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Nutritional and Bacteriological Characterization of Smoked and Dried *Clarias gariepinus* Fish Sold in the Town of N'Djamena (Chad)

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Abstract

In Africa—and more specifically in Chad—fish consumption remains relatively low, despite the fact that fish is a rich source of proteins, vitamins, and essential fatty acids. This study aimed to assess the microbiological and nutritional quality of processed fish consumed in N'Djamena, the capital of Chad. A total of 16 samples of *Clarias gariepinus* (African catfish), processed through smoking and drying, were collected from the Dembé and Taradona markets in October 2024. A survey was conducted among processors and traders to document the various processing techniques used. Nutritional analyses included determination of dry matter and moisture content using the AOAC 950.01 method (1990), total ash by AOAC 923.03 (1997), total protein via the Kjeldahl method (NF EN ISO 20483:2014), and lipid content using Soxhlet extraction. Results revealed protein contents of 49.75% ± 7.35% in dried fish and 55.27% ± 5.35% in smoked fish. Microbiological analyses of smoked fish samples indicated the presence of *Staphylococcus* spp. ($2.1 \times 10^4 \pm 1.5 \times 10^3$ CFU/g) and *Escherichia coli* ($1.3 \times 10^3 \pm 3.2 \times 10^2$ CFU/g). These findings highlight the need for stricter hygiene controls during fish processing and greater awareness of good manufacturing practices among stakeholders in the sector.

Keywords

Clarias gariepinus, Smoked Fish, Dried Fish, Nutritional Quality, Microbiological Quality, Chad

1. Introduction

In Chad, fish are commonly sold smoked and dried in open-air markets, often displayed on plastic sheets laid directly on the ground. In some cases, these products are stored in poorly ventilated and confined spaces. Moreover, the frequent lack of hygiene protocols during handling, coupled with the use of rudimentary equipment for fish processing, can promote microbial contamination and the accumulation of volatile chemical compounds [1]-[3]. In Africa, as in other countries of the West and Central African sub-region, smoking and drying are two traditional processing techniques commonly used either individually or in combination by most actors involved in the fish product value chain. These methods aim to reduce post-harvest losses, extend the shelf life of fish products, and facilitate distribution to remote or rural [4]. However, numerous cases of microbiological and physicochemical contamination of food products sold in markets have been reported, often leading to incidents of food poisoning in African countries and beyond [5]. Within the animal kingdom, fish represent the largest group, with approximately 30,000 known species, primarily exploited for their oil and nutritional value [6]. Notably, fish meat contains less cholesterol than many other animal proteins and is often recommended for regular consumption, especially among the adult population [7]. According to regulatory bodies, fish consumption is recommended 1 to 2 times per week, with each portion of oily fish providing between 200 and 500 mg of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [8] [9]. However, fish is highly susceptible to bacterial contamination during storage, processing, and food preparation [10]. It is recognized as a potential vector for various human pathogenic bacteria, including *Pseudomonas* spp., *Escherichia coli*, *Staphylococcus aureus*, *Vibrio* spp., *Mycobacterium* spp., *Salmonella* spp., *Shigella* spp., *Enterococcus* spp., and *Proteus* spp. [11]. In particular, *Salmonella* and *Shigella* species are frequently isolated from fish and other aquatic organisms and pose serious public health concerns [12]. In rural areas, traditional drying and smoking methods often fail to meet hygienic standards, which adversely affects not only the microbial safety but also the textural and sensory quality of the final products [13]. To preserve the microbiological and nutritional qualities of fish during processing and storage, it is crucial to master the processing methods currently in use [14]. This mastery involves applying these methods under appropriate conditions to ensure not only the hygienic quality and the textural and organoleptic properties of the processed products, but also to safeguard consumer health [15].

General Objective

Nutritional and bacteriological characterisation of smoked and dried *Clarias gariepinus* fish sold in the town of N'Djamena (Chad).

Specific Objectives

To carry out a nutritional analysis of the processed fish;

To conduct a microbiological analysis of the processed fish.

2. Materials and Methods

2.1. Study Area, Survey, Transformed Fish Diagram

2.1.1. Study Area

Our study targeted two markets, namely the Dembé market and the Taradona market in the city of N'Djamena. It is located between 11˚ and 12˚8' North latitude and 14˚2' and 15˚2' East longitude. It is bordered to the north by the Hadjer-Lamis region, to the east and south by the Chari Baguirmi region, and to the west by the Logone river. The population of the city of N'Djamena is estimated at 951,418 according to the general housing census [16]. The city of N'Djamena has 10 districts, with an estimated average maximum temperature of 35.8˚ and average rainfall of 509.8 mm. The experimental and prospective study, nutritional and microbiological analyses were carried out at the food quality control centre (CECOQDA) and the isolated strains were transported to the mother and child hospital for API and antibiogram analyses (**Figure 1**).

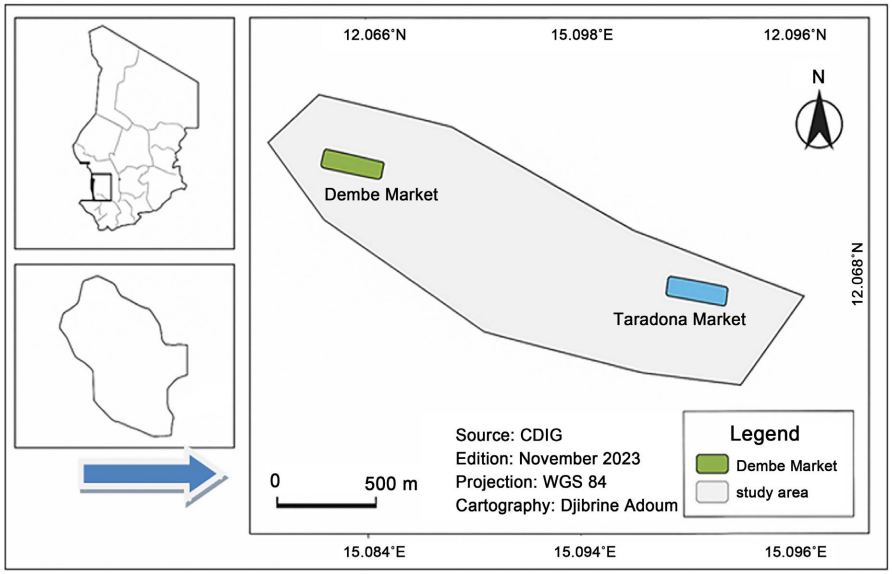

Figure 1. Location of sampling zones.

2.1.2. Sampling

These samples were taken in the city of N'Djamena, more specifically in the Dembe and Tarodona markets in the 6th and 7th districts respectively. A total of 16 samples of smoked and dried *Clarias gariepinus* fish (Each five fish equals one sample) were purchased. These samples were transported to the laboratory in a hermetically sealed container, then coded as soon as they were received and kept

in a cool place pending analysis.

2.1.3. Sociodemographic Survey

A survey to assess the knowledge and activities of the study site was carried out among the populations of two marches and were interviewed after obtaining their informed consent. The survey took place in October 2024. We drew up two sheets for the population: A sheet for fish consumers and traders. They were questioned or interviewed in the field using a questionnaire administered face-to-face and comprising various types of questions: open-ended questions that would allow people to answer voluntarily, closed-ended questions to which operators would answer yes or no, and leading questions in which respondents would choose one or two of the proposed answers. The interviews covered nationality, age, gender and level of education.

2.1.4. Diagrams of Improved Artisanal Fish Processing

During our survey, questions were asked about the artisanal fish processing method; observation of sales outlets to note all the stages in the processing process; body hygiene parameters; packaging; information on processed fish; information on processing techniques and preservation (storage). The results obtained were used to draw up and modify fish processing diagrams.

2.2. Methodologies

In this section on methodologies, we focus on nutritional and microbiological methods.

2.2.1. Determination of Dry Matter (DM)

Dry matter was determined by the method [17]. The sample is placed in a branded drying oven (DL53, VWR model, series 12.11745) maintained at 105˚C until a constant weight is obtained, all the water evaporates and the dry residue is called dry matter (DM). The formula used for the calculation is as follows:

$$\%H_2O = ((P1 - P2) \times 100)/(P1 - P0)$$

$$\%MS = 100 - \%H_2O$$

P0: Empty crucible P1: Crucible plus fresh sample P2**:** Crucible plus dry test sample.

2.2.2. Determination of Moisture Content

Moisture content was determined by weighing a sample before and after passing through a branded drying oven (DL53, model VWR, 12.11745) at 105˚C until a constant weight of 5 g (PE) of dried and fresh fish was obtained for 24 H in accordance with the standard. The formula used for the calculation is as follows:

$$H\% = \frac{Pe - (Pw - Po)}{Pl} \times 100$$

H: Humidity (%);

Po: Cradle empty weight;

Pl: Test load;

Pw: Final weight (cradle + test load).

2.2.3. Determination of Total Ash Content

Once the dry matter content had been determined, the various dried parts of our fish were crushed in a porcelain mortar. Total ash was quantified according to the method described in the standard [18]. Samples in porcelain crucibles were introduced into the Marque muffle furnace (L15/11/B180, Nebertherm model, series 247900). Heated to 550˚C for 24 hours. Removed using tongs and then cooled in a desiccator for about 1 hour before being weighed. Ash is the inorganic residue obtained after calcination of the organic matter. It is white in colour and gives an idea of the quantity of mineral elements present in the feed. The ash content was calculated using the formula below:

$$\text{Dfac}(\%) = ((\text{P3} - \text{P1}) \times 100)/(\text{P2} - \text{P1})$$

where

Dfac(%): dried fish ash content;

P1: mass of the empty crucible;

P2: mass of powder plus crucible on leaving the oven and,

P3: mass of crucible plus ash. The result is the average of two tests.

2.2.4. Determination of Total Proteins

The determination of total proteins by the Kedah method, according to the standard [19]. This was carried out in three stages:

Digestion or mineralisation of the sample

The following operations should be carried out in a well-ventilated sulphuric acid-proof hood. Place the test sample in a digestion tube (mode K-425, Buchi brand, series 1000119681), add a catalyst tablet, weigh out exactly 0.38 g of fish meal in a mass of concentrated sodium sulphate ($NaSO_4$) of 9.7801 g and a mass of copper sulphate ($CuSO_4$) of 0.6003 g, then add 20 ml of sulphuric acid (H_2SO_4) 98%, shake the mixture well to homogenise it; all the work must be done in a chemical hood; add 5 pumice stones per test sample, then add 5 drops of antifoam (silicone) to each test sample; also add 5 Kjeltabls tablets. The volume of distilled water poured per test is 50 ml, so the cooling time after mineralisation is 20 min. Insert the tube into the mineralisation hopper, fit the smoke sensor and heat the mineralisation temperature for 2 h 30 min at 400˚C, until a viscous, whitish solution is obtained. The aim is to oxidise the organic matter and transform the protein nitrogen into NH_3 ammonia.

Ammonia distillation

Before steam distilling the ammonia using a distiller model K-350, Buchi brand, series 1000119682, the ammonia must be liberated in the form of the $(NH_4)_2SO_4$ salt by adding a concentrated solution of 75 ml volume of 32% NaOH sodium hydroxide poured into each test sample, necessary to neutralise the quantity of sulphuric acid used. Add 50 ml of 40 g/l boric acid solution; also 10 drops of 0.04% bromocresol green, add drops of 0.02% methyl red under a value of 4. The distil-

lation time per test sample is 6 min.

Ammonia titration

Ammonia in the form of ammonium borates is titrated directly using a standardised acid solution, such as HCl (0.1 N) for the blank (control) and the test samples. The equivalence point can be determined by visual colorimetry, using a magnetic stirrer, model VMS-AS40, VWR.

