

Study of the effects of the dosage of extracts of *Thymus vulgaris* (Thyme) and *Salvia rosmarinus* (Rosemary) on the quality (organoleptic, chemical and microbiological) of smoked *Clarias gariepinus*

Sitor Diouf

Institut Universitaire de Pêche et Aquaculture (IUPA), Cheikh Anta Diop de Dakar (UCAD),

BP 5005 Dakar-Fann,II bâtiment pédagogique/Rez de chaussée BP 5005 Dakar-Fann,

Sénégal.

Jean Fall

Institut Universitaire de Pêche et Aquaculture (IUPA), Cheikh Anta Diop de Dakar (UCAD),

BP 5005 Dakar-Fann, II bâtiment pédagogique/Rez de chaussée BP 5005 Dakar-Fann,

Sénégal.

Abdoulaye Diouf

Institut Universitaire de Pêche et Aquaculture (IUPA), Cheikh Anta Diop de Dakar (UCAD),

BP 5005 Dakar-Fann,II bâtiment pédagogique/Rez de chaussée BP 5005 Dakar-Fann,

Sénégal.

Ndeye Khadidia Sall

Institut Universitaire de Pêche et Aquaculture (IUPA), Cheikh Anta Diop de Dakar (UCAD),

BP 5005 Dakar-Fann,II bâtiment pédagogique/Rez de chaussée BP 5005 Dakar-Fann,

Sénégal.

Diégane Ndong

Direction of Animal and Halieutic Resources, Department of Agriculture, Water Resources and Environment, UEMOA Commission, 380 Av. Pr. Joseph KI-ZERBO, 01 BP 543 Ouagadougou 01-Burkina Faso.

Abstract

In Senegal, smoking and drying are the most common methods of preserving catfish. However, the quality of the products and their ability to preserve them are still a recurring problem because of post-treatment contamination and the favourable climate that facilitates their deterioration. Thus, the present study aims to evaluate the effect of different concentrations of medicinal plant extracts such as *Thymus vulgaris* and *Salvia rosmarinus* during the smoking process on the organoleptic, chemical and microbiological properties of smoked catfish. The results of the sensory evaluation showed that the samples with the plant extracts, especially those containing 2% *Salvia rosmarinus* and 2% *Thymus vulgaris*, obtained better scores for the criteria of color, texture, taste and aroma compared to the other samples. The results of the chemical analysis showed satisfactory concentrations of Total Volatile Basic Nitrogen (TVBN), with levels below the standards of the Senegalese Association for

Standardization (ASN), indicating good chemical quality of the products. The absence of particularly toxic PAHs such as benzo(a)pyrene, a carcinogenic compound potentially formed during the smoking process, is noted. Samples treated with the plant extracts showed a reduction in the concentrations of certain PAHs compared to the control samples, suggesting that the use of these plants could reduce the formation of these compounds that are harmful to the health of consumers. Microbiological testing revealed the absence of dangerous pathogens such as *E. coli*, *Salmonella*, and Staphylococcus coagulase in all samples. However, Total Aerobic Mesophilic Flora (TAMF), yeasts and molds were detected in some samples, with higher concentrations in the control compared to the treated samples, suggesting better management of microbiological quality in products treated with plant extracts.

Keywords: *Clarias gariepinus*, extracts, *Salvia rosmarinus*, *Thymus vulgaris*, smoking, quality.
DOI: 10.7176/FSQM/125-04
Publication date: May 30th 2025

Introduction

Senegal, once known for its large marine fisheries production, estimated at 533,479.98 tons per year (DPM, 2020), is experiencing a significant drop in these volumes, with 510,444.91 tons in 2020 (DPM, 2020). This decline is mainly attributed to the overexploitation of the main fish stocks, insufficient management of the monitoring, control and surveillance (MCS) of fishing activities in the country's exclusive economic zone (EEZ). At the same time, the increase in demand for fish, due to population growth and the diversification of eating habits, is marginalizing low-income social groups, who are often replaced by more powerful actors in the exploitation of natural fishery resources that have become scarce.

In this context, aquaculture is emerging as an alternative to meet the growing demand for animal proteins. However, the consumption of catfish, such as *Clarias*, remains marginal in Senegal, due to the absence of this food in traditional dietary habits. To compensate for this low popularity, the processing of fresh fish into smoked, salted-dried or fermented-dried products is a viable solution. These products, which are widely appreciated by the Senegalese, not only offer increased added value, but also improve their taste and extend their shelf life, thus meeting consumer expectations (Mbaye, 2005; Diouf et al., 2024).

However, artisanal processing, which dominates this sector, faces many socio-economic and technological constraints. The simplicity of the techniques used, often practiced in poorly equipped sites, leads to risks to public health, such as contamination by toxic substances or pathogenic microorganisms. These shortcomings are aggravated by the absence of formal quality and hygiene control systems, thus compromising the sensory and sanitary quality of processed fish.

Thus, this study is part of a process to improve the processing and valorization of farmed *Clarias gariepinus*, with a particular emphasis on smoking. The general objective was to evaluate the effect of dosages of medicinal plant extracts (*Thymus vulgaris* and *Salvia rosmarinus*) during the smoking process on the organoleptic, chemical and microbiological properties of smoked fish. By rigorously applying Good Manufacturing and Hygiene Practices (GMP/H), this work specifically aims to guarantee superior quality products, meet consumer requirements and contribute to the sustainable development of aquaculture in Senegal.

1. Material and methods

1.1. Fish processing method

The processing of the fish used in this study consisted of two pre-experimental phases whose objective was to determine the doses of plant extracts of *Thymus vulgaris* and *Salvia rosmarinus* that would be accepted by the evaluators of organoleptic parameters. The first step was to test the appropriate proportions for smoking *Clarias gariepinus* with the incorporation of extracts of *Thymus vulgaris* and *Salvia rosmarinus*. For this purpose, solutions of 7% and 14% for both *Thymus vulgaris* and *Salvia rosmarinus* were prepared for soaking fish ready to be smoked. However, organoleptic analyses of the products after smoking showed that these concentrations of plant extracts used were very high. A second test was made, with much smaller percentages of 1% and 2% solutions of *Thymus vulgaris* and *Salvia rosmarinus* extracts. This time, the results of sensory evaluation were encouraging, according to the evaluators. This is how these two proportions were chosen.

1.1.1. Preparation of thyme and rosemary doses

The preparation consists of macerating thyme and rosemary, bought in the supermarket, in water. After mixing, the maceration is filtered to produce a soaking solution. The concentrations of 1% and 2% are obtained by adjusting the ratio between the amount of thyme and rosemary and the volume of water used. The filtrate obtained will be used to evaluate the action of the extracts on the quality of the smoked catfish. The following figure 1 describes the protocol for the preparation of Thyme and Rosemary soaking solution or extract.

