African J. Trop. Entomol. Res. 2(1) :14-25
https://doi.org/10.58697/AJTER020103 Ngunte et al., 2023

African Journal of Tropical Entomology Research
ISSN : 2791-0113 (Online)
Journal homepage: www.ajter.com, Lenaf homepage: www.lenaf-ifa.org

Research article **OPEN ACCESS**

Situation of smoked freshwater fish sold in the markets of Yaoundé city (Central Region of Cameroon) and evaluation of control methods against their insect pests during storage

Tekou Ngunte, H.[1]*, Peyieno, M. J.[2], Yantcho Tahon, L. F[1], Tamgno, B. R.[1,3] & Tchoumbougnang, F. [1,4]

[1]Laboratory of Ecosystems and Fisheries Resources, Training Unit for Applied Sciences of the Postgraduate School for Pure and Applied Sciences, University of Douala P.O. Box 2701, Douala Cameroon.
[2]Department of Biochemistry, Faculty of Science, University of Douala, P. O. Box 24157, Douala, Cameroon.
[3]Department of Aquatic Ecosystems Management, Institute of Fisheries Sciences of the University of Douala, P.O. Box 7236, Douala Cameroon.
[4]Department of Processing and Quality Control of Aquatic Products, Institute of Fisheries Sciences of the University of Douala, P.O. Box 7236, Douala Cameroun.

**Corresponding author*, E-mail: *tekoungunte@gmail.com*

Received: 14 March 2023 | Accepted: 13 May 2023 | Published : 22 June 2023

ABSTRACT

The smoking, storage and conservation of smoked fish remain the most efficient means of ensuring the almost permanent availability of seasonal fishing products. However, stored smoked fish can be infested by insect pests. The aim of this study was to present the situation of smoked fishes sold in the city of Yaoundé and the methods used by the traders to control insect pests. For this purpose, a study was conducted from October to December 2022 in seven markets in Yaoundé where 65 traders were interviewed mainly on their activities, the origin of smoked fishes and the methods used to control insect pests. The inventory and the quantity of smoked fishes was made in different markets. The storage tools were inspected and the samples of infested smoked fish (commons names) (Catfish, Kanga, Carp, Tilapia, Eel fish, Redtail) and samples of apparently not infested fish (Catfish, Kanga, Carp) were bought from traders according to availability and brought back to laboratory. In the Laboratory, the identification of insect pests was done, the number of insect and the galleries of fish's collection was counted. It emerges from this study that 80.37% traders are women; according to the age group, 41.44% of traders are between [41-50] years old. 53.67% of traders have a primary education level. Cardboard boxes are the most used tools in fish storage (100%). Six (6) freshwater smoked fish are sold and catfish are the most represented with 2,604 boxes of 50 kg. *Dermestes maculatus* De Geer 1774 (Coleoptera: Dermestidae) (221 larvae and 54 adults) and *Necrobia rufipes* De Geer 1775 (Coleoptera: Cleridae) (65 larvae and 37 adults) are the insects pests. Catfish is the smoked fish that revealed the largest number of galleries (86). The chemicals used by traders are Rambo (14.10%) and DD force (24.36%). Mayo-Danay provides 49.86% of smoked fish sold in Yaoundé markets. The ANOVA and Duncan tests have shown that significant differences are observed in the various storage tools and control methods used by traders in the various Yaoundé markets to protect smoked fish from insect pests ($p<0.001$).

Keywords: Smoked fish, insect pests, emergence, pesticides, infestation, loss

RÉSUMÉ

Situation des poissons d'eau douce fumés vendus dans les marchés de la ville de Yaoundé (Région du Centre du Cameroun) et évaluation des méthodes de contrôle contre leurs insectes ravageurs au cours du stockage