2.2.5. Calculation Formula and Expression of Results

The total nitrogen content, expressed by mass, is equal to:

$$\text{Protein } \% = \frac{(V1 - V0) \times T\ 14,007 \times 100}{m} \times \frac{100}{100 - wH}$$

where

V0: volume (in millilitres) of the sulfuric acid solution used for the blank test;

V1: volume (in millilitres) of the sulfuric acid solution used for the sample test;

T: normality (or molarity) of the sulfuric acid solution used in the titration;

14.007: molar mass of nitrogen (in grams per mole);

m: mass (in grams) of the test sample;

wH: moisture content (in %) of the test sample;

6.5: conversion factor for total nitrogen to protein content;

The factor 100 − *w H* 100−w H;

100 adjusts the protein content to a dry matter basis.

2.2.6. Determination of Total Lipid Content

Lipid content was determined by the Soxhlet method (model SMA6, brand Bchr, series 111373). After grinding the solid sample; dry the sample in the oven for one hour at a T˚ of 105˚C; weigh the weight m of the dried sample into an extraction capsule; introduce the capsule containing m gram into the extraction tube and overcome with a refrigerator connected to the tap of running water; pour about 120 ml of solvent (nHexane or petroleum ether) into a flask or Soxhlet heating tube; mount the extraction devices (see Soxhlet data sheet); program the temperature controller above the solvent vaporisation temperature at 105˚C for 8 hours and press RUN; after extraction weigh the initial weight of the flask; transfer the MG solvent mixture into the flask and connect to the steam rota to separate at a T˚ of 100˚C for approximately 20 minutes.

2.2.7. Calculation Formula and Expression of Results

The total lipid (fat) content, expressed as a percentage of the dry matter, is given by the relationship:

$$FC\% = \frac{(M2 - M1) * 100}{SW}$$

FC%: fat content;

M1: mass of test sample;

M2: mass of balloon containing fat;

SW: Sample weight.

2.2.8. Searched for Germs

1) Preparation of the stock solution and decimal dilutions

Twenty-five (25 g) of fish were weighed into one (1) sterile stomacher bag, then 225 ml of previously sterilised buffered peptone water (BPW) was added. The mixture was ground and homogenised using a stomacher, brand inter science, model Bag Mixer, series 120322348 for 30 seconds. This solution was left to rest for 30 minutes to ensure the revival of bacteria stressed by the shock exerted during grinding. Under a Flow Activahf vertical laminar flow hood, Sn. 807/12 series [20].

2) Microbiological criteria

The microbiological criteria (CFU/g) are those of the Food Safety Division of the Ministry of Health. Grand Duchy of Luxembourg, 2016 (Table 1).

Table 1. Applied microbiology criteria.

Search parameters	Methods	Microbiological criteria UFC/g (DSA, 2016)
Total Mesophilic Aerobic Flora (TMAF)	ISO 4833-1 (2013)	$\leq 10^5$
Coliforms at 37˚C	NF ISO 4832 (2006)	$\leq 10^2$
Escherichia coli	NF ISO 16649-2 (2001)	$\leq 10^2$
Coagulase + Staphylococcus	NF EN ISO 6888-2 (1999)	$\leq 10^2$
Yeast-Mould	NF V 08-059 (2009)	$\leq 10^2$
Bacillus cereus	ISO 7932 (2005)	$\leq 10^2$
Salmonella	NF EN ISO 6579 (2017)	Absence in 25 g
Sulphite-reducing anaerobes (SRA)	ISO 26461-2-(2011)	$\leq 10^2$

3) Enumeration of *total mesophilic aerobic flora* (TMAF)

The enumeration of total mesophilic aerobic flora is based on the pour plate method using Plate Count Agar (PCA). A series of decimal dilutions (usually from 10^{-1} to 10^{-4}) is prepared, and 1 ml of each dilution is aseptically transferred into sterile Petri dishes. Then, 12 to 15 ml of molten PCA (cooled to 45˚C) is added to each dish. The mixture is gently swirled to ensure even distribution of the microorganisms and allowed to solidify. A second layer of PCA (5 to 7 ml) is poured over the solidified medium to prevent overgrowth by motile bacteria such as Proteus, which could hinder accurate colony counting. The prepared plates are then incubated at 30˚C for 72 hours in an incubator (Binder model BD053), with the lids facing downward to avoid condensation. After incubation, all colonies that have grown between the two layers of agar are counted either with the naked eye or using a colony counter with a magnifier. Results are expressed in colony-forming units (CFU) per gram or per milliliter of sample, based on counts from two successive dilutions, following the standard [21].

4) Research and enumeration of *Coliforms*

The medium used is VRBL agar (crystal violet, neutral red, bile and lactose agar), melted and cooled in a water bath. 1 ml of dilutions 10^{-1}, 10^{-2}, 10^{-3} and 10^{-4} of the sample are respectively inoculated into two petri dishes. Next, 10 to 15 ml of VRBL are poured into these dishes and homogenised by gentle circular movements. Once this first layer has solidified, a second, thinner layer is poured on. Inoculate 1 ml of the product to be analysed or its decimal dilutions into sterile petri dishes. Pour approximately 15 ml of the medium, previously melted and cooled to 44˚C to 47˚C. Homogenise well and leave to cool on a cool, perfectly horizontal surface. Pour a second layer (about 4 ml) of this medium maintained at 44˚C to 47˚C and leave to solidify again. When solidification is complete, turn the dishes upside down and incubate in this position: For 24 h ± 2 h for coliform detection and dismemberment in the 37˚C ± 1˚C oven, Binder brand, model BD053, series 12-23810. For 24 h ±2 h for the detection and dismemberment of thermo-Tolerant *coliforms* in the oven 44˚C ± 1˚C Binder brand, model KB053, series 12-01560 [22].

5) *Salmonella* detection and enumeration

The standard [23]. is the horizontal reference method for the detection of *Salmonella* pp. in a foodstuff, but also in environmental samples collected in agri-food businesses. The EPT medium will be used to detect *Salmonella*. According to the current standard *Salmonella* is tested in 25 g of products. The test will be carried out in 4 stages:

Pre-enrichment

Inoculate buffered peptone water (BPW) with the test sample, then incubate at 37˚C ± 1˚C for 18 h ± 2 h. In the case of large quantities, the buffered peptone water should be heated to 37˚C ± 11˚C before inoculation with the test sample.

Enrichment with selective media

Transfer 0.1 ml of the culture obtained into a tube containing 10 ml of RVS broth and 1 ml of the culture obtained into a tube containing 10 ml of MKTTn broth. Incubate the seeded RVS at 41.5˚C ± 1˚C for 24 h ± 3 h and the MKTTn broth at 37˚C ± 1˚C for 24 h ± 3 h.

Isolation

Using the culture obtained in RVS broth, inoculate the surface of XLD medium with a loop. Repeat with the second selective isolation medium. Do the same for the culture obtained in MKTTn broth. Invert the plates of XLD medium and incubate at 37˚C. For the second isolation medium, follow the manufacturer's recommendations. After 24 h ± 3 h incubation, examine the plates for the presence of *Salmonella* colonies, as well as atypical colonies that are likely to be *Salmonella*. Typical *Salmonella* colonies grown on XLD agar have a black centre and are surrounded by a clear transparent red halo.

Purification

Five characteristic colonies are picked from each Hektoen plate and transferred to Nutrient Agar (NA) for purification. The GN plates are incubated at 37˚C for 24 hours. Purified colonies appear whitish on reading.

6) Research and enumeration of *Staphylococci*

The culture medium of choice for this research is Baird-Parker (BP) agar, supplemented with a mixture of egg yolk and potassium tellurite. The BP agar was melted and cooled, then poured into sterile petri dishes containing homogenised potassium tellurite and egg yolk. Once the mixture has solidified, 0.1 ml of the stock suspension or decimal dilutions are spread on the surface using a sterile glass or plastic spreader. Incubation takes place at 37˚C for 48 hours. A first reading is taken after 24 hours and a second after 48 hours incubation. For counting purposes, plates containing between 15 and 150 characteristic colonies for 2 successive dilutions are selected. *Staphylococcus* colonies are black, shiny, bulging, surrounded by a white precipitate and a halo of lightening. Confirmation is obtained by the catalase and coagulase tests [24].

7) Research and enumeration of *yeasts* and *moulds*

The fungal flora was counted on glucose agar with Oxytetracycline (OGA). A 10 ml sample of OGA agar was poured into sterilised petri dishes. After solidification, the plates were inoculated with 0.1 ml of dilutions 10^{-1} and 10^{2} from the stock solution (SM) on the surface and then incubated at 25˚C for 3 to 5 days. For counting purposes, plates containing fewer than 150 colonies after 5 days of incubation are retained [25].

8) Search for and enumeration of *Sulphite Reducing Anaerobes* (SRAS)

Sporulated forms are sought. Two selective media can be used: Trypticase Sulfite Neomycin Agar (TSN). TSN was used for the study. TSN medium is inoculated in tubes to detect RSA. The TSN medium, melted and cooled in a water bath, was poured at a rate of 12 to 15 ml per tube. 1 ml of stock suspension at 10^{-1} and 1 ml of dilution at 10^{-2} were transferred to the sterile tubes. After homogenisation and solidification, a second layer is poured. The tubes with the solidified agar are incubated anaerobically at 46˚C for 24 hours. Characteristic colonies appear black in the incubation tubes [26].

9) Enumeration of *Escherichia coli*

Take a sterile Petri dish and use a pipette or micropipette to transfer 1 ml of the test sample (if liquid), or 1 ml of the stock suspension (10^{-1}) in the case of other products. If necessary, repeat these operations with the following decimal dilutions, using a new sterile pipette for each dilution. Pour approximately 15 ml of TBX medium, previously cooled to between 44˚C and 47˚C in the water bath, into the Petri dish. Carefully mix the inoculum with the medium and allow the mixture to solidify, placing the Petri dishes on a cool horizontal surface. Repeat these same operations with sterile buffered Peptone Water (blank test). The time elapsing between depositing the inoculum in the Petri dish and adding the medium should not exceed 15 min. Turn the plates over and incubate them in an oven set at 44˚C for 18 to 24 hours. If the presence of stressed micro-organisms is suspected, incubate first for 4 h at 37˚C, then for 18 h to 24 h at 44˚C. The incubation temperature must not exceed 45˚C. [27].

10) *Bacillus cereus* enumeration

Take a quantity of sample, transfer to diluent and homogenise; prepare decimal dilutions; surface plating with a spreader of 0.1 ml of sample or dilution of a solid selective medium with Mannintol egg Yolk Polymyxin Agar (MYP) and incubation for 18 to 24 hours at 30˚C; count the number of typical colonies on plates containing MYP agar (large pink colonies surrounded by a zone of precipitation). If this type of colony is observed, then carry out the confirmation phase using a haemolysis test: take a few typical colonies, perform a streak inoculation on the blood agar and incubate for 24 hours at 30˚C. If it is confirmed that the colonies sampled are indeed *B. cereus*, then count the number of cfu from the number of colonies counted, taking into account the dilutions performed [28].

11) Calculation formula and expression of results

Retain plates containing a maximum of 200 colonies in two successive dilutions or tubes containing a maximum of 30 well-separated colonies; but at least 10 characteristic colonies according to the standard [29].

$$N = \frac{\sum C}{V \times \left[n1 + \left(0.1n2 \right) \right] d}$$

where

$\sum C$: Sum of characteristic colonies on the two boxes selected;

V: volume of inoculum applied to each dish;

$n1$: number of plates retained for the first dilution;

$n2$: number of plates used in the second dilution;

d: dilution rate corresponding to the first dilution.

Round the calculated results to two significant figures.