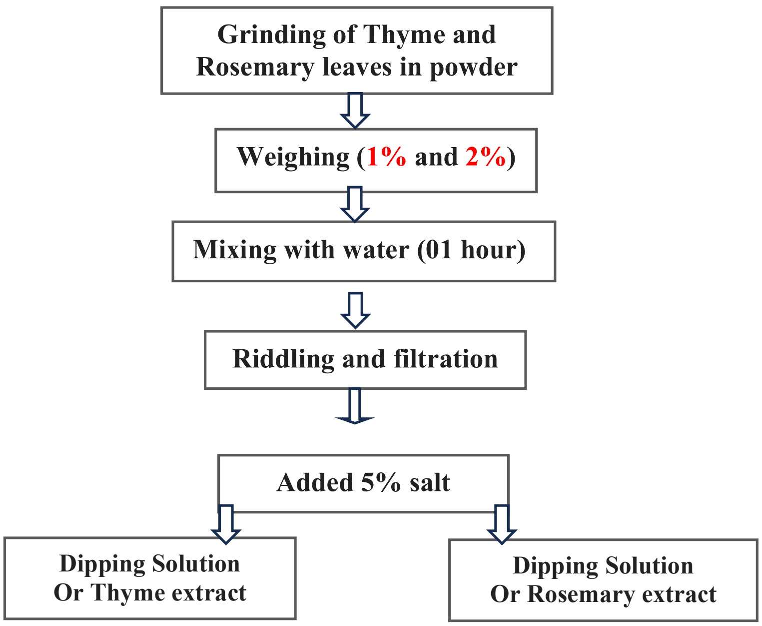

Figure 1: preparation of thyme and rosemary extracts

NB: There is also a control solution that has been made from a brine of 5% salt and without plant extracts. All soaking solutions (control and plant extracts) have 5% salt.

1.1.2. Smoking processes of *Clarias gariepinus*

After the soaking solutions have been obtained, smoking involves the steps described below.

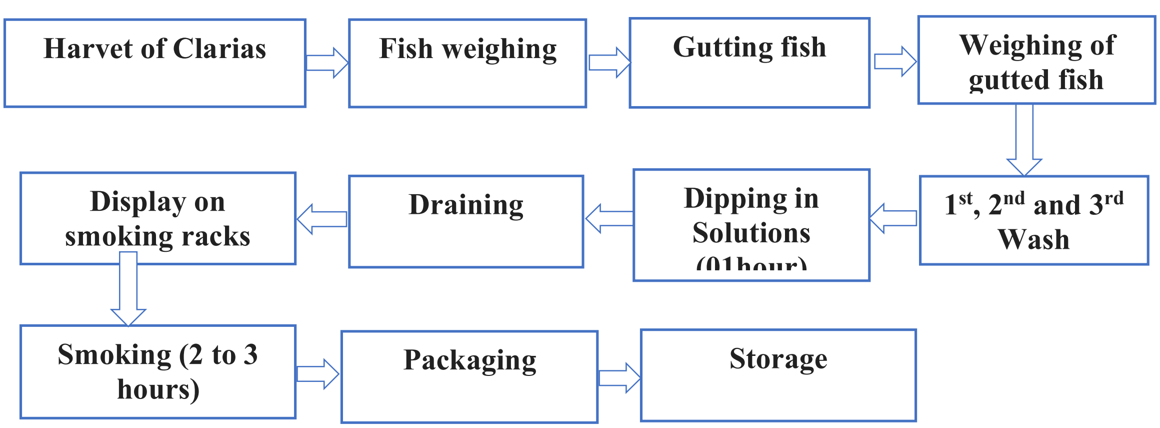

Figure 2: Manufacturing diagram of smoked *Clarias*

1.2. Sampling method

For chemical and microbiological analyses for each batch of smoked catfish from a well-defined dip (control, Thyme extracts at a dose of 1% (Th1), Thyme extracts at a dose of 2% (Th2), Rosemary extracts at a dose of 1% (Rom1) and 2% and Rosemary extracts at a dose of 1% (Rom2)), Three samples were taken, for a total of 15. For each type of processed catfish, the flesh used for testing came from a mixture of small pieces from all individuals in each batch. These samples are sent to the laboratories for chemical analyses (proteins, lipids, fats, Total Volatile Basic Nitrogen (TVBN), etc.) and microbiology (*E. coli*, SRA, yeasts and molds, salmonella, coagulase-positive staphylococci and thermotolerant coliforms) which are carried out at the National Laboratory for Analysis and Control (LANAC), while the determination of the PAH content is done at the CERES LOCUSTOX Laboratory. It should be noted that the samples were taken under aseptic conditions in order to avoid any kind of contamination.

1.3. Organoleptic analysis method

The organoleptic analyses were carried out by choosing 10 people at random who are used to the consumption of smoked fish and who did not attend the experiment to get a clear idea of the taste, smell, texture, color and level of satisfaction of the smoked catfish. The findings of these evaluators were collected and recorded for processing.

1.4. Chemical and microbiological analytical method

The methods of chemical and microbiological analysis are summarized in Tables I and II. **Table I: Chemical analyses methods**

Parameters	Methods
Protein	The KJELDAHL method divided into 3 steps: - mineralization of organic matter by sulfuric acid; - the release of NH3 from the mineralized sample by adding excess NaOH; -steam distillation of this ammonia with boric acid.
Fat	- A method of reflux extraction of a test portion with diethyl oxide that promotes solvent removal by distillation, desiccation and weighing of residues.
Ash	- Product incineration method at 600°C (LAB23 I-MET006-Crude ash v11 2013-02-01-3/5).
TVBN	- The method used is that of the distillation of an extract deproteinized by perchloric acid, which is the reference method chosen by the European Union
Humidity	-Desiccation method following the thermogravimetry approach
PAHs	-Gas chromatography method with mass spectrometry detection (GC-MS).

Table II: Microbiological analysis method

Microorganisms	Analytical methods
E. coli	Enumeration and identification in Tryptone-bile-glucuronide (TBX) culture medium at 44°C
Salmonella	Pre-enrichment, enrichment, isolation, confirmation, identification and reading
Staphylococci	Enumeration and identification in Baird-Parker (BP) culture medium at 37°C
Thermotolerant coliforms	Enumeration, identification in Violet Red Bile Lactose Agar (VRBL) culture medium at 30 °C
TVBN	Enumeration, identification in a culture medium of Plate Count Agar (PCA) at 30 °C
Yeasts and molds	Enumeration and identification in a culture medium of Chloramphenicol glucose Agar (CGA) agar at 25 °C

The counts and identification of the microorganisms sought are carried out according to French standardized methods (AFNOR, 1996). The results obtained on the chemical and microbiological analyses underwent an ANOVA by the SAS (Statistical Analysis System) software with the DUNCAN test to see if there is a statistically significant difference between the samples.

2. Results

2.1 . Results of organoleptic analyses

The results on the evaluation of the color, odor, taste, texture, salinity and satisfaction level of the finished products are summarized in Tables III to VIII. To do this, we had the participation of 10 people, who kindly contributed to the assessment of the various aspects mentioned above.

