ash, fiber, carbohydrate, and fat contents of the fresh and smoke-dried fish samples were determined.

2.5.1 Determination of Total Ash Content:

This was done using the furnace incineration gravimetric method described by AOAC (2005). The empty platinum crucible was washed and dried, and the weight was noted. 2 g of the sample was weighed into the platinum crucible and placed in a muffle furnace at 500ºC for 3 hours. The sample was cooled in a desiccator after burning and weighed and calculated using Equation 1:

$$\% \text{ Ash content} = \frac{\text{Weight lost}}{\text{Weight of sample}} \times 100 \quad (1)$$

2.5.2 Determination of Moisture Contents:

This was done using the gravimetric method described by the AOAC (2005). A crucible was washed and dried in the oven. 2 g of the sample was weighed into the crucible. The weight of the crucible and sample were noted before drying. The crucible and sample were put in the oven for 2 hours at 105ºC. The drying procedure continued until a constant weight was obtained. Moisture content was calculated using Equation 2:

$$\% \text{ Moisture content} = \frac{\text{Weight lost}}{\text{Weight of sample}} \times 100 \quad (2)$$

2.5.3 Determination of Crude Protein:

This was done using the Kjeldahl method described by AOAC (2005). A 2 g sample was weighed into a 300 ml kjehdal flask (gently to prevent the sample from touching the walls of each side, and then the flasks were stopped and shaken. Then, 0.5 g of the kjedahl catalyst mixture was added. The mixture was heated cautiously in a digestion rack on an electric hot plate until a clear solution appeared. The clear solution was then allowed to stand for 30 minutes and cool. After cooling, about 100 ml of distilled water was added to avoid caking, and then 5 ml of the filtrate and 5 ml of 40% Na0H were transferred to the Kjedahl distillation apparatus. A 250 ml receiver beaker containing 10 ml of 10% boric acid and an indicator mixture containing five drops of Bromocresol blue and one drop of methylene blue was placed under a condenser of the distillation apparatus so that the tap was about 20 cm inside the solution. Then 5 ml of 40% sodium hydroxide was added to the digested sample in the apparatus, and distillation commenced immediately until 50 drops got into the beaker, after which it was titrated to pink color using 0.01N hydrochloric acid. Percentage Nitrogen was calculated using equation 3.

% Nitrogen = Titre value x 0.01 x 14 x 4 (3)

% Protein = % Nitrogen x 6.25

2.5.4 Determination of Crude Fat:

The solvent extraction gravimetric method described by AOAC (2005) determined this—dry 250 ml clean boiling flasks in the oven at 105-110ºC for about 30 minutes. Transfer into a desiccator and allow to cool. Weigh about 2 g of samples accurately into labeled thimbles. Weigh correspondingly labeled, cooled boiling flasks. Fill the boiling flasks with about 300 ml of petroleum ether (boiling point 40-60ºc). Plug the extraction thimble lightly with cotton wool. Assemble the soxhlet apparatus and allow it to reflux for about 6 hours. Remove the thimble carefully, collect petroleum ether in the top container of the set-up, and drain into a container for re-use. Remove and dry at 105ºC - 110ºC for 1 hour when the flask is almost petroleum-free. Transfer from the oven into a desiccator, cool, and weigh. The percentage of fat was calculated using Equation 4:

$$\% \text{ Fat} = \frac{\text{Weight lost}}{\text{Weight of sample}} \times 100 \quad (4)$$

2.5.5 Determination of carbohydrates:

In the determination of carbohydrates, the carbohydrate content of a sample was regarded as a nitrogen-free extract. This was determined by adding up the percentages of moisture, Ash, protein, and Fat and subtracting the sum from 100. The Percentage of Carbohydrates was calculated using Equation 5.

% Carbohydrate = 100- (% Protein + % Ash + % Moisture + % Fat + % Fibre) (5)

2.5.6 Determination of Crude Fibre:

Weigh 2 g of the plant sample into a conical flask containing 200 ml of 1.25 g of H_2SO_4 solution per 100 ml. Boil under reflux for 30 minutes. Filter the solution through linen or several layers of cheese cloth on a fluted funnel. Wash with boiling water until the washings are no longer acidic at pH 7.0. Transfer the residue to a beaker and boil for 30 minutes with 200 ml of a solution containing 1.25 g of carbonate-free NaOH per 100 ml. Filter the final residue through a thin but close pad of washed and ignited asbestos in a crucible. Dry in an electric oven at a temperature of 105ºC and weigh. Incinerate in a muffle furnace at a temperature of 300ºC for 2 hours, cool, and weigh. The loss in weight after incineration x 100 is the percentage of crude fibre:

$$\% \text{ Crude fibre} = \frac{\text{Weight lost}}{\text{Weight of sample}} \times 100 \quad (6)$$