12) Statistical Analysis

The Statistical analysis and processing of the data set of mean, standard deviation, with a confidence interval of 95%, the difference between the values was considered significant when $p < 0.05$ were processed by different software which are: xlstat 2016.02.27444 associate with artificial intelligence.

3. Results and Discussion

3.1. Field Survey Results and Diagram

3.1.1. Results of the Field Survey

The socio-demographic characteristics taken into account in this survey are: Gender, age, level of education, processors and traders. The results obtained for these different characteristics are presented in **Table 2**.

3.1.2. Results of the Diagrams

To help processors and traders improve processing quality, a new diagram was amended by adapting new production techniques. A new approach was adopted, making it possible to address producers' constraints by properly controlling the risks of contamination. Feedback sessions were organized with the processors to explain good hygiene practice (GHP) and good manufacturing practice (GMP) in

order to adapt the improved diagram (Figure 2 and Figure 3).

Table 2. Results of field survey.

Variable	Category	Transformers	Retailers	TOTAL
Old	18 - 25	12	9	21
	25 - 30	30	36	66
	30 - 45	33	31	64
	40 and over	25	24	49
Sexes	Male	81	24	105
	Female	19	76	95
Level of education	Francais	22	38	60
	Arabic	78	62	140

Figure 2. Traditional diagram to improve drying of fresh fish.

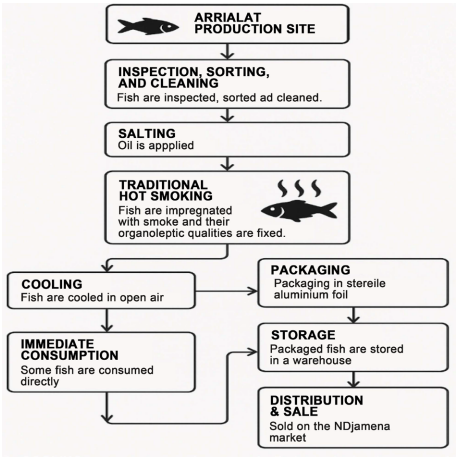

Figure 3. Process diagram for smoking *Clarias gariepinus* fish sold at the N'Djamena market.

3.2. Results of Nutritional Descriptive Statistics for Dried *Clarias gariepinus*

An analysis of samples was conducted to assess the variability and central tendencies of five key compositional parameters: lipid content, protein content, humidity level, ash content, and dry matter. Table 3 below presents the results of the analyses of dried *Clarias gariepinus* fish.

Table 3. Descriptive statistics (quantitative data) for dried *Clarias gariepinus*.

Variable	Observations	Minimum	Maximum	Average	Standard deviation
lipid	24	5.490	12.980	9.632	2.372
Protein	24	40.010	66.360	49.755	7.354
Humidity level	24	11.370	21.390	15.860	3.606
Ash content	24	4.280	9.250	6.428	1.613
Dry matter	24	0.670	0.910	0.773	0.077

Principal Component Analysis (PCA) of dried *Clarias gariepinus* is a multivariate statistical analysis method used to reduce the dimensionality of a dataset while retaining maximum variance information (Figure 4).

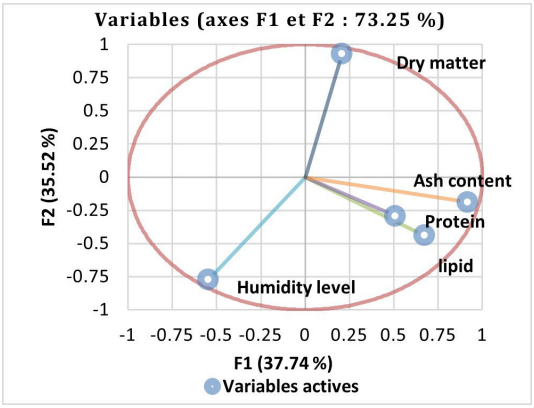

Figure 4. Principal component analysis (Biplot) of individual sample variabilities *Clarias gariepinus* dried.

The eigenvalue Table 4 and scree plot (Figure 5) in *Clarias gariepinus* dried: indicate that the first two principal components (F1 and F2) have eigenvalues greater than 1 and together explain approximately 73.26% of the total variance. Based on both the Kaiser criterion and the elbow method, F1 and F2 are the most meaningful components and should be retained. Components F3 to F5 contribute relatively little to the explanation of the variance and can be considered less important for further analysis.

Correlation Matrix Heatmap for dried *Clarias gariepinus* fish

The following table refers to a correlation matrix, which shows the relationships between different variables. Each variable (Q1-1 to Q1-8 and the components

measured such as lipids, proteins, moisture, etc.) has its own correlation matrix (Table 5).

Table 4. Eigenvalues of dried *Clarias gariepinus*.

Component	Eigenvalue	Variability (%)	Cumulative (%)
F1	1.887	37.739	37.739
F2	1.776	35.516	73.255
F3	0.954	19.081	92.336
F4	0.226	4.520	96.856
F5	0.157	3.144	100.000

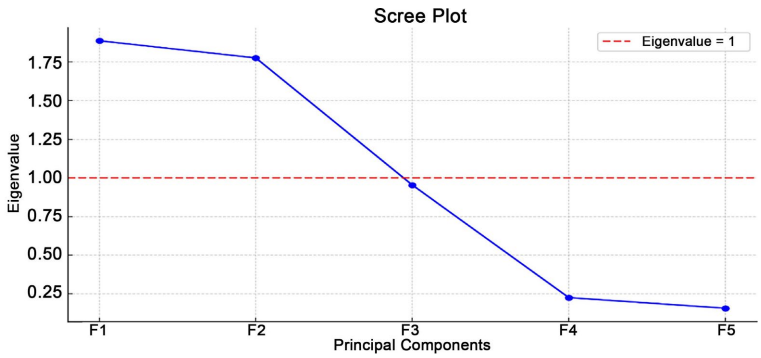

Figure 5. The scree plot.

Table 5. Correlation matrix for dried *Clarias gariepinus* fish.

	Q1-1	Q1-2	Q1-3	Q1-4	Q1-5	Q1-6	Q1-7	Q1-8	Lipid	Protein	Humidity level	Ash content	Dry matter
Q1-1	**1**	−0.143	−0.143	−0.143	−0.143	−0.143	−0.143	−0.143	−0.082	−0.103	−0.479	−0.173	0.640
Q1-2	−0.143	**1**	−0.143	−0.143	−0.143	−0.143	−0.143	−0.143	−0.085	−0.238	0.464	−0.422	−0.082
Q1-3	−0.143	−0.143	**1**	−0.143	−0.143	−0.143	−0.143	−0.143	−0.077	−0.150	0.324	−0.047	−0.233
Q1-4	−0.143	−0.143	−0.143	**1**	−0.143	−0.143	−0.143	−0.143	−0.076	−0.511	−0.056	0.166	−0.182
Q1-5	−0.143	−0.143	−0.143	−0.143	**1**	−0.143	−0.143	−0.143	−0.080	−0.072	−0.318	−0.511	0.203
Q1-6	−0.143	−0.143	−0.143	−0.143	−0.143	**1**	−0.143	−0.143	−0.079	0.871	−0.216	0.427	−0.317
Q1-7	−0.143	−0.143	−0.143	−0.143	−0.143	−0.143	**1**	−0.143	0.555	0.037	−0.308	0.671	0.472
Q1-8	−0.143	−0.143	−0.143	−0.143	−0.143	−0.143	−0.143	**1**	−0.075	0.166	0.589	−0.110	−0.501
Lipid	−0.082	−0.085	−0.077	−0.076	−0.080	−0.079	0.555	−0.075	**1**	0.022	−0.170	0.375	0.267
Protein	−0.103	−0.238	−0.150	−0.511	−0.072	0.871	0.037	0.166	0.022	**1**	−0.141	0.399	−0.240
Humidity level	−0.479	0.464	0.324	−0.056	−0.318	−0.216	−0.308	0.589	−0.170	−0.141	**1**	−0.297	−0.741
Ash content	−0.173	−0.422	−0.047	0.166	−0.511	0.427	0.671	−0.110	0.375	0.399	−0.297	**1**	0.033
Dry matter	0.640	−0.082	−0.233	−0.182	0.203	−0.317	0.472	−0.501	0.267	−0.240	−0.741	0.033	**1**

3.3. Results Descriptive Nutritional Statistics for Smoked *Clarias gariepinus*

Cluster Dendrogram of Correlation Matrix

This document presents the hierarchical clustering (dendrogram) based on the

correlation matrix of variables Q1-1 to Q1-8 and key compositional attributes (Lipid, Protein, Humidity, Ash, Dry Matter). The dendrogram below shows the similarity structure between variables (Figure 6).

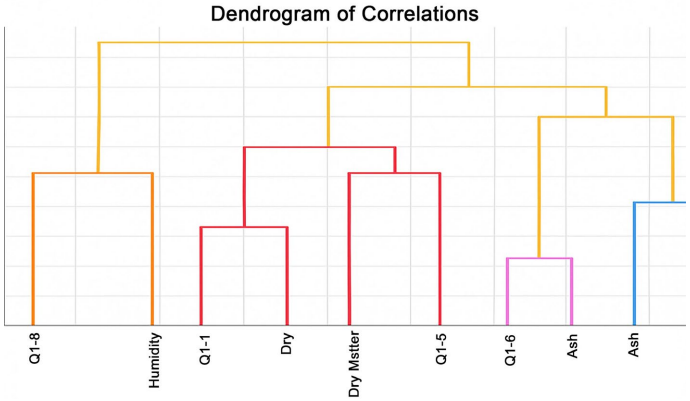

Figure 6. Dendrogram of correlation matrix.

The dataset comprises 24 observations for five key compositional variables: lipid content, protein content, humidity level, ash content, and dry matter. A descriptive statistical summary is presented below: Table 6 shows the results of analyses of smoked *clarias gariepinus* fish (Table 6).

Table 6. Descriptive statistics (Quantitative data) for *Clarias gariepinus* Smoked.

Variable	Observations	Minimum	Maximum	Average	Standard deviation
lipid	24	1.760	13.650	8.528	3.989
Protein	24	46.020	61.490	55.270	5.346
Humidity level	24	8.710	41.700	21.495	11.448
Ash content	24	4.800	9.550	6.860	1.620
Dry matter	24	0.580	0.920	0.784	0.112

This plot represents the projection of active variables onto the first two principal components (PCs), F1 and F2, which together explain 68.53% of the total variance in the dataset (39.76% by F1 and 28.77% by F2). The quality of this representation makes it suitable for preliminary dimensionality reduction and interpretation of variable relationships (Figure 7).

The scree plot (Figure 8) and eigenvalue Table 7 in *Clarias gariepinus* smoking. This table appears to summarize the results of a Principal Component Analysis (PCA), showing the eigenvalues, percentage of variability explained, and the cumulative percentage for five principal components (F1 through F5).

This table presents the hierarchical clustering (dendrogram) derived from the correlation matrix of variables Q1-1 to Q1-8, along with key compositional attributes (Lipid, Protein, Humidity, Ash, and Dry Matter). The dendrogram illustrates the similarity structure among these variables (Table 8).

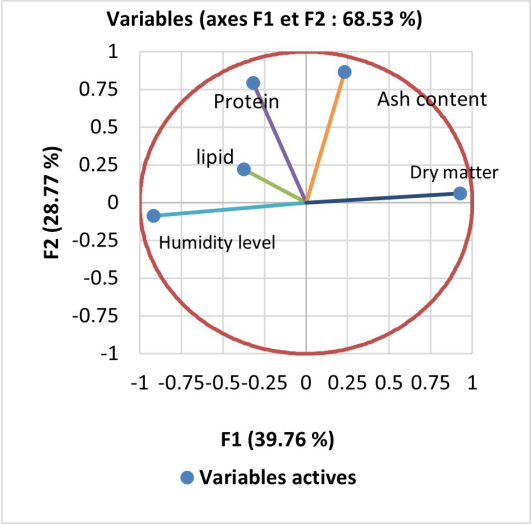

Figure 7. Principal component analysis (Biplot) of individual sample variabilities *Clarias gariepinus* smoked.