Table III : Results of the assessment of the color of smoked fish

Samples / Colors	Whitish (%)	Ligth brown (%)	Dark brown (%)	Blackish (%)
Control	30	36	34	0
Th1	67	22	11	0
Th2	70	0	20	10
Rom1	22	45	33	0
Rom2	11	11	67	11

Table III presents the evaluation of the perception of the color of the finished products. These results show a varied distribution of preferences across samples. For the control, opinions were divided between light brown (36%), dark brown (34%), whitish (30%) and no evaluator described the color as blackish. Products enriched with *Thymus vulgaris* have a majority of whitish color, according to 67% of participants for Th1 and 70% of evaluators for Th2, while those enriched with *Salvia rosmarinus* tend to have a brunette or brown coloration. Regarding Rom1 products, 45% of assessors perceive it as brunette compared to 33% who describe it as brown and for Rom2 67% of surveyors find it brown. These differences show the influence of plant extracts on the appearance of smoked products.

Table IV : résultats de l'appréciation de l'odeur des poissons fumés

Samples \ Smells	Heavy smoke (%)	Chimney smoke (%)	Smoked fish (%)	Other to be specified (%)
Witness	7	14	65	14
Th1	0	0	100	0
Th2	0	0	100	0
Rom1	0	0	100	0
Rom2	0	0	100	0

Table IV highlights the evaluators' perceptions of the smell of finished products. The results show a clear difference between the control and the samples treated with plant extracts. This is reflected in the fact that the products treated with thyme (Th1, Th2) and rosemary (Rom1, Rom2) extracts are distinguished by an odor uniformly perceived as smoked fish by all participants (100%). On the other hand, the control presents a greater diversity of olfactory assessments, including 65% of the raters who describe the smell as smoked fish, 14% who perceive an odor associated with a chimney smoke, 7% who identify a smell of strong smoke and 14% of the opinions mention another odor.

Table V : Results of the taste assessment of smoked fish

Samples \ Tastes	Very pleasant (%)	Pleasant (%)	Less pleasant (%)	Bitter (%)
Control	21	48	21	0
Th1	56	44	0	0
Th2	50	50	0	0
Rom1	56	44	0	0
Rom2	60	40	0	0

Table V illustrates the assessment of the taste of the processed products, showing a positive overall assessment by the evaluators. However, products treated with plant extracts are distinguished by a better preference compared to the control. For the Th1 product, 56% of reviewers rate it as very pleasant, while 44% find it pleasant. Regarding Th2, opinions are evenly divided: 50% of participants consider the product very pleasant, and 50% consider it pleasant. For Rom1, 56% of assessors find it very pleasant, compared to 44% who consider it pleasant. Finally, Rom2 gets the best evaluations, with 60% of reviews in favor of a very pleasant product and 40% qualifying it as pleasant. These results confirm that the incorporation of extracts of *Thymus vulgaris* and *Salvia rosmarinus*, especially at higher concentrations, significantly improves the taste perception of the products.

Tableau VI: Results of the assessment of the salinity of the products

Samples \ Salinity	Too salty (%)	Salty (%)	Moderately Salty (%)	Salt deficiency (%)
Control	0	36	57	7
Th1	0	0	100	0
Th2	0	0	100	0
Rom1	0	0	100	0
Rom2	0	0	100	0

The analysis of Table VI representing the assessment of the salinity of the smoked catfish product shows that the evaluators state that they are moderately salty, and this is justified by the fact that:

- the majority (57% of the evaluators) find the control moderately salty, 36% consider it salty, and 7% perceive a salt deficiency;

- All samples containing plant extracts are systematically judged to be moderately salty by 100% of the participants.

The addition of thyme and rosemary extracts stabilizes the perception of salinity at a moderately salty level.

Table VII: Results of the texture assessment of smoked fish

Texture / Samples	Very rigid (%)	Rigid (%)	Soft (%)	Little soft (%)
Control	0	36	57	7
Th1	0	11	89	0
Th2	0	0	89	11
Rom1	0	0	90	10
Rom2	0	33	67	0

The study of the texture of smoked fish shows that all samples are distinguished by a predominantly soft texture, with Rom1 products showing the highest proportion with 90% of participants, followed by Th1 and Th2 with 89% of raters, then Rom2 with 67% of participants and finally the control with 57% of the population. These results confirm that the incorporation of plant extracts promotes a softer texture, responding to consumer preferences.

Table VIII: Level of satisfaction of evaluators on the smoked fish

Satisfaction / Samples	Very satisfied (%)	Satisfied (%)	Less satisfied (%)	Not satisfied (%)
Control	7	71	22	0
Th1	60	40	0	0
Th2	50	50	0	0
Rom1	70	30	0	0
Rom2	50	37,5	12,5	0

Table VIII shows the evaluators' levels of satisfaction with the smoked catfish products. The results reveal significant differences between the control and the samples treated with plant extracts. Products fortified with plants, especially Rom1 get the highest overall satisfaction rate with 70% very satisfied, followed by Th1 with 60% and finally Rom2 and Th2 with 50%. On the other hand, the control shows more moderate levels of satisfaction, dominated by the satisfied category with 71% of opinions.

2.2. Results of chemical analyses

Tables X and XI represent the results of the chemical analyses, which were carried out to evaluate the physicochemical characteristics of smoked fish. These analyses include moisture, TVBN (Total Volatile Basic Nitrogen), fat, protein, ash and PAHs.

Table IIX: results of chemical analyses (TVBN, humidity, protein, ash, fat)

Chemical parameters	Control	Th 1%	Th 2%	Rom 1%	Rom2%
TVBN	6,5±0,3ᵃ	6,3±0,20ᵃ	5,5±0,3ᵇ	6,10±0,1ᵃ	4,30±0,1ᶜ
Humidity	51,2±0,1ᵃ	48,2±0,2ᶜ	37,6±0,3ᵈ	48,1±0ᶜ	50,6±0,2ᵇ
Protein	44,1±0,1ᵇ	46,7±0ᵃ	40±0ᶜ	34,1±0ᵈ	44,1±0ᵇ
Ash	1,57±0,41ᶜ	3±0,2ᵃᵇᶜ	3,57±0,41ᵃᵇ	4,3±0,1ᵃ	2,1±0ᵇᶜ
Fat	10,6±0,3ᵇ	10,7±0,2ᵇ	18±2ᵃ	10,6±0,2ᵇ	8,5±0,2ᶜ

NB: superscript a, b, c and d show the differences between the results of the statistical analyses.

The analysis of Table IX shows that: The **TVBN** rate varies depending on the sample. The analysis shows that there is no statistically significant difference in the Control, Th1 and Rom1 samples. On the other hand, the Th2 and Rom 2 samples show a statistically significant difference between them and all the other samples. In addition, the analysis shows that the control recorded the highest **TVBN** value (6.5 mg/100 g of flesh), followed by Th1 (6.3 mg/100g), Rom1 (6.1 mg/100g), Th2 (5.5 mg/100g) and Rom2 with the lowest value (4.3 mg/100g). Regarding the **humidity** content, the products of Th1 and Rom1 show a statistically significant difference compared to the other products. The highest was recorded by the Rom2 sample (50.6%), followed by the control (51.2%), Rom1 (48.1%), Th1 (48.2%) and Th2 (37.6%).
For protein, only Rom2 products did not show a statistically significant difference from the control. The Th1 sample has the highest **protein** content and Rom1 has the lowest value (34.1%). An intermediate value at the product level with Th2 (40%) is obtained. Adding *Thymus vulgaris* to 2% appears to improve the protein content, while adding 1% reduces this content.