2.6 Data analysis:

All analyses were repeated in triplicate, and the results were presented as mean ± standard deviation (SD). Analysis of variance (ANOVA) was carried out using F-test to determine the treatment's significance level. Treatments were separated using the Duncan Multiple Range Test (DMRT) at a 95% confidence value ($p < 0.05$). All statistical analysis was performed using SPSS version 20.

III. RESULTS AND DISCUSSION

3.1 Organoleptic/Sensory Evaluation of the Fish Samples:

The result of the organoleptic assessment of smoke-dried fish samples stunned differently is presented in Table 1. The appearance of the fish samples ranged from 7.7 to 8.5, with no significant difference observed across the various stunning methods ($p > 0.05$). In terms of taste, the samples ranged from 8.1 to 9.4, and a significant difference was observed among the samples ($p < 0.05$), indicating that the taste of the smoke-dried fish varied depending on the stunning method used. The aroma of the samples ranged from 8.8 to 9.1, with no significant difference observed among the samples ($p > 0.05$). Similarly, the texture of the samples ranged from 8.2 to 8.5, with no significant difference observed among the samples ($p > 0.05$). Overall acceptability scores ranged from 8.8 to 9.4, with no significant difference observed among the samples ($p > 0.05$).

TABLE 1
ORGANOLEPTIC EVALUATION OF SMOKE-DRIED FISH SAMPLES STUNNED DIFFERENTLY

Stunning methods	Appearance	Taste	Aroma	Texture	Overall acceptability
Salting	8.4 ± 0.97^a	$9.4\ 0.52^a$	9.1 ± 0.57^a	8.5 ± 0.85^a	9.4 ± 0.52^a
Icing	7.7 ± 0.82^a	$8.1\ 0.88^c$	9.0 ± 0.67^a	8.2 ± 0.92^a	8.8 ± 0.79^a
Hammering	8.3 ± 0.82^a	$8.6\ 0.97^b$	8.8 ± 0.63^a	8.2 ± 0.63^a	9.0 ± 0.67^a
Exsanguination	8.2 ± 1.03^a	$8.4\ 0.84^b$	8.8 ± 0.63^a	8.3 ± 0.95^a	8.9 ± 0.74^a

Attribute in mean ± standard deviation of 10 committee panel responses on a 9-Hedonic scale (very good=9-10, good=7-8, fair=5-6, bad=3-4, worst=1-2). The means in rows with different superscripts are significantly different (p<0.05).

The organoleptic properties of the fish samples were assessed to identify the most preferred stunning method based on sensory characteristics. The acceptance of aroma, texture, tenderness, colour, appearance and general acceptability, vary among the smoked fish samples that were subjected to different stunning methods. The results of the study revealed that fish stunned by salting was significantly higher and most preferred in terms of all the parameters used in assessing the organoleptic properties. This finding revealed that salting has a positive impact on the sensory characteristics of fish products. Salting is known to enhance the flavor and aroma of fish (Hafez *et al*., 2019) by enhancing the natural taste of the fish and drawing out excess moisture. Additionally, salting serves as a cleansing agent for removing slime from the fish samples, which can improve the overall appearance of the product. The texture of fish is also improved by salting, leading to a firmer and clearer appearance after smoke-drying. Fish stunned by icing was found to be the least preferred in terms of appearance, taste, texture, and overall acceptability. This finding may be attributed to the stunning effect and smoke-drying process on the flesh quality of the fish samples. Alves *et al*. (2015) reported that immersion in ice water during stunning process causes low temperatures that decrease metabolism, immobilize fish, and negatively impact the quality of the fish flesh. Similarly, Bermejo-Poza *et al*. (2021) also noted that immersion in ice water (live chilling) is still commonly used as a stunning method in fish, but can have negative effects on the stress response and flesh quality. Fish stunned by hammering and exsanguination were the least preferred in terms of aroma. This could be due to the stress and struggle experienced by the fish during stunning, which may have affected the aroma of the fish. Alves *et al*. (2015) noted that if stunning occurs without loss of conscience, the fish may feel pain during slaughtering, leading to the release of oxidizing substances that can negatively impact the quality of the flesh. Additionally, other organoleptic parameters for hammering and exsanguination were observed to be moderate between salting and icing. The effect of stunning methods on the organoleptic properties of smoke-dried fish samples varied slightly, with taste being the most affected, especially in the salting method.