Table 7. Eigenvalues of smoked *Clarias gariepinus*.

	F1	F2	F3	F4	F5
Eigenvalue	2.298	1.416	0.882	0.322	0.082
Variability (%)	45.970	28.313	17.635	6.439	1.643
% Cumulative	45.970	74.283	91.918	98.357	100.000

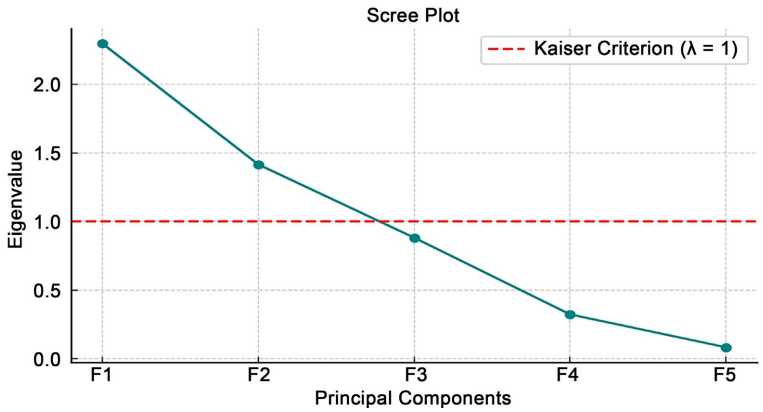

Figure 8. The scree plot.

Table 8. Combined heat map in clusters of hierarchical relations of correlation matrix for smoked fish *Clarias gariepinus*.

	Q1-1	Q1-2	Q1-3	Q1-4	Q1-5	Q1-6	Q1-7	Q1-8	Lipid	Protein	Humidity level	Ash content	Dry matter
Q1-1	**1**	−0.143	−0.143	−0.143	−0.143	−0.143	−0.143	−0.143	−0.111	−0.654	−0.431	−0.285	0.433
Q1-2	−0.143	**1**	−0.143	−0.143	−0.143	−0.143	−0.143	−0.143	−0.471	−0.279	−0.310	0.087	0.365
Q1-3	−0.143	−0.143	**1**	−0.143	−0.143	−0.143	−0.143	−0.143	0.304	0.355	0.675	−0.488	−0.665
Q1-4	−0.143	−0.143	−0.143	**1**	−0.143	−0.143	−0.143	−0.143	−0.653	0.338	−0.075	0.200	0.056
Q1-5	−0.143	−0.143	−0.143	−0.143	**1**	−0.143	−0.143	−0.143	−0.006	−0.392	0.578	−0.096	−0.471

Continued

Q1-6	−0.143	−0.143	−0.143	−0.143	−0.143	**1**	−0.143	−0.143	0.377	0.442	−0.106	0.636	0.308
Q1-7	−0.143	−0.143	−0.143	−0.143	−0.143	−0.143	**1**	−0.143	0.068	0.217	−0.187	0.396	−0.173
Q1-8	−0.143	−0.143	−0.143	−0.143	−0.143	−0.143	−0.143	**1**	0.493	−0.028	−0.143	−0.450	0.147
Lipid	−0.111	−0.471	0.304	−0.653	−0.006	0.377	0.068	0.493	**1**	0.228	0.281	−0.212	−0.244
Protein	−0.654	−0.279	0.355	0.338	−0.392	0.442	0.217	−0.028	0.228	**1**	0.238	0.415	−0.283
Humidity level	−0.431	−0.310	0.675	−0.075	0.578	−0.106	−0.187	−0.143	0.281	0.238	**1**	−0.333	−0.915
Ash content	−0.285	0.087	−0.488	0.200	−0.096	0.636	0.396	−0.450	−0.212	0.415	−0.333	**1**	0.307
Dry matter	0.433	0.365	−0.665	0.056	−0.471	0.308	−0.173	0.147	−0.244	−0.283	−0.915	0.307	**1**

3.4. Comparison of Descriptive Results for Dried and Smoked *Clarias gariepinus*

Figure 9 presents a comparative analysis of the average lipid content in *Clarias gariepinus* fish subjected to two different preservation methods: smoking and drying. The data, labeled for the first quarter (Q1), indicate clear variations in lipid concentrations between the two treatments.

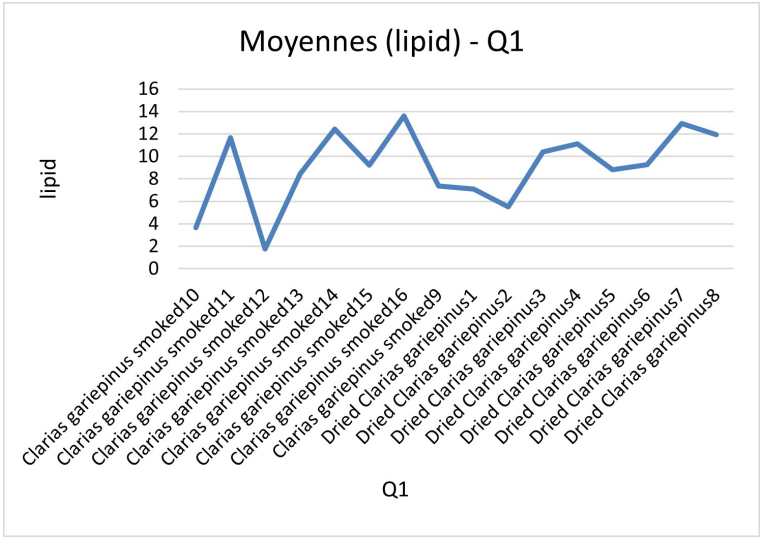

Figure 9. Lipid comparison results for dried and smoked *Clarias gariepinus*.

This graph shows the average protein content (in Q1) of various samples of *Clarias gariepinus* and its dried and smoked variants (Figure 10).

Moisture is a critical factor influencing the biochemical stability, microbial safety, and shelf life of fish products. The figure illustrates the average moisture content across various samples of dried and smoked *Clarias gariepinus* fish. As shown, smoked samples generally retain higher moisture levels compared to dried ones, which may affect their susceptibility to microbial growth and limit their storage duration. These variations underscore the importance of moisture control in post-harvest processing to ensure product quality and safety (Figure 11).

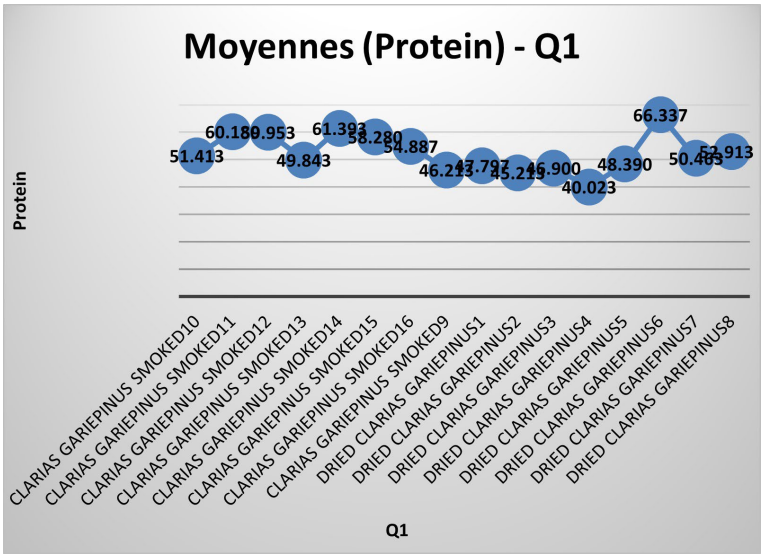

Figure 10. Protein comparison results for dried and smoked *Clarias gariepinus*.

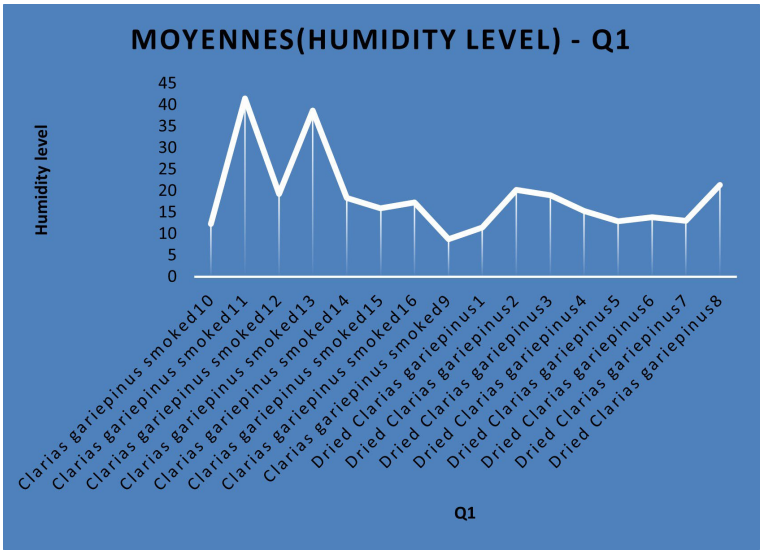

Figure 11. Results of comparison of T. Water from dried and smoked *Clarias gariepinus*.

Analysis of the ash content of *Clarias gariepinus* samples shows a clear influence of the processing method on mineral composition. Smoked fish had higher ash contents than dried fish, suggesting a better concentration or preservation of minerals during smoking (Figure 12).

The graph shows the average dry matter content of *Clarias gariepinus* for different treatments (smoked and dried) during the first quarter (Q1). The values are fairly high, mostly between 0.7 and 0.9, indicating a low moisture content—an essential characteristic for preserving fish (Figure 13).

3.5. Microbiology Results

Table 9 and Table 10 below present the results of microbiological analyses

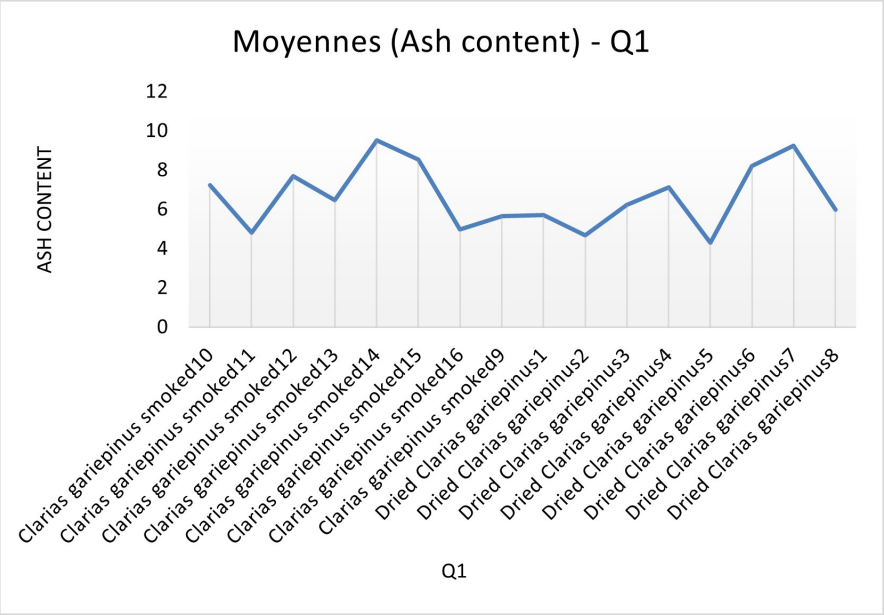

Figure 12. Results of the comparison between dried and smoked *Clarias gariepinus* ash.