The **ash** content also varies between samples, which are all statistically different. The Rom1 sample had the highest value (4.3%), followed by Th2 (3.9%), Th1 (3%), Rom2 (2.1%) and finally the control (1.9%). This shows a gradual increase with the addition of plant extracts, with samples containing 2% extracts showing the highest values for Thyme.
Finally, for **fat**, the control products, Th1 and Rom1, are statistically similar and show statistically significant differences compared to the Th2 and Rom2 products. However, the analysis of these results shows that the highest value is observed in Th2 (18%), followed by Th1 (10.7%), the control and Rom1 (10.6%), and finally Rom2 (8.5%). These results show that Rom2 has the lowest fat content.

Table X: results of chemical analyses (HAP in µg/kg)

Samples / PAHs	Control	Th1	Th2	Rom1	Rom2
Acenaphthylene	112±1,1[b]	106±2,2[c]	76±2,7[d]	62±1,6[e]	128±0,5[a]
Acenaphthene	56±3,7[c]	64±0,4[b]	40±2,5[d]	28±0,1[e]	96±0,8[a]
Fluorene	0	0	0	0	0
Phenanthrene	0	0	0	0	0
Anthracene	0	0	0	0	0
Fluoranthene	43±0,4[a]	40±5,9[ba]	36±0,2[bc]	22±0,4[c]	18±1,4[c]
Pyrene	32±0,5[a]	24±4,3[b]	30±2,1[a]	14±1,04[c]	6±3,4[d]
Benzo(a)anthracene	0	0	0	0	0
Chrysene	0	0	0	0	0
Perylene	0	0	0	0	0
Benzo(a)pyrene	0	0	0	0	0
Benzo(k)fluoranthène	0	0	0	0	0
Indeno(1,2,3-cd)	0	0	0	0	0

Analysis of PAHs in samples reveals variation in the presence of compounds across products. **Acenaphthylene**: This compound is detected in all samples with statistically significant differences between samples. However, the analysis shows that Rom2 has the highest value with a concentration of 128 (µg/kg) followed by control 112 (µg/kg), then Th1 106 (µg/kg), Th2 768 (µg/kg) and finally Rom1 which has the lowest value 62 (µg/kg).

Acenaphthene: also present in all samples with statistically significant differences, its highest concentration (96 µg/kg) is noted in Rom2 products. The lowest values are observed in Rom1 products with 28 µg/kg, followed by Th2 products with 40 µg/kg, then in the control 56 µg/kg and at the end of Th1 with 64 µg/kg.

For **Fluoranthene**, the results vary between samples and only Rom1 and Rom2 samples do not show any statistically significant differences between them. The control has the highest value with 43 (µg/kg). In the case of samples treated with plant extracts, the increase in the dose (from 1% to 2%) of thyme and rosemary decreases the concentration of fluoranthene from 40 to 36 (µg/kg) for thyme and from 22 to 18 (µg/kg) for rosemary.

In the case of pyrene, its highest concentration (32 µg/kg) is noted in the products of the control sample, followed by Th2 with 30 µg/kg, Th1 with 24 µg/kg, then Rom1 with 14 µg/kg and at the end of Rom2 with the lowest value (6 µg/kg). For the other PAHs, compounds such as fluorene, phenanthrene, anthracene, benzo(a)pyrene, and indeno (1,2,3-cd) were not detected in any of the samples.

2.3. Microbiological results

Table XI: Evaluation of microbiological analyses

Germs	Samples	Expression of Results in CFU/g
***Salmonella*, Thermotolerant coliforms, *E. coli*, SRA, Coagulase positive Staphylococci**	Control	No detected
	Th1	No detected
	Th2	No detected
	Rom1	No detected
	Rom2	No detected
TAMF	Control	$3{,}1.10^{7}\pm80^{b}$
	Th1	68000 ± 200^{a}
	Th2	55000 ± 520^{e}
	Rom1	72000 ± 900^{d}
	Rom2	53000±850c
Yeasts and molds	Control	$670\pm2{,}0^{c}$
	Th1	820 ± 50^{b}
	Th2	730 ± 100^{a}
	Rom1	450 ± 3^{e}
	Rom2	200 ± 26^{d}

The analysis in Table XI shows a complete absence of ***Salmonella*, thermotolerant coliforms, *Escherichia coli*, SRA and coagulase-positive staphylococci** in all samples (control, Th1, Th2, Rom1, Rom2). On the other hand, **TAMF** was detected in all batches. At the control level, the TAMF load is very high, reaching 3.1×10^7 CFU/g. The addition of 1% of *Thymus vulgaris* (Th1) reduced this load to 68,000 CFU/g. By increasing the concentration to 2% (Th2), the load decreased further to 55,000 CFU/g. Thus, the 1% increase in *Thymus vulgaris* extract resulted in a 19% reduction, or 13,000 inhibited germs. Similarly, for *Salvia rosmarinus*, the **TAMF** load decreased from 72,000 CFU/g with 1% (Rom1) to 53,000 CFU/g with 2% (Rom2). This increase in concentration of *Salvia rosmarinus* resulted in a reduction of 26.39%, or 19,000 inhibited germs.

As for **yeasts** and **molds**, they were also detected in all the batches. For the control, the load is 670 CFU/g, with Th1 the load reached 820 CFU/g, but the increase to 2% (Th2) made it possible to reduce it to 730 CFU/g, i.e. a decrease of 10.98%, corresponding to 90 inhibited germs. At the same time, with *Salvia rosmarinus*, the yeast and mold load increased from 450 CFU/g with 1% (Rom1) to 200 CFU/g with 2% (Rom2). This increase in concentration resulted in a reduction of 55.56%, or 250 inhibited germs.

3. Discussion

3.1. Organoleptic parameters

According to the results of the organoleptic **taste test**, the analysis shows a general positive appreciation of the products, with Rom2 having the highest score 60%, followed by Rom1 and Th1 (55%), then Th2 50% and finally the control 48%, i.e. an average of 55%. These results are very satisfactory in terms of flavor, surpassing those of **Petersson (2001)** and **Oduor-Odote et al. (2010)**, who reported low average of 50% from taste evaluators for smoked fish without plant treatments. However, although these results show a positive appreciation, they are lower than those of **Faye (2022)** who obtained an average of 80% on smoked catfish containing curry and parsley extracts. This could be due to differences in the types of extracts, their concentration. Nevertheless, these results remain satisfactory with better appreciation proportions for samples treated with thyme and rosemary extracts.

As far as **texture** is concerned, the analysis shows that the predominance is on the soft aspect for all samples, with an overall average of 78% of the surveyors. The control sample was indicated to be soft in texture by 57% of the evaluators. This proportion increases for samples treated with thyme, reaching 88% for Th1 and Th2, as well as for the sample treated with 1% Rom1 with 90% of the raters. The sample containing 2% rosemary

(Rom2) has a slightly lower proportion, with 66% of evaluators judging it to be soft in texture. These results show that the addition of medicinal plant extracts, particularly at low concentrations (1%), promotes a softer texture, although Rom2 has a slight rigidity according to 33% of assessors. These observations are partly comparable to those of **Faye (2022)**, who obtained a satisfaction rate of 55% for samples incorporating 7% and 14% of different spices. However, the results of this study stand out for a notable predominance for soft textures, far exceeding the average of 55% satisfaction obtained by **Faye (2022)**. Compared to the work of **Simko (2005)**, who indicated that a rigid texture with a 70% satisfaction rate was preferred, these results show a different trend. **Simko (2005)** demonstrated that the longer the smoking time, the stiffer the texture becomes. The differences observed between the studies could be explained by several factors, including variation in the species used, smoking conditions or taste preferences of the tasting panels.