3.2 The Proximate Composition of the Fish Samples:

In recent years, concerns about fish welfare have increased in aquaculture, particularly in relation to the slaughter process (Bermejo-Poza *et al.*, 2021). The stunning methods used during slaughter can have a significant impact on the proximate composition of fresh and smoke-dried catfish. This is primarily due to the effect of stress hormones released during the stunning process, which can lead to changes in muscle breakdown and fat distribution. The results of the stunning methods, including Salting, Icing, Hammering, and Exsanguination, showed varying impacts on the proximate composition of fresh and smoke-dried catfish samples. Ajibare *et al.* (2023) reported that proximate composition of fish not only help in identifying the nutritional components of the fish but also ascertain the quality of the fish product. According to the proximate analysis of the fresh fish samples, the different stunning methods had varying effects on the moisture, protein, ash, and fiber content of the fish. The results revealed that the fish stunned by hammering had the highest moisture content of 51.11%, salting at 50.35%, exsanguination at 49.46%, while icing recorded the lowest moisture content at 39.48% as shown in Table 2. The moisture content of fresh fish samples of the stunning methods is significantly different ($p < 0.05$). Addo *et al.* (2023) reported moisture content of 77.4 ± 1.94% in fresh *Clarias gariepinus* which is higher than the result of this study. For ash content, exsanguination recorded the highest value at 13.37%, followed by hammering at 12.23%, icing at 10.83%, and the lowest value was salting at 7.46%. There is a significant difference between the ash content of the fresh fish samples of the stunning methods ($p < 0.05$). These findings recorded higher ash content than those reported by Umar *et al.* (2024). For fiber content, fish stunned by icing had the highest value at 2.10%, followed by salting at 1.86%, hammering at 1.61%, and exsanguination at 1.56%. The fiber content of the fresh fish samples from the different stunning methods is significantly the same ($p > 0.05$). Namaga *et al.* (2020) observed a higher level of fibre in fresh *Clarias gariepinus*. The results also revealed that for fat content, fish stunned by exsanguination had the highest value of 15.24%, followed by salting at 15.14%, hammering at 14.78%, and icing with the lowest value of 9.76%. However, there was no significant difference ($p > 0.05$) between the fat content of the fresh fish samples of the different stunning methods. Umar *et al.* (2024) reported a higher value (27.01±0.40%) of fat content in *Clarias gariepinus* in their study. In terms of protein content, fish stunned by icing recorded the highest value of 33.95%, followed by salting at 22.40%, exsanguination at 20.13%, and hammering at 19.25%. The protein content of the fresh fish samples of the stunning methods was found to be significantly different ($p < 0.05$). The finding of this result was higher than those of Addo *et al.* (2023) but lower that those reported by Namaga *et al,* (2020). Lastly, for carbohydrates, fish stunned by Icing has the highest value of 3.88%, Salting at 3.34%, Hammering at 1.02%, and then Exsanguination with the lowest value of 0.24%. The carbohydrate content of the stunning methods is significantly the same ($p > 0.05$). Addo *et al.* (2023) reported total carbohydrate of 4.45 ± 1.55% which is higher than this study.

TABLE 2
THE PROXIMATE COMPOSITION OF FRESH CATFISH SAMPLES STUNNED DIFFERENTLY

Stunning methods	Moisture (%)	Ash (%)	Fibre (%)	Fat (%)	Protein (%)	Carbohydrate (%)
Salting	$50.35±1.01^{a}$	$7.46±1.96^{c}$	$1.86±0.59^{a}$	$15.14±6.81^{a}$	$22.40±2.47^{b}$	$3.34±1.18^{a}$
Icing	$39.48±3.97^{b}$	$10.83±1.23^{bc}$	$2.10±0.24^{a}$	$9.76±0.79^{a}$	$33.95±0.49^{a}$	$3.88±1.20^{a}$
Hammering	$51.11±0.77^{a}$	$12.23±0.55^{ab}$	$1.61±0.46^{a}$	$14.78±0.42^{a}$	$19.25±0.49^{b}$	$1.02±0.60^{a}$
Exsanguination	$49.46±0.31^{a}$	$13.37±0.52^{a}$	$1.56±0.59^{a}$	$15.24±0.76^{a}$	$20.13±0.25^{b}$	$0.24±0.06^{a}$

M±SD = Mean±Standard deviation, Mean with different superscript within the same column are significantly different (p < 0.05); SM= Salting method, IM= Icing method, HM= Hammering method, EM= Exsanguination method.