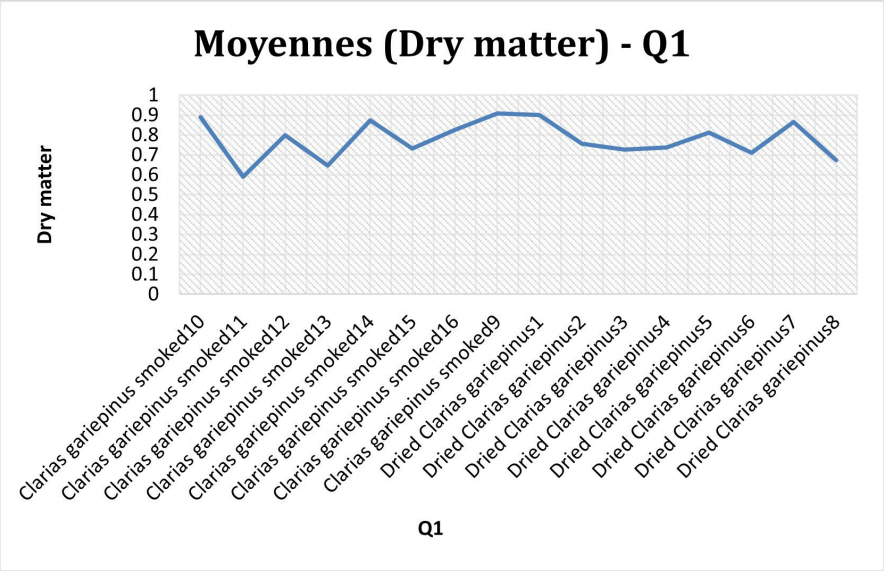

Figure 13. Comparative results for dry matter of dried and smoked *Clarias gariepinus*.

performed on dried and smoked samples of *Clarias gariepinus* (African catfish). The evaluation focused on key microbial indicators, including *total aerobic mesophilic flora*, *coliforms*, *Escherichia coli*, *Bacillus cereus*, coagulase-positive *Staphylococcus*, yeasts and moulds, and *Salmonella.* For each microorganism, the mean colony count and standard deviation (expressed in CFU/g) are reported, along with the corresponding regulatory limits used to assess compliance with microbiological safety standards. These results provide critical insight into the hygienic quality and safety of the processed fish products and serve as a basis for evaluating the effectiveness of current processing and handling practices.

Table 9. Microbiological enumeration results for dried fish.

The germs		*Clarias gariepinus*
TAMF	Mean and standard deviation ufc/g	$3.6.10^6 \pm 6.9.10^4$
	Criteria ufc/g	$\leq 10^5$
***Coliforms at* 37˚C**	Mean and standard deviation ufc/g	$2.10^5 \pm 1.2.10^4$
	Criteria ufc/g	$\leq 10^2$
Escherichia coli	Mean and standard deviation ufc/g	$1.7.10^3 \pm 3.10^2$
	Criteria ufc/g	$\leq 10^2$
Bacillus cereus	Mean and standard deviation ufc/g	$1.4.10^4 \pm 8.10^2$
	Criteria ufc/g	$\leq 10^2$
Coagulase + Staphylococcus	Mean and standard deviation ufc/g	$1.5.10^4 \pm 4.10^2$
	Criteria ufc/g	$\leq 10^2$
Yeast-Mould	Mean and standard deviation ufc/g	$1.4.10^4 \pm 8.10^2$
	Criteria ufc/g	$\leq 10^2$
Salmonella	Mean and standard deviation ufc/g	Absence dans 25 g
	Criteria ufc/g	$\leq 10^2$

Legend: TAMF: *Total aerobic mesophilic Flora*, ***E. Coli***: *Escherichia coli*; **Staph**: *Staphylococcus*; ufc/g: Units forming colony.

Table 10. Microbiological enumeration results for smoked fish.

The germs		*Clarias gariepinus*
TAMF	Mean and standard deviation ufc/g	$3.5.10^6 \pm 2.3.\ 10^5$
	Criteria ufc/g	$\leq 10^5$
***Coliforms at* 37˚C**	Mean and standard deviation ufc/g	$1.8.10^5 \pm 1.3.10^4$
	Criteria ufc/g	$\leq 10^2$
Escherichia coli	Mean and standard deviation ufc/g	$1.4.10^3 \pm 1.5.10^2$
	Criteria ufc/g	$\leq 10^2$
Bacillus cereus	Mean and standard deviation ufc/g	$1.25.10^4 \pm 6.74.10^2$
	Criteria ufc/g	$\leq 10^2$
Coagulase + Staphylococcus	Mean and standard deviation ufc/g	$1.6.10^4 \pm 6.7.10^2$
	Criteria ufc/g	$\leq 10^2$
Yeast-Mould	Mean and standard deviation ufc/g	$1.4.10^4 \pm 1.3.\ 10^3$
	Criteria ufc/g	$\leq 10^2$
Salmonella	Criteria ufc/g	Absence dans 25 g

Legend: TAMF: *Total aerobic mesophilic Flora*, ***E. Coli***: *Escherichia coli*; **Staph**: *Staphylococcus*; ufc/g: Units forming colony.

4. Discussion

Discussion of survey results and improvement diagrams. A **professional inter-**

pretation of the data based on the three variables: **Age, Sex, and Level of Education**, with insights drawn from the differences between *Transformers* and *Retailers*. Age Distribution: The 25 - 30 age group is the most represented overall (66 individuals), with a fairly even split between Transformers (30) and Retailers (36). 30 - 45 years old is also a dominant group (64), again with a balanced distribution. The youngest group (18 - 25) is the least represented (21 individuals), which may indicate that younger people are less involved in these roles, possibly due to lack of experience. Similarly, 40 and over represents a smaller but significant portion (49), suggesting either early retirement, career shifts, or fewer older professionals entering or staying in these roles. The workforce in both categories is concentrated in the 25 - 45 age range, indicating that these professions attract individuals with some experience but still in the early to mid-career stage. Transformers are predominantly male (81 males vs. 19 females). Retailers, by contrast, are predominantly female (76 females vs. 24 males). There is a clear gender segmentation in roles: Transformers (possibly more technical or manual roles) are male-dominated. Retailers (potentially involving customer interaction or sales) are female-dominated. This could reflect societal roles, job preferences, or even access to training opportunities based on gender. Among Transformers, the majority were educated in Arabic (78), with fewer in French (22). Among Retailers, the distribution is more balanced: 62 Arabic. 38 French. Transformers are more likely to come from an Arabic-language education background, possibly indicating they are from more local or rural educational institutions. Retailers show a more diverse background, with a relatively higher percentage of French-educated individuals, perhaps due to the nature of retail involving communication skills or the influence of international commerce. The Transformer role tends to attract Arabic-educated males between 25 - 45 years old. The Retailer role attracts French- and Arabic-educated females, also in the 25 - 45 age range (**Table 2**).

Improving Fish Processing Quality: Guidelines and Best Practices To enhance the quality of fish processing, a new workflow diagram has been developed that incorporates appropriate modern techniques. In support of this initiative, correction sessions have been organized for all stakeholders, with the goal of promoting the adoption of this new diagram. These sessions focus on educating participants about Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP), encouraging their implementation throughout the process. **Key Precautionary Measures:** To ensure optimal quality and safety, certain precautions must be taken at all stages of the fish processing chain: Before Loading the Fishing Shipment: Ensure that all equipment and containers are clean and sanitized. During the Fishing Operation: Handle fish with care to avoid contamination and damage. **During Shipment to Delivery Points:** Maintain cold chain protocols and ensure hygienic conditions during transportation. Drying Process for *Clarias gariepinus* (African Catfish) (**Figure 2**). One of the most crucial stages in the processing of *Clarias gariepinus* is drying. **The following steps are recommended:** Resting After Washing: After thoroughly washing the fish, allow it to rest for 30 to 45

minutes. This step helps reduce the overall drying time. Initial Drying: Begin the drying process immediately after the resting period. Turning the Fish: After 2 to 4 hours of drying, turn the fish over to promote even ventilation on all surfaces. Protection Against Insects and Flies To prevent insect and fly infestation during drying, use the following protective methods: Sterilized Aluminium Foil: Cover the fish to create a physical barrier; Salt Solution Spray: Lightly moisten the fish with a salt solution recommended by FAO and WHO. This method is effective and safe. The use of insecticides is strongly discouraged due to their harmful effects on human health. Compliance with Standards Traditional preservation methods used by some fishermen and wholesalers may pose significant health risks to consumers. Therefore, any use of chemical substances must strictly comply with the standards set by international organizations such as the FAO. Specifically, refer to the guidelines published in FAO Bulletin No. 804, October 1987 for approved practices. (**Figure 3**). Our results are in line with those reported by [30]. The fish arrive at the production site where they are inspected, sorted and cleaned to ensure their quality. Once prepared, the fish undergo a salting process followed by an application of oil to promote preservation and add flavour. The traditional smoking process is carried out hot, impregnating the fish with smoke and fixing their organoleptic qualities. The fish are left to cool in the open air to stabilise their temperature and prevent condensation forming during packaging. Immediate consumption: Some fish are consumed directly after cooling. Fish intended for sale go on to the packaging stage. Packaging in sterile aluminium foil: To guarantee product hygiene. To facilitate transport and storage. The fish are then stored in a well-packaged warehouse to preserve their freshness. The packaged and stored fish are sold on the N'Djamena market**.** Our results are in line with those reported by [31].

An analysis of 24 samples of dried *Clarias gariepinus* fish was carried out to assess variability and central trends in five key compositional parameters: lipid content, protein content, moisture content, ash content and dry matter.The mean lipid content was 9.632, with a standard deviation of 2.372, indicating moderate variability; Values ranged from 5.490 to 12.980, suggesting the presence of both low-fat and high-fat samples;: The observed dispersion may reflect differences in raw material origin or processing conditions. This level of variability could impact energy content and functional properties, particularly in food or feed applications. The average protein concentration was 49.755, with a range from 40.010 to 66.360 and a standard deviation of 7.354.: Protein content exhibited significant variability, which may be attributed to differences in sample composition, extraction efficiency, or biological origin. This has implications for nutritional profiling and potential industrial applications where protein quality and quantity are critical. Humidity levels averaged 15.860, with values spanning from 11.370 to 21.390 and a standard deviation of 3.606. Interpretation: The moderate to high variability in moisture content suggests potential differences in drying efficiency, sample storage, or environmental exposure. This parameter is particularly important for

shelf-life, microbial stability, and texture in biological and food matrices. The mean ash content was 6.428, with a range from 4.280 to 9.250 and a standard deviation of 1.613. Ash content reflects the total mineral content, and its moderate variability may be due to differences in mineral accumulation or contamination. This parameter is relevant for nutritional evaluation and regulatory compliance, especially in food and pharmaceutical products. Dry matter values were highly consistent, averaging 0.773, with a narrow range of 0.670 to 0.910 and a standard deviation of 0.077. The low variability indicates a stable solid fraction across all samples, suggesting controlled processing conditions or homogeneous sample types. This consistency supports reliability in comparisons of other compositional parameters. Overall, the dataset reveals notable variability in protein, lipid, and humidity, indicating heterogeneous sample characteristics. Meanwhile, the dry matter content remains remarkably stable, implying consistency in total solids. These findings highlight the importance of considering individual component variability in quality control, formulation, and product development (**Table 3**). The lipid content ranged from 1.76% to 13.65%, with an average of 8.53% and a relatively high standard deviation of 3.99%. This indicates a considerable degree of variability in fat composition among the samples, possibly reflecting differences in biological origin, processing methods, or sample maturity. Protein levels were observed between 46.02% and 61.49%, averaging 55.27% with a standard deviation of 5.35%. This suggests that protein content was fairly consistent across the samples, though the variation may still be biologically or industrially significant, depending on the context (e.g., nutritional analysis or quality grading). Humidity levels exhibited a wide range, from 8.71% to 41.70%, with an average of 21.50% and a notably high standard deviation of 11.45%. This substantial variability suggests inconsistent moisture control, which could affect product stability, shelf life, or microbial safety. The ash content ranged from 4.80% to 9.55%, averaging 6.86% with a moderate standard deviation of 1.62%. Ash content reflects the total mineral content in the samples and suggests some variability in mineral composition or contamination levels (e.g., due to processing residues or raw material origin). Dry matter values varied from 0.58 to 0.92, with a mean of 0.784 and a low standard deviation of 0.112. These results suggest that the majority of the samples are relatively consistent in their total solid content, which is critical for formulating concentration or dosing in product development. The observed variability, especially in lipid and humidity levels, may point to underlying differences in raw material composition or post-harvest/processing conditions. Protein and dry matter contents appear more stable, which could be advantageous in applications requiring nutritional consistency. Ash content shows moderate variability, highlighting the need for control over mineral residues or standardization of input materials (**Table 6**). Our results are similar to those reported by [32].