Regarding the **smell** of the samples, the analysis shows a clear predominance for the good smell of smoked fish, especially for samples treated with plant extracts. In fact, 100% of the assessors revealed that the Th1, Th2, Rom1 and Rom2 samples gave off a characteristic good smell of smoked fish. The control sample, on the other hand, has a diversity of perceived smells: 65% of the evaluators associated it with products with a smell of smoked fish, while 14% reported that these products smell like a fireplace, and 7% reported that these products smelled like a fireplace, and 7% reported a smell of strong smoke. Overall, the products are appreciated on average by 93% of surveyors who stipulated that they have a good smell of smoked fish. These observations are significantly higher than those of **Faye (2022)**, who had obtained an average satisfaction of 63% for the smell of smoked fish with samples treated with 7% and 14% of Chinese Parsley spices. Moreover, these results of the present study differ from those of **Jonsdottir et al. (2008**), who obtained an average of 80% for products with a strong smell of strong smoke. This difference could be explained by factors such as the duration of smoking or the type of fuel used.

The present study showed that for samples treated with *Thymus vulgaris* (Th1 and Th2), a predominance of whitish color was observed, according to 67% of the evaluators for Th1 and 70% for Th2. The control sample showed a balanced distribution between brunette (36%), brown (34%) and whitish (30%), with no perception of blackish color. For samples treated with *Salvia rosmarinus* extracts (Rom1 and Rom2), the color perception evolves towards darker shades. Rom1 is mostly considered brown (45%) and brown (33%), reflecting a typical coloration of a smoked fish. Rom2, on the other hand, has a clear dominance of the brown color (67%).

Compared to the work of **Faye (2022)**, where an average of 90% of the assessors appreciated the typical color of smoked fish, the samples from this study, show inferior results in terms of compliance with the expected appearance. These results are also lower than those reported by **Espe et al. (2004)** and **Toth and Potthast (1984)**, which achieved 70% satisfaction with the color of smoked fish. These differences could be explained by the nature of the extracts used, the duration and intensity of smoking, or by variations in experimental conditions.

As for the **salinity** of the samples, the analysis shows that the finished products are mostly perceived as moderately salty, with a clear influence of plant extracts on the overall perception. The control sample shows variability in judgments, with 57% of the evaluators finding it moderately salty, 36% describing it as salty, and 7% perceiving a salt deficiency. These results reflect a certain heterogeneity in the assessment of the salinity of the control product. On the other hand, samples containing plant extracts of *Thymus vulgaris* and *Salvia rosmarinus* (Th1, Th2, Rom1 and Rom2) were unanimously judged to be moderately salty by 100% of the participants. The incorporation of these extracts appears to play a role in stabilizing the salt content in products. These results differ from those of **Sène and al. (2020)**, where products with a high salt concentration (33%) were perceived as too salty in the study on the fermentation and drying of catfish hybrids. However, they are consistent with those of **Kouakou et al. (2013)**, who had demonstrated that moderate salt concentrations (20-35%) resulted in products that were well accepted organoleptically. Thus, the results of this study show that the addition of plant extracts in the smoking process does not change the objective salinity of the products, but positively influences its perception by the evaluators. This homogeneity in sensory appreciation is an asset for improving the acceptability of products, while reducing the risk of rejection due to too much variability in salinity. With regard to the assessment of the **level of satisfaction**, the results show that the majority of the evaluators are generally satisfied with the processed products based on *Clarias gariepinus*, with variations depending on the sample. The control sample is considered very satisfactory by 7% of the evaluators and satisfactory by 71% of the assessors, while 22% of the latter find it less satisfactory. Samples treated with plant extracts (Th1, Th2, Rom1, and Rom2) recorded higher levels of satisfaction. This is shown by the levels of appreciation of the evaluators, with whom the Rom1 sample is judged very satisfactory by 70% of people, followed by Th1 (60%), Rom2 (50%) and Th2 (50%). None of the samples treated with plant extracts were classified as unsatisfactory or less satisfactory. On this note, extracts of *Thymus vulgaris* and *Salvia rosmarinus* seem to have improved the organoleptic properties of smoked *Clarias gariepinus*, thus enhancing the satisfaction of tasters.

3.2. Chemical parameters

The present study showed that the **TVBN** rate varies depending on the sample. The control recorded the highest value (6.5 mg/100 g of flesh), followed by Th1 (6.3 mg/100g), Rom1 (6.1 mg/100g), Th2 (5.5 mg/100g) and Rom2 with the lowest value (4.3 mg/100g). These values remain below the standards set by the **Senegalese Association for Standardization** (**ASN**), which stipulates that the **TVBN** of processed fish products must be less than or equal to 350 mg/100g. Comparatively, the studies by **Anihouvi et al. (2005)** and **Dione (2003)** on fermented and dried products show higher values, reaching 119.74 mg/100g and 249.1 mg/100g, respectively. The difference in these results would be related to the type of treatment applied (fermentation for these authors and smoking for this study).

In addition, the low **TVBN** values obtained in this study would indicate good chemical preservation of smoked *Clarias gariepinus*, likely due to the stabilizing effect of *Thymus vulgaris* and *Salvia rosmarinus* extracts.

Regarding the **humidity** (moisture) content, the highest value is recorded by the Rom2 sample (50.6%), followed by the control (51.2%), Rom1 (48.1%), Th1 (48.2%) and Th2 (37.6%). This shows that Th2 has the lowest humidity level, which could promote better preservation. These values are close to the standards reported for smoked fish, but Th2 remains slightly lower than those found by **Diouf (2021)** with a moisture content of 46.82%. At the same time, the moisture content of Th1 (48.2%) and Rom1 (48.1%) products is better in terms of preservation of smoked products than those found by **Fall et al. (2017)** with a moisture content of 50.3% for fermented and dried products. Samples with plant extracts, including Th2 and Rom2, have lower humidity's, suggesting better conservation, as low humidity limits microbial growth.

As far as **proteins** are concerned, the Th1 sample shows the highest content (46.7%), followed by the control (44.10%), Rom2 (44.3%), Th2 (40%) and finally Rom1, which has the lowest value (34.1%). Thus, only products treated with *Thymus vulgaris* extracts at a dose of 1% have a better protein content compared to the control products. The use of extracts of the medicinal plant (*Thymus vulgaris*) with a dose of 1% seems to have improved the protein quality of smoked *Clarias gariepinus*. In addition, the protein content of products treated with *Salvia rosmarinus* extracts, regardless of the dose, is lower than in the control products, and the same is true for Th2 products. This is thought to be due to the fact that these doses contribute to burn protein when *Clarias gariepinus* is smoked. However, these values are higher than those (18.24 %) found by **Salihu-Laisisi et al. (2013)** on *Clarias gariepinus* smoked without plant extracts. This difference can be justified by the nature of the fish used, whose protein content can vary between 18 and 72%, but also by the effect of plant extracts.