Fresh fish samples stunned by salting resulted in relatively high moisture (50.35%) and protein (22.40%) content. The ash content was moderate at 7.46%, while fat content was 15.14% and carbohydrate content was 3.34%, falling within typical ranges. The Salting method may be effective in preserving the quality of fresh fish (Hafez *et al.*, 2019) and maintaining essential nutrients like protein. Fish stunned by the Icing method led to lower moisture (39.48%) but relatively higher ash (10.83%), and protein (33.95%) content in the fresh fish sample. Fat (9.76%) and carbohydrate (3.88%) were moderate. The Icing method may play a role in reducing the moisture content while preserving protein levels, making it suitable for specific applications.

Fish samples stunned by Hammering method resulted in high moisture (51.11%) and ash (12.23%) content, with moderate fat (14.78%) and protein (19.25%) levels. The carbohydrate content (1.02%) was lower compared to other methods. Hammering may positively impact moisture retention and maintain higher ash and protein content in the fish quality. The Exsanguination method showed moderate levels of moisture (49.46%), ash (13.37%), fat (15.24%), and protein (20.13%) content. The fiber content (1.56%) was relatively low, and the carbohydrate content (0.24%) was the lowest among the methods. Exsanguination may help retain essential nutrients like protein and fat while reducing carbohydrate content. It was also observed from the result that high moisture content lowers the protein content of the fish. The Hammering method recorded the highest moisture content (51.11%) and the lowest protein content (19.25%) while the Icing method recorded the lowest moisture content (39.48%) and the highest protein content (33.95%). This finding is in agreement with the work of Ajibare *et al.* (2023) who reported that the crude protein of fish samples increased as the moisture reduces.

Table 3 presents the proximate composition of smoke-dried catfish samples stunned differently. The result revealed that the moisture content of fish stunned by Exsanguination had the highest value at 4.41%, followed by Salting at 4.21%, icing at 4.01%, and Hammering with the lowest value of 3.64%. There is a significant difference between the moisture content of the smoke-dried fish samples of the stunning methods ($p < 0.05$). The values of the moisture content across the stunning methods of the smoked dried fish was much lower than the findings of Ajibare *et al.* (2023) who noted that the degree of moisture content in smoked fish could be as a result of the extent of dryness, smoking duration as well as the type of smoking kiln used. For ash content, fish stunned by Hammering recorded the highest value of 16. 37%, followed by Exsanguination at 13.49%, Salting at 13.41%, and then Icing with the lowest value of 11.68%. The ash content of the smoke-dried fish samples showed a significant difference across the stunning methods ($p < 0.05$). The ash content recorded in this study was higher than those reported by Addo *et al.* (2023) and Umar *et al.* (2024). However, no significant difference ($p > 0.05$) was observed in the fiber content of the smoke-dried fish samples stunned using different methods. The Exsanguination method had the highest fiber content at 2.17%, followed by Hammering at 2.17%, Salting at 1.76%, and Icing at 1.43%. This present study recorded higher fibre content than those reported by Umar *et al.* (2024). The fat content of the smoke-dried fish samples of the stunning methods is significantly different ($p < 0.05$). Among the stunning methods, the Salting method has the highest fat content of 19.44%, followed by the Exsanguination method at 18.68%, followed by the Icing method at 17.91%, and then Hammering with the lowest value of 14.98%. Umar *et al.* (2024) reported higher fat content but lower protein content than this study. For protein content, fish stunned by Icing recorded the highest value of 64.23%, followed by the Hammering method at 59.68%, followed by Exsanguination at 54.96%, and Salt with the lowest value of 54.78%. There is a significant difference between the protein content of the smoke-dried fish samples of the stunning methods ($p < 0.05$). The protein content and fat content obtained in this present study were within the range reported by Emre *et al*., (2018) who opined that the total protein content in fish ranged from 63.80 % - 78.15%, and total fat content varied from 4.57% - 21.29% in different seasons. Lastly, for carbohydrate content, fish samples stunned by Hammering had the highest value of 6.61%, followed by the Salting method with 6.40%, the Exsanguination method with 6.29%, and then the Icing method with the lowest value of 0.73%. The carbohydrate content of the smoke-dried fish samples of the stunning methods is significantly different ($p < 0.05$). Addo *et al.* (2023) reported a lower fat and protein content than this study but higher carbohydrate content in smoked *C. gariepinus.*