Figure 4 shows the results of analyses of dried *Clarias gariepinus* fish from the marches of N'djamena. The principal Component Analysis (PCA). Variable Correlation Circle The presented PCA biplot illustrates the relationships among five active variables projected onto the first two principal components (F1 and F2),

which together explain 73.25% of the total variability in the dataset (F1: 37.74%, F2: 35.52%). Dimensionality Reduction and Explained Variance Axis F1 (37.74%) primarily captures variance associated with compositional variables such as protein, lipid, and ash content. Axis F2 (35.52%) is predominantly influenced by the contrast between dry matter and humidity level. The high cumulative explained variance (over 70%) indicates that these two components sufficiently summarize the underlying structure of the data. **Variable Contributions and Groupings Dry Matter:** Projects strongly along the positive F2 axis. It has the longest vector, suggesting a high contribution to the model and that it captures significant variance. Positively correlated with F2 and nearly orthogonal to F1, indicating it contributes little to F1. **Humidity Level:** Positioned opposite to dry matter along F2, indicating a strong negative correlation with dry matter. This inverse relationship reflects their inherent physical link—higher moisture implies lower dry matter content. **Protein, Lipid, and Ash Content:** These variables cluster closely in the positive F1 region, indicating: Strong positive correlations among them. They co-vary in the dataset and jointly contribute to the first principal component. Their moderate vector lengths imply meaningful, though less dominant, contributions compared to dry matter and humidity. Correlation Structure Dry Matter vs. Humidity Level: Strongly negatively correlated (vectors nearly 180° apart). **Protein, Lipid, Ash Content:** Positively correlated (small angles between vectors). Weak or no correlation with dry matter and humidity (vectors nearly orthogonal). **Implications for Analysis The PCA suggests two main dimensions of variability:** F1: Related to compositional richness (protein, lipid, ash). F2: Related to physical properties (moisture vs. dry content). Understanding these dimensions can inform clustering, classification, or quality assessment in domains like food science, agriculture, or material analysis. For smoked *Clarias gariepinus* fish, the factorial plane formed mainly by the axes (F1 and F2) explains 68.53% of the variability (Figure 7). This is a PCA (Principal Component Analysis) correlation circle plot. It helps visualize how variables contribute to the principal components and their relationships with each other. Here's a professional interpretation of this chart: Title & Axes Explanation Axes F1 (39.76%) and F2 (28.77%) together explain 68.53% of the total variance in the dataset. The two principal components (F1 and F2) are plotted on the x- and y-axes, respectively. **Interpretation of Variables Ash content and Dry matter:** Located strongly on the positive side of F1, indicating a strong correlation with the first principal component. Also, closely grouped and aligned, suggesting a strong positive correlation between them. **Protein:** Positioned in the positive quadrant of F2, suggesting a strong correlation with the second principal component. Less influence on F1 compared to Ash and Dry matter. **Lipid:** Moderate projection between F1 and F2, indicating a weaker correlation with both components. Not strongly associated with any particular group. **Humidity level:** Located on the negative side of F1, opposite to Ash content and Dry matter. This indicates a negative correlation with those two variables (*i.e.*, as humidity increases, ash and dry matter likely decrease). General Observations Vari-

ables far from the center (like Ash content and Humidity level) are better represented by the PCA model. Angles between vectors indicate correlations: Small angles (acute): High positive correlation (Ash content & Dry matter). Angles near 180˚ (opposite directions): Negative correlation (Humidity level vs. Dry matter). Angles around 90˚: No correlation (Lipid and Protein).

Results of the analysis of dried fish from *Clarias gariepinus*. Eigenvalues greater than 1 generally indicate components worth retaining (based on Kaiser's criterion). That would be F1 and F2 together explain ~73.26% of the total variability in the data. That's quite high, so a 2-factor solution may be sufficient. F3, although its eigenvalue is <1, still contributes a fair amount of variability (~19%), which might be considered depending on the context. F3, F4, and F5 fall below the red line (eigenvalue < 1), suggesting they contribute less unique information and may mostly represent noise. The "elbow" (a sharp drop in the plot) appears after F2, which is a visual cue that additional components don't significantly add value this is known as the elbow criterion. Keep F1 and F2: These are the most meaningful in explaining variability. Ignore F3 - F5: They add little to the explanation and may complicate interpretation without benefit (**Table 4**). Le scree plot montre que les deux premières composantes principales (F1 et F2) ont des valeurs propres supérieures à 1 et expliquent ensemble environ 73.26% de la variance totale. Sur la base du critère de Kaiser et de la méthode du coude, F1 et F2 sont les composantes les plus significatives et doivent être conservées. Les composantes F3 à F5 contribuent relativement peu à l'explication de la variance et peuvent être considérées comme moins importantes pour la suite de l'analyse (**Figure 5**). Our results simulate those reported by [33].

The results of the analysis of *Clarias gariepinus* smoked fish. The analysis extracted five principal components (F1 to F5), with the following eigenvalues and associated variance explained: F1 has an eigenvalue of 2.298, explaining 45.97% of the total variance. This component captures the largest proportion of variability in the dataset and is therefore the most significant in representing the underlying data structure. F2 contributes an additional 28.31% of the variance, bringing the cumulative explained variance to 74.28%. Together, F1 and F2 account for nearly three-quarters of the total variability, indicating that the majority of the information in the dataset can be effectively summarized using just two dimensions. F3 adds 17.64% to the cumulative variance, raising it to 91.92%. While this component contributes meaningfully, its added value beyond F1 and F2 should be considered in light of the specific research context or application. F4 and F5 explain 6.44% and 1.64% of the variance respectively, together contributing less than 10%. These components may represent noise or minor patterns and are typically less useful for interpretation or further analysis. Conclusion From a practical standpoint, dimensionality reduction to 2 or 3 components (F1 - F2, or F1 - F3) would retain a significant proportion of the total information (74% - 92%). This makes the PCA highly effective for visualization, clustering, or simplifying the dataset for predictive modeling. Further analysis should focus on interpreting the

loadings of the variables on F1, F2, and potentially F3, to understand the nature of the relationships and underlying latent dimensions represented by these components (Table 7). The scree plot visually represents the eigenvalues associated with each principal component extracted during the Principal Component Analysis (PCA). It is a diagnostic tool used to determine the number of components to retain based on their relative contribution to total variance. Elbow Criterion: The plot shows a distinct "elbow" after the second component (F2), where the curve flattens significantly. This indicates that most of the variance is captured by the first two components, while subsequent components contribute marginally. The elbow point suggests that retaining two principal components is optimal for dimensionality reduction without substantial information loss. Kaiser Criterion: A horizontal red dashed line at eigenvalue = 1 represents Kaiser's criterion, which recommends retaining components with eigenvalues greater than 1. F1 (2.298) and F2 (1.416) exceed this threshold, further justifying their retention. Components F3 to F5 fall below this line and are considered to contribute minimal unique variance, likely representing noise or redundancy in the data. Variance Concentration: The steep decline from F1 to F2 reflects a rapid concentration of variance in the first few components. This indicates that the dataset's structure is highly compressible, allowing for effective dimensionality reduction and easier interpretation in lower-dimensional space (Figure 8). Our results simulate those reported by [34].

Linear correlation coefficient for dried *Clarias gariepinus* fish: Strong Inverse Relationship: Humidity level vs. Dry matter: r = −0.741. This is expected, as these two variables are inversely proportional by nature. As moisture content increases, the amount of dry matter decreases, and vice versa. They capture the same physical property from opposite perspectives. **Strong Positive Correlations:** Q1-6 vs. Protein: r = 0.871. Q1-6 is highly predictive of protein content, likely measuring a spectral or compositional aspect closely related to proteins. Q1-7 vs. Ash content: r = 0.671. Suggests that Q1-7 is linked to mineral content, possibly indicating inorganic material concentration. Q1-7 vs. Dry matter: r = 0.472 and Q1-7 vs. Lipid: r = 0.555 Q1-7 may reflect a shared structural or compositional signature common to ash, lipid, and dry matter. Q1-6 vs. Ash content: r = 0.427. Indicates a secondary relationship between Q1-6 and mineral content. **Moderate to Weak Relationships:** Several of the Q1 variables (Q1-1 to Q1-5) show weak and consistent correlations with other variables, typically around r = −0.143. These may represent background signals, instrument noise, or less informative features. Q1-1 and most others = r ≈ −0.143, likely a default or negligible correlation. **Opposing Trends:** Protein. Humidity level: r = −0.141. Lipid. Humidity level: r = −0.170. These negative correlations suggest that higher water content tends to dilute concentrations of lipids and proteins. Ash content. Humidity: r = −0.297. Ash also tends to decrease as water content increases, though to a lesser degree. To identify latent dimensions. Hierarchical clustering (as shown in the dendrogram) to group correlated features. Feature selection to eliminate redun-

dancy. Summary of Implications Q1-6 is a strong proxy for Protein. Q1-7 bridges Ash, Lipid, and Dry Matter, suggesting it captures a composite composition signal. Humidity and Dry Matter are antagonistic and essential to balance in compositional modeling. Several Q1 variables may be informationally redundant, suggesting dimensionality reduction could improve model performance (Table 7). **Group 1: Humidity & Dry Matter:** These two variables are strongly inversely correlated (r = −0.741), indicating they describe the same water-related dimension in opposite directions. **Group 2: Q1-6 & Protein:** These variables show a very high correlation (r = 0.871). Q1-6 is likely a strong indicator of protein content. **Group 3: Q1-7, Ash, Lipid:** Q1-7 is moderately to strongly correlated with both Ash and Lipid, suggesting a shared dimension between mineral and organic components. **Group 4**: Q1-1, Q1-2, Q1-3, Q1-5: These show similar correlation patterns and may reflect general spectral or background variability. **Group 5**: Q1-4 & Q1-8: These two variables cluster together likely due to a similar correlation profile with other variables, representing unique latent features (Table 5). Our results collaborate with those reported by [35]. **Linear correlation coefficient for smoked *Clarias gariepinus* fish:** Interpretation of the Correlation Matrix The correlation matrix shows the relationships between eight sample groups (Q1-1 to Q1-8) and five measured variables: lipid, protein, humidity rate, ash content, and dry matter. Pearson correlation coefficients were used to evaluate the strength and direction of linear associations. **Dry Matter and Humidity Rate Correlation**: -0.915. This is a very strong negative correlation, indicating that as dry matter content increases, humidity rate decreases. This inverse relationship is expected, as higher moisture content naturally reduces dry mass. **Q1-4 and Lipid Content Correlation:** -0.653. There is a strong negative correlation between Q1-4 and lipid content, suggesting that the treatment or condition represented by Q1-4 is associated with a reduction in lipid levels. **Q1-3 vs. Humidity Rate Correlation:** 0.675. This strong positive correlation implies that Q1-3 samples tend to have higher moisture content, possibly due to formulation, storage conditions, or processing. **Protein and Ash Content Correlation:** 0.415. A moderate positive correlation is observed, indicating that samples with higher protein content also tend to have higher ash content. This may reflect nutrient-rich compositions. **Lipid and Protein Correlation:** 0.228. A weak positive correlation exists, showing a slight tendency for lipid-rich samples to also have more protein, although this relationship is not particularly strong. Inter-sample Group Correlations (Q1-1 to Q1-8) Most sample groups (Q1-1 to Q1-8) show low mutual correlations (mostly around -0.143), indicating they may have been independently varied or are orthogonal in design. This supports the assumption that each group represents a distinct condition or treatment. Implications The strong inverse relationship between humidity and dry matter should be considered when evaluating shelf life and stability. Treatments similar to Q1-4 may be effective for reducing lipid content, which could be relevant for health-oriented formulations. Understanding these correlations can guide product optimization, especially when targeting specific nutri-