For **ash content**, Rom1 products have the highest value (4.3%), followed by Th2 (3.9%), Th1 (3%), Rom2 (2.1%) and finally the control (1.9%). It appears that products treated with medicinal plant extracts (*Thymus vulgaris* and *Salvia rosmarinus*) have the highest ash content compared to Control products.

These results are comparable to those reported by **Huss (1999)**, who states that smoked products generally have ash contents between 2% and 5%. The higher values observed for samples with plant extracts (especially Rom1) could be related to the mineral content of the plants used.

For fat (fat), the highest value is observed in Th2 (18%), followed by Th1 (10.7%), control and Rom1 (10.6%), and finally Rom2 (8.5%). These results show that Rom2 has the lowest fat content, which can be favorable for a balanced diet. These values are slightly higher than the observations of **Salihu-Laisisi et al. (2013)** who found 4.49 ± 2.22% for fresh *Clarias gariepinus* and 12.10 ± 1.01% for smoked *Clarias gariepinus*. The variation in fats can be influenced by plant extracts, which could act as protective agents, limiting lipid oxidation.

Concerning polycyclic aromatic hydrocarbons (PAHs), the results show that significant concentrations of PAHs, such as acenaphthylene, acenaphthene, fluoranthene and pyrene, are present in samples of smoked *Clarias gariepinus*. Compared to the control sample, acenaphthylene and acenaphthene concentrations were reduced in samples treated with *Thymus vulgaris* and *Salvia rosmarinus* extracts, particularly in Th1 and Rom1 samples. However, a higher concentration of acenaphthylene was noted in Rom2 (128 µg/kg), suggesting variability in smoking conditions. For fluoranthene and pyrene, incremental reductions in these compounds were observed in the treated samples compared to the control sample. The Rom2 sample had the lowest concentrations of fluoranthene (18 µg/kg) and pyrene (6 µg/kg). Higher concentrations of PAHs are often observed in several food products, particularly smoked meat and fish (EU, 2020). The European regulation stipulates that some EU countries cannot comply with low levels of PAHs, despite the application of good smoking practices. This led to a double amendment of Regulation (EC) 1881/2006 by Regulations (EU) 835/2011 and (EU) 2020/1255 (EC, 2006; EU, 2011; EU, 2020). The presence of PAHs in smoked products has been well documented and known for several decades. Previous studies have shown that wood smoke is a primary vector of these compounds. **Thys and al. (1983)**, **Lenges and al. (1976)**, and **AFSSA (2007)** all reported significant concentrations of PAHs in smoked food products, highlighting the importance of strict control of smoking conditions to minimize exposure to these contaminants.

However, the other major PAHs such as benzo(a)pyrene, benzo(a)anthracene, chrysene and benzo(k)fluoranthene are absent in all samples. These compounds are of particular concern because of their toxicity and carcinogenic potential. These results are in accordance with strict regulations (CE, 2006; EU, 2011; EU, 2020) which sets the maximum limit for benzo(a)pyrene at 2 µg/kg for smoked fishery products and the maximum limit for the sum of the four PAHs (benzo(a)pyrene, chrysene, benzo(a)anthracene and benzo(b)fluoranthene) at **12 µg/kg**. This compliance testifies to a good control of the smoking process, particularly in terms of temperature, duration and choice of wood, but also the positive effect of plant extracts limiting the presence of these PAHs. According to **Aké et al. (2014)**, PAH levels in fish are influenced not only by smoking but also by sampling sites. These authors report benzo(a)pyrene levels ranging from 14.65 µg/kg in fresh fish to 64.97 µg/kg in smoked fish, values well above the European regulatory limits. Contrary to these observations, the samples in this study present a much more favourable situation with a total absence of benzo(a)pyrene and other regulated PAHs. This difference could be attributed to the effects of *Thymus vulgaris* and *Salvia rosmarinus* extracts, factors such as the low fat content of the fish, the type of wood used, and better control of smoking parameters. **Arias et al. (2009)** and **Aké et al. (2010)** emphasize that these elements are decisive in limiting the formation of PAHs.

3.3. Microbiological parameters

- ***Salmonella***

All samples (Control, Th1, Th2, Rom1, Rom2) show the absence of *Salmonella*, with results not detected. This is in line with expectations, as the presence of *Salmonella* in processed fish products is an indicator of food contamination. The absence of this pathogenic bacterium suggests that the smoking process applied in this study is effective in inhibiting *Salmonella* contamination. This observation is in agreement with the results obtained by **Farougou et al. (2011)**, who also reported the absence of *Salmonella* in samples of *Trachurus trachurus* fish smoked and sold in the markets of Abomey-Calavi (Benin). On the other hand, they are different from those of **Djinou (2001)** with 0.5% and **Gouen et al. (2006)** with 0.16% found in smoked fish.

- **Thermotolerant coliforms**

No thermotolerant coliforms were detected in the samples. This absence is a positive indicator of the microbiological quality of the products, and suggests that they have been handled under strict hygienic conditions. These results are different from those of **Oulaï et al. (2007)** who found an average of 4.8 10^4 germs per gram of product for a percentage of 27.3%. At the same time, the results of the present study are better than those of **Atobla et al. (2022)** who noted the presence of thermotolerant Coliforms at a rate of 80% in their work on the microbiological quality of traditionally smoked fish sold in markets in Abidjan, Côte d'Ivoire. On the other hand, **Diouf (2021)** and **Fall and al. (2017)** reported similar results to those of this study, where the absence of thermotolerant coliforms was noted in their work. The satisfaction of the results of this study with the absence of faecal contamination is linked to the conditions of smoking and handling of these products in accordance with hygiene and food safety standards.

- ***Escherichia coli* (*E. coli*)**

None of the samples showed *E. coli* contamination, which is an excellent result. The presence of *E. coli* in food products is a direct indicator of fecal contamination, posing a risk to public health. The results observed here are in line with food safety standards, and indicate that the products are microbiologically safe. These results are consistent with **ICMSF (1986)** setting the acceptable limit at **2 cfu/g**, which proves compliance with good processing practices.

- **Sulphate-reducing anaerobic (SRA)**

All samples showed an absence of **SRA**, which is also a good result, as the presence of these bacteria is often associated with the spoilage of food products. The results of this study are different from those of **Gouen (2006)** who noted 0.88% of the presence of **SRA** in his smoked fish samples. The results of this study are also better than those of **Thiam (1993)** who found an average of 43.26 germs per gram of product on braised-dried fish. The absence of SRA in all samples here indicates that the processing conditions are appropriate, and that the products are stable.

- **Coagulase positive Staphylococci**

None of the samples show contamination with coagulase-positive staphylococci, which is a positive sign, as these bacteria can be responsible for food poisoning. These results differ from those of **Dohou (2018)** who worked on the microbiological quality of smoked fish along the shoreline villages of Lake Ahémé. Also, those of **Khallaf et al. (2014)** who obtained a bioburden of 468 cfu/g. This means that the smoked fish products in this study are free of contamination by these pathogenic bacteria, thus enhancing their food safety.
Concerning these germs (*Salmonella*, thermotolerant coliforms, *E. coli*, ASR and coagulase-positive Staphylococci), the results of the present study are in accordance **with Order No.14351 of 28-09-2016** setting the microbiological criteria, the sampling plan and methods of analysis applicable to the controls of fishery and aquaculture products intended for human consumption.