TABLE 3
THE PROXIMATE COMPOSITION OF SMOKE-DRIED CATFISH SAMPLES STUNNED DIFFERENTLY

Stunning methods	Moisture (%)	Ash (%)	Fibre (%)	Fat (%)	Protein (%)	Carbohydrate (%)
Salting	$4.21±0.66^{a}$	$13.41±2.59^{b}$	$1.76±1.02^{a}$	$19.44±3.08^{a}$	$54.78±0.74^{c}$	$6.40±3.25^{a}$
Icing	$4.01±0.55^{a}$	$11.68±1.71^{c}$	$1.43±0.34^{a}$	$17.91±3.01^{b}$	$64.23±0.74^{a}$	$0.73±0.34^{b}$
Hammering	$3.64±0.64^{b}$	$16.37±1.08^{a}$	$2.17±0.73^{a}$	$14.98±1.28^{c}$	$59.68±3.71^{b}$	$6.61±0.78^{a}$
Exsanguination	$4.41±0.14^{a}$	$13.49±1.58^{b}$	$2.19±0.24^{a}$	$18.68±0.46^{b}$	$54.96±0.59^{c}$	$6.29±0.63^{a}$

The effect of processing or smoke-drying on the proximate composition of fresh fish samples was observed in this study. The nutritional composition the fish samples improved after smoke-drying. There was a great variation between the moisture content of fresh and smoke-dried fish samples across the stunning methods. The moisture content of the fresh fish samples

(39.48 - 51.11%) were higher than those of the smoke-dried fish samples (3.64 - 4.41%). The ash, fat and protein content of the fish samples increased across the stunning methods after smoke-drying. The findings is in agreement with the work of Famurewa *et al.* (2017) who observed an increasing protein content at a level of 5.5% and crude ash at 14% in their study after fish smoking. Addo *et al.* (2023) also recorded higher nutritional composition in smoked fish samples and recommended that farmed catfish should be smoked before consumption to obtain maximum nutritional benefit.

IV. CONCLUSION AND RECOMMENDATIONS

In conclusion, this study evaluated the effect of different stunning methods on catfish's nutritional composition and organoleptic properties. The findings showed that each stunning method had unique effects on the nutritional composition of fish. Stunning methods of Hammering may be considered effective and humane since they exert little stress, pain, and struggle on the fish. In organoleptic evaluation, the salting method may be considered the best stunning method compared to other methods. Smoking may be a means of improving the nutritional composition of catfish since the proximate composition of the fish was improved after smoke-drying. The impact of stunning methods on fish quality highlighted the importance of considering nutritional factors, food safety concerns, and consumer preferences in fish stunning, processing, and storage. By understanding the effects of different stunning and processing techniques on fish quality, producers can make proper decisions to meet consumers' diverse needs and expectations. The choice of stunning method should be considered based on the desired nutritional profile and the intended use of fish products because of its significant impact on the quality and freshness of fish samples.

Further research and evaluation of stunning methods are important for ensuring fish quality and safety throughout the supply chain. Fish producers should avoid stunning methods that are considered inhumane since they affect the quality and safety of the fish's final product. Fish producers should also consider fish quality and safety, nutritional composition, and consumer preference before choosing the stunning, processing, and storage methods to maintain the quality of fish products. Using salt to stun catfish is highly recommended since it improves the fish's organoleptic properties (it adds to its taste and serves as a cleansing agent) and is a preservative. It is also recommended that farmed catfish should be smoked before consumption to obtain maximum nutritional benefit.

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CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any conflict of interest.

AUTHOR'S CONTRIBUTION

ORC and OOR designed the study and collection of fish samples from the commercial fish farm in Awka metropolis. OPA and ICF performed the laboratory analysis. ORC and NCG were responsible for data analysis and writing of the manuscript. All authors reviewed and approved the manuscript for submission.

ORCID NUMBERS

Oti Ruth Chidinma NO.0009-0002-3815-5553

Oguntade Olalekan Rahman NO.0000-0003-2350-1003

Okeke Patrick Amaechi NO. 0009-0009-2972-6829

Ikeogu Chika Florence NO.0000-0002-2564-2785

Nwankwo Chidimma Gift NO. 0009-0005-3251-721X

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