tional profiles. Cluster Analysis Report (Combined Heatmap). The Interpretation of Combined Clustered Heatmap. This combined clustered heatmap visualizes the correlation structure among 13 variables, with hierarchical clustering applied to both rows and columns. Variables include eight sample groups (Q1-1 to Q1-8) and five compositional properties (lipid, protein, humidity rate, ash content, and dry matter). The hierarchical clustering reveals distinct groupings, where similar variables or samples are positioned closer together. This helps identify patterns and relationships that may not be apparent in a non-clustered correlation matrix. Strong inverse and direct correlations are grouped visually by color and proximity; Variables such as Protein, Ash Content, and Lipid are closely related; Humidity rate and Dry Matter show strong negative correlation, clustering inversely; Sample groups like Q1-1, Q1-2, and Q1-5 show similarities in profile. This analysis supports variable selection, data simplification, and better decision-making based on inherent variable relationships (**Table 8**). Our results collaborate with those reported by [36] [37].

In the comparison between dried and smoked *Clarias gariepinus*, the results show that the lipid content of smoked *Clarias gariepinus*[16] is the highest among all the samples analysed (**Figure 9**). Analysis of protein content indicates that dried *Clarias gariepinus*[6] has a value of 66.337%, higher than those recorded for the other dried and smoked samples (**Figure 10**). In terms of moisture content, smoked *Clarias gariepinus*[11] reached 41.500%, representing the highest value observed (**Figure 11**). In addition, the ash content of smoked *Clarias gariepinus*[14], evaluated at 9.527%, is also higher than those of the other samples (**Figure 12**). Finally, dry matter analysis reveals that smoked *Clarias gariepinus*[9] records a value of 0.910%, surpassing all the values obtained for dried and smoked samples (**Figure 13**).

The microbiological evaluation of Dried *Clarias gariepinus* samples revealed widespread contamination that significantly exceeds the regulatory limits established for animal-origin food products. These results indicate poor microbiological quality and raise serious concerns regarding food safety for consumers. *Total Aerobic Mesophilic Flora* (TAMF): The mean count (3.6×10^6 cfu/g) substantially exceeds the maximum allowable limit ($\leq 10^5$ cfu/g). Such a high microbial load generally reflects poor hygienic practices throughout the production and distribution chain, including slaughtering, processing, storage, and transportation. *Coliforms* at 37˚C: The coliform count (2.0×10^5 cfu/g) is considerably higher than the standard limit ($\leq 10^2$ cfu/g). As *coliforms* serve as indicators of hygiene, their elevated levels suggest indirect fecal contamination, often linked to the use of contaminated water or unclean equipment. *Escherichia coli*: Detected at a concentration of 1.7×10^3 cfu/g, the presence of E. coli is a direct indicator of fecal contamination. This bacterium is associated with gastrointestinal infections, and its detection above acceptable thresholds is considered a serious health hazard. *Bacillus cereus*: The mean count of *B. cereus* was 1.4×10^4 cfu/g, significantly surpassing the acceptable limit ($\leq 10^2$ cfu/g). As a spore-forming bacterium, *B. cereus*

can produce toxins that cause food poisoning, particularly when present in high concentrations. Coagulase-positive *Staphylococcus*: Quantified at 1.5×10^4 cfu/g, this pathogen is commonly linked to human contamination through handling (hands, respiratory secretions) and can produce heat-stable enterotoxins. Its elevated presence indicates a breach in hygienic handling practices. Yeasts and Moulds: The fungal count (1.4×10^4 cfu/g) reflects potential spoilage and improper storage conditions (e.g., high humidity or poor temperature control). While not always pathogenic, certain fungal strains may produce harmful mycotoxins. *Salmonella spp.*: No data was provided for *Salmonella*. However, regulatory standards require its absence in 25 grams of the sample. The presence of *Salmonella* would immediately disqualify the product for human consumption due to its high pathogenicity. The microbial profile of the *Clarias gariepinus* samples demonstrates significant non-compliance with established food safety standards. These findings suggest critical failures in the fish production and supply chain, particularly in hygiene, cold chain management, and quality control procedures. To ensure consumer safety and product marketability, it is imperative to implement corrective measures, including strict hygiene protocols, regular microbiological monitoring, and the adoption of food safety systems such as HACCP (Hazard Analysis and Critical Control Points) (**Table 9**) Our results are similar [38] [39]. As well as the bacteriological smoking analysis of *Clarias gariepinus* (**Table 10**). The microbiological results reveal significant contamination of the fish sample, with most microbial counts exceeding acceptable safety limits: *Total Aerobic Mesophilic Flora* (TAMF): The high count (3.5×10^6 CFU/g) reflects a heavy overall microbial load, which is often indicative of poor hygiene during handling, processing, or storage. It may also suggest prolonged storage time or a break in the cold chain. *Coliforms* at 37˚C: The elevated count (1.8×10^5 CFU/g) indicates possible fecal contamination, suggesting poor-quality water, environmental contamination, or inadequate sanitation during processing. *Escherichia coli* (E. coli): Though moderate in number (1.4×10^3 CFU/g), it still exceeds safety thresholds. The presence of E. coli is a direct indicator of recent fecal contamination, posing a public health risk, especially if the product is undercooked or consumed raw. *Bacillus cereus:* Found at 1.25×10^4 CFU/g, this spore-forming bacterium can produce toxins that cause food poisoning. Its presence suggests improper storage conditions, such as extended time at room temperature, or inadequate reheating/cooking practices. *Coagulase-positive Staphylococcus:* With a level of 1.6×10^4 CFU/g, this suggests human-origin contamination, likely due to poor personal hygiene of workers (skin, hands, nasal flora) during handling. *Yeasts and Moulds:* The high count (1.4×10^4 CFU/g) points to a moist environment conducive to fungal growth, which can cause spoilage or even mycotoxin production, depending on the species present. *Salmonella:* Absent in 25 g, which is within regulatory limits. This is a positive finding, as the presence of *Salmonella* would lead to automatic rejection of the batch due to its serious health implications. The tested *Clarias gariepinus* batch is not compliant with microbiological safety standards,

except for the absence of *Salmonella*. These results indicate: Inadequate hygiene and sanitary practices during farming, processing, and storage; A high risk to consumer health, particularly if the product is not properly cooked; Urgent need for corrective measures, such as reviewing and improving hygiene protocols, staff training, and cold chain management our results are similar [40].

5. Conclusions

The survey of processed fish sales outlets enabled us to assess the hygienic condition of products intended for human consumption. Observations at the marketing sites revealed a general lack of awareness and frequent non-compliance with good hygiene practices, which could represent a health risk for consumers. A socio-demographic analysis of the players involved shows that young people aged between 25 and 30 are the most active in fish processing and trading. This predominance of young people could be explained by the search for accessible economic opportunities and the flexibility offered by the informal sector. In terms of gender distribution, it appears that women are less represented than men in this area. This imbalance could be attributed to socio-cultural factors limiting women's access to certain commercial activities, or to the physical and organisational constraints associated with fish processing work. These findings highlight the need to set up food hygiene awareness and training programmes, targeting young traders in particular, in order to improve the health quality of the processed fish offered to consumers. The improvement of fish processing quality, particularly for *Clarias gariepinus* (African catfish), relies on the integration of modern techniques and best practices at every stage of the processing chain. The adoption of practices such as Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) minimizes contamination risks, leading to a significant enhancement in product quality and safety. Strict hygiene management, adherence to cold chain protocols during transport, optimized drying techniques, and strategies to prevent insect infestations all contribute to maintaining the fish's freshness, safety, and quality. Moreover, compliance with international standards, particularly those set by the FAO, is essential for ensuring global sanitary compliance and consumer safety. Ongoing education and training for stakeholders are crucial to ensuring effective implementation of these practices. By adopting these modern approaches, the fish processing industry can not only improve product quality and consumer safety but also promote sustainability and competitiveness in global markets. The results presented in this study confirm that adherence to these modern practices and compliance with international standards is essential for ensuring sustainable and high-quality fish processing, thereby contributing to the competitiveness of the sector on a global scale.

Nutritional analyses of processed fish revealed high levels of essential nutrients, particularly lipids and proteins, which are key components of a balanced diet. Among the products studied, dried *Clarias gariepinus* showed the highest concentrations, with approximately 9.63% lipids and 49.76% proteins. These values indi-

cate a high nutritional density, making dried fish an excellent source of energy and essential nutrients for local populations. Smoked Clarias gariepinus also demonstrated significant lipid and protein contents, with 8.53% lipids and 55.27% proteins, respectively. The high protein concentration in smoked fish highlights its important role in providing essential amino acids for the body. These results confirm the importance of processed fish products, especially dried and smoked forms, as high-quality nutritional sources, particularly in areas with limited access to other protein sources.

The microbiological quality assessment of processed fish collected from the Dembe and Taradona markets revealed generally unsatisfactory quality, raising significant concerns regarding the safety of these products. Microbiological analyses primarily isolated a total aerobic mesophilic flora, composed of microorganisms capable of growing at moderate temperatures, which is often used as a general indicator of microbial load. Among these microorganisms, species such as *Staphylococcus* spp., *Bacillus cereus*, and *Escherichia coli* were detected, along with yeasts and molds. The presence of *Staphylococcus* spp., bacteria frequently involved in food poisoning, may indicate inadequate hygiene practices during handling or processing of the fish. Similarly, *Bacillus cereus* is known for its ability to form resistant spores that can survive processing conditions and is associated with foodborne illnesses. The detection of *Escherichia coli*, a classic indicator of fecal contamination, suggests contamination from unhygienic water, surfaces, or direct contact with handlers. Finally, the presence of yeasts and molds highlights a potential risk of product spoilage, which can affect both sensory quality and safety. However, despite the concerning microbial load, no strains of *Salmonella* spp. were detected in the samples analyzed. This observation aligns with several previous studies that found no *Salmonella* spp. in smoked and dried seafood products. This absence is primarily explained by the physicochemical conditions resulting from processing, notably the significant reduction of water activity (aw) following dehydration. The decrease in water activity strongly limits the availability of free water necessary for the growth of pathogenic microorganisms such as *Salmonella* spp. Additionally, smoking may contribute to microbial inhibition due to antimicrobial compounds present in the smoke. Nevertheless, even though *Salmonella* is absent, the presence of other pathogenic or indicator microorganisms suggests that handling, processing, and storage practices need improvement to ensure the safety of fishery products intended for consumption. Implementing strict hygiene measures and regular microbiological monitoring is therefore essential to reduce health risks and guarantee the quality of products offered to consumers.