Le fumage, le stockage et la conservation du poisson fumé restent les seuls moyens d'assurer la disponibilité quasi permanente des produits saisonniers de la pêche. Cependant, le poisson fumé stocké peut être infesté par des insectes nuisibles. L'objectif de cette étude était de présenter la situation des poissons fumés commercialisés dans la ville de Yaoundé et les méthodes utilisées par les commerçants pour lutter contre les insectes ravageurs. A cet effet, une étude a été menée d'octobre à décembre 2022 dans sept marchés de Yaoundé où 65 commerçants ont été interrogés principalement sur leurs activités, l'origine des poissons fumés et les méthodes utilisées pour lutter contre les insectes ravageurs. L'inventaire et la quantité de poissons fumés ont été réalisés dans les différents marchés. Les outils de stockage sont inspectés et les échantillons de poissons fumés infestés (noms communs) (Poisson-chat, Kanga, Carpe, Tilapia, Anguille, queue rouge) et ceux apparemment non infestés (Poisson-chat, Kanga, Carpe) ont été achetés à des commerçants en fonction des disponibilités et ramenés au laboratoire. Au Laboratoire, l'identification des insectes ravageurs a été faite, le nombre d'insectes et les signes d'infestation sur les poissons ont été comptés. Cette étude révèle que 80,37% des vendeurs sont des femmes et l'âge des commerçants est compris entre [41-50] ans. 53,67% des commerçants ont un niveau primaire. Les cartons sont les outils les plus utilisés dans le stockage du poisson (100%). Six (6) poissons fumés d'eau douce sont commercialisés et les silures sont les plus représentés avec 2 604 cartons de 50 kg. *Dermestes maculatus* De Geer 1774 (221 larves et 54 adultes) et *Necrobia rufipes* De Geer 1775 (65 larves et 37 adultes) sont les insectes nuisibles. Le silure est le poisson fumé avec le plus grand nombre de signes d'infestation (86). Les produits chimiques utilisés par les commerçants sont Rambo (14,10%) et DD force (24,36%). Le Mayo-Danay fournit 49,86% du poisson fumé vendu sur les marchés de Yaoundé. Les Test ANOVA et Duncan ont montrés qu'on observe des différences significatives sur les divers outils de stockage et méthodes de luttes utilisées par les commerçants des différents marchés de Yaoundé pour protéger les poissons fumés des insectes ravageurs ($p<0,001$).

Mots-clés : Poisson fumé, insectes ravageurs, émergence, pesticides, infestation, perte

INTRODUCTION

Despite the large volume of freshwater that serves as an aquatic biotope for fish in Cameroon, only around 30% of the demand for fish is currently met by local supply. The most common method of preserving fish for optimal supply is smoking. During storage under certain conditions, the infestation rate can reach 99.49%, resulting in quantitative losses of the order of 80% to 100% depending on the different species of smoked fish stored in addition to qualitative losses favoring a depreciation of the product (Tamgno et al., 2020a). Fish, in addition to its nutritional value, is a major source of employment and trade for millions of people living near water through harvesting, handling, processing and distribution (Mufutau, 2012). During storage, smoked fish remain highly perishable and suffer both quantitative and qualitative impairments due to microbial proliferation and infestation by harmful insects (Ndrianaivo et al., 2016; Sameza et al., 2016; Tamgno et al., 2020b).

Review for Manuscript AJTER-2023-0208 is due soonal and hot climate areas where refrigeration techniques are not common and especially not always available (Gamane et al., 2016). Due to constraints related to the preservation of fish after fishing, only a small quantity is sold fresh, a large part being subject to the artisanal transformation such as smoking and drying to allow actors to keep the finished product as long as possible (Ikenweiwe et al., 2010; Babarinde et al., 2016b). The smoked fishes continue to be attacked during the processing and storage by many biotic factors, mainly the insects and may be a source of poisoning for populations (Tamgno et al., 2021). Indeed, as fisheries management systems improve and resource-related wealth begins to be produced on a sustainable basis, it may be possible to reduce estimated losses (Tamgno et al., 2020a). These insect pests usually infest dried fish during storage, transportation and marketing, causing significant damage to marketed fish, resulting in huge weight loss (Tamgno et al., 2020b). Beetles of the Dermestidae family invade fish from the early stages of drying and reproduce in the dried product (Abolagba et al., 2015).