- **Total Aerobic Mesophilic Flora (TAMF)**

The Control has a high bioburden (3.1×10^7 CFU/g), well above the **AFNOR 1996 standard** which stipulates that the **TAMF** should be between 10^5 and 10^6 CFU/g, which suggests advanced microbial degradation in this sample. However, samples with extracts of *Thymus vulgaris* (Th1) and *Salvia rosmarinus* (Rom1, Rom2) show a significant reduction in this load, ranging from 5.3×10^4 CFU/g to 7.2×10^4 CFU/g, suggesting an inhibitory effect of plant extracts on microbial proliferation. This reduction is consistent with the results observed by **Jiminez-Arellances et al. (2006)**, who demonstrated that the use of *Thymus vulgaris* inhibits microbial growth and the study by **Georgantelis et al. (2007)**, which supports the use of medicinal plants such as *Salvia rosmarinus* to effectively inhibit the growth of microorganisms in food products.

- **Yeasts and moulds**

The control products have a high yeasts and molds load (670 CFU/g). However, samples treated with plant extracts show a significant reduction in this load, especially Rom2, which has the lowest load (200 CFU/g). The contamination of smoked fish could be explained by the great capacity of yeasts and molds to develop on substrates with low water activity **(Bourgeois et al. 1991)**. These results are different from those of **Djinou (2001)** who found a contamination percentage of 9.8%, **Gouen et al (2006)**, 2.09% and **Oulaï et al. (2007)** who found an average of 4.6,102 germs per gram of product for a percentage of 0.15%. Moreover, they are similar to those of **Fall et al. (2014)**, who observed that the use of plant extracts in fermented and smoked products reduced the load of yeasts and molds. The addition of extracts of *Thymus vulgaris* and *Salvia rosmarinus* in this study therefore has a protective effect, reducing the proliferation of these microorganisms and helping to improve the microbiological quality of smoked products. In addition, the microbiological results of this study show that extracts of *Thymus vulgaris* and *Salvia rosmarinus* have a significant effect in reducing the bioburden in smoked *Clarias gariepinus* products. These extracts not only inhibited the proliferation of Total Aerobic Mesophilic Flora and yeasts and molds, but also contributed to the microbiological safety of the products by preventing the growth of pathogens such as Salmonella, *E. coli*, and Staphylococcus coagulase. These results encourage the use of medicinal plant extracts as natural antimicrobial agents in the processing of food products, especially those undergoing smoking processes.

CONCLUSION

This study aimed to evaluate the organoleptic, chemical and microbiological quality of smoked *Clarias gariepinus*, dosed with extracts of *Thymus vulgaris* and *Salvia rosmarinus*. The results highlighted the positive effects of the addition of these plant extracts on the overall quality of the product, in terms of health safety, preservation and nutritional properties.

Organoleptic tests have revealed that products containing thyme and rosemary extracts have sensory characteristics that can meet consumer expectations, with acceptable scores for texture, smell, and taste. These results indicate that the incorporation of plant extracts helps to preserve the sensory qualities of smoked fish, thus offering a product that is both tasty and stable.

Chemical analyses have shown that the addition of extracts contributes to the improvement of certain nutrient parameters, such as protein and fat content, while maintaining total volatile basic nitrogen (TVNB) values within quality standards. This proves the effectiveness of these extracts in the smoking process in terms of chemical preservation of the product with the absence of particularly toxic PAHs such as benzo(a)pyrene, a carcinogenic compound potentially formed during the smoking process. The results obtained are in line with previous studies on the use of medicinal plants for the conservation of fishery products.

Microbiological testing confirmed that the products were properly processed, with an absence of pathogens such as *salmonella*, *E. coli*, and thermotolerant coliforms. However, the presence of **TAMF**, yeast and mold, although moderate, underscores the importance of good hygiene and manufacturing practices to ensure food safety and product quality.

In short, the study confirmed the hypothesis that adding extracts of *Thymus vulgaris* and *Salvia rosmarinus* to the smoking process not only improves the organoleptic and chemical properties of *Clarias gariepinus*, but also offers a microbiologically safe product for consumption.

RÉFÉRENCES BIBLIOGRAPHIQUES

AFNOR, (1996). Analyse microbiologique. Tome 2: contrôle de la qualité des produits alimentaires. Paris. Ed. AFNOR. 545p.

AGENCE FRANCAISE DE SECURITE SANITAIRE DES ALIMENTS, 2007.- Évaluation des risques sanitaires liés aux situations de dépassements des limites et références de qualité des eaux destinées à la consommation humaine. Nancy: Edition AFSSA, Tome I. 250 p.

Aké AY, Anon N, Kouamé P, Bonfoh B, Biego GHM, 2014. Assessment of the exposure to Benzo(a)Pyrene (BaP) contained in sardines (*Clupeidae*) consumed by the Ivorian adult in the area of Abidjan. *International Journal of Science and Research* 3 (11) : 2455- 2461.

Ake Y, Biego GHM, Koffi KM, Kouame P, 2010, Validation de la méthode de détermination du Benzo(a)pyrène dans les poissons frais et fumés vendus et consommés en Côte d'Ivoire. *Revue Africaine de Santé et de Productions Animales* 8 (53) : 54- 58 p.

Anihouvi V.H., Huonhouigan J.P. Ayernor G.S. (2005). La production et la commercialisation du landouin un condiment à base de poisson fermenté du Golfe du Benin Cahier agri, Vol. 4(3), 323-330.

Arias AH, Spetter CV, Freije RH, Marcovecchio JE, 2009. Polycyclic aromatic hydrocarbons in water, mussels (*Brachidontes sp., Tagelus sp.*) and fish (*Odontesthes sp.*) from Bahía Blanca Estuary, Argentina. *Estuarine, Coastal and Shelf Science* 85 : 67-81.

Arrêt N°14351 du 28-09-2016 fixant les critères microbiologiques, le plan d'échantillonnage et les méthodes d'analyse applicables aux contrôles des produits de la pêche et de l'aquaculture destinés à la consommation humaine.

Atobla K, Kouamé N´zebo D, Benié,K,D, Dadié A, Niamké S, 2022 , Qualité Microbiologique des Poissons Fumés Traditionnellement et Vendus sur des Marchés à Abidjan, Côte d'Ivoire, International Journal of Progressive Sciences and Technologies (IJPSAT), pp. 249-264, 18

CE, 2006. RÈGLEMENT (CE) No 1881/2006 DE LA COMMISSION du 19 décembre 2006 portant fixation de teneurs maximales pour certains contaminants dans les denrées alimentaires L 364 : 20p.

DIONE.B. D, (2003). Étude de la qualité microbiologique et chimique du poisson braise-séché.47p.

DIOUF.F, (2021). Effets du dosage de l'extrait de coriandre (*Coriandrum saltivum*) sur la qualité organoleptique, microbiologique et chimique du chinchard jaune (*Caranx rhonchus*).