To ensure the safety and quality of locally processed fishery products, it is necessary to:

- ✓ Improve hygiene in processing units by establishing suitable infrastructure (clean areas, potable water, easy-to-clean equipment) and adopting strict practices for cleaning, handling, and personal protection.

- ✓ Effectively train processors on good hygiene and manufacturing practices, with practical training adapted to local realities and regular follow-up to maintain standards.
- ✓ Adapt public policies to strengthen the regulatory framework, provide financial and organizational support to processors (especially artisanal and women), and encourage certification and valorization of products that meet standards.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Anihouvi, D.G.H., Kpoclou, Y.E., Abdel Massih, M., *et al.* (2019) Caractéristiques microbiologiques du poisson fumé et fumé-séché transformé au Bénin. *Food Science & Nutrition*, **7**, 1821-1827.

[2] Daramola, J.A., Alao, F.O. and Adeniyi, A.E. (2020) Estimation des bactéries et des champignons présents dans le poisson-chat fumé (*Clarias gariepinus*) disponible sur les marchés d'Ota. *Journal of Research in Forestry, Wildlife and Environment*, **12**, 65-73.

[3] Bardoe, D., Gyabeng, J., Hayford, D. and Ibrahim, I. (2023) Evaluation of Bacteria Composition in Smoked Fish Processed in Yeji-Pru East District, Ghana. *Journal of Advances in Microbiology*, **23**, 50-65. https://doi.org/10.9734/jamb/2023/v23i4720

[4] Miessan, A.P., Julien, C.K., Parfait, Y.K. and Gouli, G.B. (2022) Caractérisation socio-économique de la transformation artisanale et évaluation de l'état sanitaire des poissons *Oreochromis niloticus* (Linnaeus, 1758), *Chrysichthys nigrodigitatus* (Lacépède, 1803) fumés, séchés sur le marché de Béoumi, Côte d'Ivoire. *Journal of Applied Biosciences*, **176**, 18307-18321. https://doi.org/10.35759/JABs.176.9.

[5] Fall, N.G., Tounkara, L.T., Diop, M.B., Thiaw, O.T. and Thonart, P. (2014) Étude socio-économique et technologique de la production du poisson fermenté et séché (Guedj) au Sénégal. *International Journal of Biological and Chemical Sciences*, **8**, 2523-2538.

[6] Suseno, S., Hayati, S. and Izaki, A. (2014) Fatty Acid Composition of Some Potential Fish Oil from Production Centers in Indonesia. *Oriental Journal of Chemistry*, **30**, 975-980. https://doi.org/10.13005/ojc/300308

[7] Ayeloja, A.A., George, F.O.A., Jimoh, W.A., Shittu, M.O. and Abdulsalami, S.A. (2018) Microbial Load on Smoked Fish Commonly Traded in Ibadan, Oyo State, Nigeria. *Journal of Applied Sciences and Environmental Management*, **22**, 493-497. https://doi.org/10.4314/jasem.v22i4.9

[8] Domingo, J.L. (2007) Omega-3 Fatty Acids and the Benefits of Fish Consumption: Is All That Glitters Gold? *Environment International*, **33**, 993-998. https://doi.org/10.1016/j.envint.2007.05.001

[9] Nøstbakken, O.J., Rasinger, J.D., Hannisdal, R., Sanden, M., Frøyland, L., Duinker, A., *et al.* (2021) Levels of Omega 3 Fatty Acids, Vitamin D, Dioxins and Dioxin-Like PCBS in Oily Fish; a New Perspective on the Reporting of Nutrient and Contaminant Data for Risk-Benefit Assessments of Oily Seafood. *Environment International*, **147**, Article ID: 106322. https://doi.org/10.1016/j.envint.2020.106322

[10] Lerma-Fierro, A.G., Flores-López, M.K., Guzmán Robles, M.L. and Cortés-Sánchez, A.D.J. (2020) Microbiological Evaluation of Minimally Processed and Marketed Fish in Popular Market of the City of Tepic Nayarit, Mexico: Sanitary Quality of Tilapia (*Oreochromis niloticus*). *Tropicultura*, **38**, 1-19. https://doi.org/10.25518/2295-8010.1556

[11] Salem, M., Zharan, E., Saad, R. and Zaki, V. (2020) Prevalence, Molecular Characterization, Virulotyping, and Antibiotic Resistance of Motile Aeromonads Isolated from Nile Tilapia Farms at Northern Egypt. *Mansoura Veterinary Medical Journal*, **21**, 56-67. https://doi.org/10.21608/mvmj.2020.21.108

[12] Alkhunni, S.B.A., Gaballah, M.S.M. and Gultepe, N. (2017) Pathogenic Bacteria for Human and Fish Isolated from Fish Farm in Kastamonu, Turkey. *Journal of Aquaculture & Marine Biology*, **6**, Article No. 157. https://doi.org/10.15406/jamb.2017.06.00157

[13] Muhammad, Z., Khan, S., Khattak, F., Bashir, K., Khan, A., Sheraz, M., *et al.* (2023) Antibiotic Susceptibility Profile and Nutritional Evaluation of Raw and Cooked Meat of *Cyprinus carpio*. *Bulletin of Biological and Allied Sciences Research*, **8**, Article No. 55. https://doi.org/10.54112/bbasr.v2023i1.55

[14] Assogba, M.H.M., *et al.* (2018) Qualité de la chair des poissons: Facteurs de variations et impacts des procédés de transformation et de conservation. *International Journal of Progressive Sciences and Technologies*, **10**, 333-358.

[15] Diouf, A.B.K., Ayssiwede, S.B., Diawara, A. and Musabyemaria, B. (2022) Évaluation de la qualité microbiologique des poissons transformés artisanalement dans la Commune de Joal-Fadiouth, Département de Mbour (Sénégal).

[16] INSEED (2009) Deuxième recensement général de la population et de l'habitat (RGPH2, 2009) République du Tchad. 88 p.

[17] AOAC (1990) Official Methods of Analysis. 14th Edition, Association of Official Analytical Chemists.

[18] AOAC (1997) Official Methods of Analysis. 15th Edition, Association of Official Analytical Chemistry.

[19] NF EN ISO 20483 (2014) Céréales et légumineuses-Détermination de la teneur en azote et calcul de la teneur en protéines brutes-Méthode de Kjeldahl. V 03-750.

[20] NF EN ISO 6887-4 (2004) Préparation des échantillons, de la suspension mère et des dilutions décimales en vue de l'examen microbiologique-Partie 4: Règles spécifiques pour la préparation de produits laitiers, carnés et de de la pêche. V08-010-4.

[21] NF EN ISO 4833-1 (2013) Méthode horizontale pour le dénombrement des micro-organismes-Partie 1: Comptage des colonies à 30 °C par la technique d'ensemencement en profondeur: V08-011-1.

[22] NF ISO 4832 (2006) Microbiologie des aliments-Méthode horizontale pour le dénombrement des coliforms-Méthode par comptage des colonies (Indice de classement: V08-015).

[23] NF EN ISO 6579-1 (2017) Microbiologie de la chaîne alimentaire-Méthode horizontale pour la recherche, le dénombrement et le sérotypage des Salmonella-Partie 1: Recherche des Salmonella spp. FT91MP200.

[24] NF EN ISO 6888-4 (2004) Microbiologie des aliments-Méthode horizontale pour le dénombrement des staphylocoques à coagulase positive (*Staphylococcus aureus* et autres espèces)-Partie 4: Méthode alternative utilisant des milieux chromogènes. Association Française de Normalisation.

[25] NF V 08-059 (2009) Dénombrement des levures et moisissures par comptage des colonies à 25 °C: V08-059.

[26] ISO 15213-1 (2021) Microbiologie de la chaîne alimentaire-Recherche et dénom-brement des bactéries anaérobies sulfito-réductrices (clostridies) par la méthode du nombre le plus probable-Partie 1: Produits alimentaires *et al*. iments pour ani-maux. Organisation internationale de normalisation.

[27] NF ISO 16649-2 (2001) Microbiologie des aliments-Méthode horizontale pour le dénombrement des *Escherichia coli β*-glucuronidase positifs-Partie 2: Technique de comptage sur plaque utilisant un milieu gélosé contenant du BCIG à 44 °C. Association Française de Normalisation.

[28] NF EN ISO 7932 (2005) Méthode horizontale pour le dénombrement de *Bacillus cereus* présomptifs-Technique par comptage des colonies à 30 °C V08-023.

[29] ISO (2007) ISO 7218:2007. Microbiologie des aliments. Règles générales pour les analyses microbiologiques. Organisation internationale de normalisation.

[30] Kaffine, G., Tidjanie, A. and Micha, J.C. (2018) Qualité hygiénique du poisson transformé et commercialisé au Tchad. *Tropicultura*, **36**, 649-657.

[31] Koua, A., Desiré, K.N., Koffi Donatien, B.C., Adjehi, D. and Sébastien, N. (2022) Qualité Microbiologique Des Poissons Fumés Traditionnellement et Vendus Sur Des Marchés A Abidjan, Côte d'Ivoire. *International Journal of Progressive Sciences and Technologies*, **34**, 249-264. https://doi.org/10.52155/ijpsat.v34.2.4596

[32] Chabi, N.W., *et al*. (2014) Performance d'un dispositif amélioré de fumage (four Chorkor) sur la qualité du poisson fumé dans la commune d'Aplahoué (Sud-est du Bénin). *International Journal of Innovation and Applied Studies*, **9**, 1383.

[33] Kabré, A.T., Diarra, D. and Traoré, A. (2013) Le fumage du poisson au Burkina Faso: Comparaison des caractéristiques et de la rentabilité de trois types de fumoirs améliorés. *Cahiers Agricultures*, **12**, 409-417.

[34] Akmel, M.S. (2017) Impact socioéconomique et risques sanitaires liés au fumage du poisson à Bouaké (Côte d'Ivoire) Département d'Anthropologie et de Sociologie, Université Alassane Ouattara, Côte d'Ivoire. *International Journal of Multidisciplinary Research and Development*, **4**, 105-112. https://www.allsubjectjournal.com

[35] Forkuor, D., Peprah, V. and Alhassan, A.M. (2017) Assessment of the Processing and Sale of Marine Fish and Its Effects on the Livelihood of Women in Mfantseman Municipality, Ghana. *Environment, Development and Sustainability*, **20**, 1329-1346. https://doi.org/10.1007/s10668-017-9943-7

[36] Orewa, S.I. and Iteke, A.E. (2013) Commercialisation du poisson séché: Potentiel et dé-fis pour la création d'emplois et la réduction de la pauvreté chez les femmes urbaines au Nigéria. *International Journal of Development and Sustainability*, **2**, 909-925.

[37] Ndoazen, A., Mangar, P., Sobdibe, P.Y. and Micha, J. (2024) Etude socio-économique, environnementale et fonctionnelle de la chaîne de valeur poisson dans le Bassin Central du Chari au Tchad. *International Journal of Biological and Chemical Sciences*, **18**, 924-937. https://doi.org/10.4314/ijbcs.v18i3.16

[38] Lambert, B.C.L., *et al*. (2015) Qualité des poissons vendus au port de pêche artisanal de Cotonou (POPAC). *European Scientific Journal*, **11**, 147-158.

[39] Depo, A.A., Dossou, J. and Anihouvi, V. (2019) Itinéraire technique et évaluation de la qualité des poissons-chats (*Clarias gariepinus*) fumés et commercialisés au Bénin. *Sciences de la vie, de la terre et agronomie*, **7**, 29-34.

[40] Dalman, M., Bhatta, S., Nagajothi, N., Thapaliya, D., Olson, H., Naimi, H.M., *et al.* (2019) Characterizing the Molecular Epidemiology of *Staphylococcus aureus* across and within Fitness Facility Types. *BMC Infectious Diseases*, **19**, Article No. 69. https://doi.org/10.1186/s12879-019-3699-7