Djinou H.P.A.B., 2001. Étude de la qualité microbiologique du poisson fumé artisanalement en Côte d'Ivoire et destiné à l'exportation. Thèse : Méd. Vét : Dakar ; 2

Dohou Saraphin, 2018.Qualité microbiologique des poissons fumés le long des villages du lac Ahémé. Mémoire de fin de formation pour l'obtention du diplôme de master en norme et contrôle de la qualité des produits agroalimentaire. Université d'Abomey-Calavi,p36.

Espe, Marit Et Anna Maria Br, (2004). Qualité Du Saumon Fumé A Froid Offert Au Français Général Consommateur. Institut National De Nutrition Et Recherche Sur Les Fruits De Mer. 45p

Fall. NG, Tounkara LS, Diop MB, Thiaw OT, Thonart P. (2017). Chemical characteristics and microbial quality of Guedj a traditional fermented from Senegal. *International Journal Sciences.* 6: 48-54.

Farougou S., Hounkpe S. D., Sessou P., Yehouenou B. Sohounhloue D. (2011) : Évaluation de la qualité microbiologique du poisson *Trachurus trachurus* fumé et vendu dans les marchés de la commune d'ABOMEY-CALAVI. Acte du 3ème Colloque des Sciences, Cultures et Technologies de l'Université d'Abomey-Calavi-Benin, 3 : 337 -347.

FAYE.S, (2022). Effets des extraits de curry (*Murraya koenigii*) et de persil (*Petroselinum crispum*) sur la qualité organoleptique et microbiologique du clarias fumé (*Clarias gariepinus*).

Georgantelis, D., Ambrosiadis, I., Katikou, P., Blekas, G., Georgakis, S A. (2007). Effect of rosemary extract, chitosan and α-tocopherol on microbiological parameters and lipid oxidation of fresh pork sausages stored at 4 °C. Meat Science. 76: 172-181.

GOMIS.T.B, (2024). Étude de la qualité organoleptique, chimique et microbiologique de la marinade de murex.41p.

Gouen B.B., 2006. Contribution à l'évolution de la qualité microbiologique du poisson fumé en Côte d'Ivoire et destiné à l'exportation. Thèse de Médecine Vétérinaire : Dakar,

Huss, H.H. (1999). Quality and Quality Changes in Fresh Fish. FAO Fisheries Technical Paper No. 348, Food and Agriculture Organization of the United Nations, Rome.

International Commission on Microbiological Specification for Foods (ICMSF). (1986). Microorganisms in Foods 2. Sampling for Microbiological Analysis. Principles and Specifications. 2nd édition. Oxford: Black- well Science.

Jiménez-Arellanes A., Martinez R., Garcia R., León-Diaz R., Aluna–Herrera J., Molina – Salinas G. et Said-Fernández S. (2006). Thymus vulgaris as a potential source of antituberculosis compounds. Pharmacologyonline., 3 : 569-574.

Jónsdóttir R, Olafsdóttir G, Chanie E Et Haugen Je. (2008). Composés Volatils Adapté A La Détection Rapide En Tant Que Qualité Indicatrice De Saumon Fumé A Froid (*Salmo Salar*). *Chimie Alimentaire* 109:1895

KENEME.M, (2024). État des lieux sur les pratiques traditionnelles de valorisation et de conservation des coquillages dans les villages riverains des AMP DE Niamoune Kalounayes et Kaalolal Blouf Flogny (Casamance Sénégal) et leur impact sur la qualité sanitaire des produits.83p.

Kouakou NG, Kouadio FNG, Dadie AT, Montet D, Djé MK. (2013). Production et commercialisation de l'adjuevan, poisson fermenté de Côte d'Ivoire. *Cahier Agriculture*, 22 : 559-567.

Lenges J., LUKS D., VO THI N. B., 1976.- Dosage du 3,4 benzopyrène dans les produits de viande et de poissons fumés. Partie 2. Dosage quantitatif du 3,4 benzopyrène dans les poissons fumés. Revue Ferm. Ind. Alim., 31: 20-22.

Oduor-Odote Pm, Obiero M Et Odoli C. (2010). Effet Organoleptique De l'utilisation Différentes Matières Végétales Lors Du Fumage De poisson-Chat Marin Et d'eau Douce. Africain Journal Of Food Agriculture Nutrition Développement 10(6):2658-267.

Oulaï S.F., Koffi R.A., Koussemon M., Djè M., Kakou C., et Kamenan A., 2007. Évaluation de la qualité microbiologique des poissons *Etmalosa fimbriata* et *Sardinella aurita* fumés traditionnellement. *Microbiologie et Hygiène Alimentaire*, 19(55) :37-42.

Petersson G. (2001). Phénolique Antioxydants Dans La Fumée De Bois. La Science De l'environnement Total 279-75.

Salihu-Laisisi M. Akpabio C.J. and Ogunsola M.O. (2013). Comparative nutritional studies on fresh and smoked *Claras gariepinus* (Catfish) and *Tilapia nilotica* (Tilapia) fishes. European Journal of Experimental Biology, 3:183-185

Sene.W, Fall.J, Loum. A, Diago. M, Sagne. M, Diouf. A, Diouf. N, Jatta. S, Ndong. D, Pelebe. R.O.E, Diouf. M, (2020).Effets du salage, de la température et du séchage sur la qualité biochimique et microbiologique des hybrides de poisson-chat (*Clarias anguillaris* et *Clarias gariepinus*) en milieu d'élevage au Sénégal. Sciences de la vie, de la terre et agronomie.Vol.08.ISSN 242467235.8sp.

Simko P. (2005). Facteurs Affectant l'élimination d'hydrocarbures Aromatiques Polycycliques A Partir d'aliments A Base De Viande Fumée Et De Liquide Arôme De Fumée : Une Revue De Nutrition Moléculaire. *Recherche Alimentaire* 49:637-647.

Thiam A., 1993. Contribution à l'étude de la qualité microbiologique et chimique du poisson braisé-séché (Ketiakh) commercialisé sur le marché dakarois. Thèse : Méd. Vét : Dakar ; 15

Toth, L. et Potthast Et (1984). Chimique Aspect Du Fumage De La Viande Des Produits. Dans : Avancé En Alimentation Recherche. Vol : 27. Presse Académique, Londres. 87-158.

UE, 2011. Règlement (UE) nº835/2011 de la Commission du 19 août 2011 modifiant le règlement (CE) n 1881/2006 en ce qui concerne les teneurs maximales pour les hydrocarbures aromatique polycyclique dans les denrées alimentaires. Journal officiel de l'Union Européenne. Bruxelles.

UE, 2020. RÈGLEMENT (UE) 2020/1255 DE LA COMMISSION du 7 septembre 2020 modifiant le règlement (CE) no 1881/2006 en ce qui concerne les teneurs maximales en hydrocarbures aromatiques polycycliques (HAP) des viandes, produits à base de viande, poissons et produits de la pêche fumés de façon traditionnelle et fixant une teneur maximale en HAP pour les poudres de denrées alimentaires d'origine végétale utilisées pour la préparation de boissons, L 293 : 4p.