The means used to protect smoked fish in West Cameroon against the attacks of harmful insects are chemical insecticides applied directly to the fish as a contact product and pesticides in the form of fumigants applied in gaseous form for a longer action (Tamgno et al., 2020a). More recent observations show that market processors, sellers and wholesalers in the Logone and Bénoué basins use no registered pesticides in Cameroon commonly called "pia-pia", powder and liquid pesticides. They also use other powders such as RAMBO (permethrin) and IMIDALM (imidachloprid). Indeed, they sprinkle these products on the fish drying racks and inject the pesticide into the cargoes and the bags or spray all the storage spaces of the dried fish. Powdered pesticides are regularly sprinkled on fish. These products can protect smoked fish from parasites for over a year (Beramgoto, 2019).

In Mali, fishermen and wholesalers use pesticides and traditional preservation methods to protect smoked, dried and burnt fish from harmful insects and other undesirable bacteria. Nowadays, the most used insecticide product on smoked and dried fish in the markets is Nopest. Made in Nigeria, it is highly toxic to consumer health, as is preservation by salting (Maliki, 2020). To reduce these post-storage losses,

the populations of West Cameroon continue to resort to synthetic chemicals in the absence of alternatives; these chemical insecticides are applied directly to the fish as a contact product and in the form of fumigants applied in gaseous form for a longer action (Fopa, 2019; Tamgno, 2020b).

It is urgent, for the protection of the consumer and the environment, to lean towards the incorporation into the brine of the extracts of condiment plants with an insecticidal virtue. The growth and development of smoked fish pests are favored by poor traditional methods of processing, storage and packaging. Local fish traders are facing severe deterioration of smoked fish due to *D. maculatus* attack. There are few studies that focus on the activities of fish traders, sources of fish, processing, level of insect infestation and damage to many species of smoked fish especially for the city of Yaoundé, Centre Region-Cameroon. This study aims to assess the impact of insect pest infestation on the depreciation of smoked fish in Yaoundé markets.

MATERIAL AND METHODS

Study area and data collection

The study was conducted among 65 smoked fish traders in seven (7) markets located in the Mfoundi division (3°51'28'' N and 11°31'05''): Mfoundi, Etoudi and Elig-Edzoa (Youndé 1 sub-division), Essos (Yaoundé 5 sub-division), Mokolo and Briqueterie (Yaoundé 2 sub-division), Mvog-Bi (Yaoundé 4 sub-division) (Figure 1). These markets were chosen for their reputation for selling smoked freshwater fish.

The hydrographic network of the study area is very dense and essentially composed of the surface water stream that are rejected to river Mfoundi and its effluents. These ensure the natural drainage of runoff and surface water which is discharged into the Mfou river, which in turn discharges its water into the Nyong river. It is upstream of this last discharge point that the current catchment area for raw water intended for the production of drinking water for the inhabitants of the city of Yaoundé and its surroundings is found. Alongside these rivers, the city has a few lakes and natural sub-artificial ponds whose waters are made dangerous to public health because of the discharge of water (Boulleys, 2006).

Questionnaires and interviews were administered to obtain demographic data on smoked fish sellers, origins of smoked fishes sold in differents markets and their methods of fish preservation. This study made it possible to draw up a map of the main markets for the sale of smoked fish in the city of Yaoundé, each of which belongs to a district whose coordinates were taken using a Global Positioning System (GPS) (Figure 1).

Socio-demographic characterization of smoked fish traders in the Mfoundi division

This characterization was made on a sample of 65 smoked fish traders accepted to submit to our exchanges and distributed over the 07 prospected markets: 09 traders from the Mfoundi market, 04 from the Etoudi market and 08 from the Elig-Edzoa market (Youndé 1 sub-division), 21 traders from the Mokolo market and 10 from the Briqueterie market (Yaoundé 2 sub-division), 07 at the Mvog-Bi market (Yaoundé 4 sub-division), 06 traders from the Essos market (Yaoundé 5 sub-division). To this end, the information collected using a framework of surveys previously developed focused on gender, age, level of education, types of traders, relationship with suppliers and ethnicity.

Determination of the diversity of storage tools and smoked fish in Yaoundé markets

The diversity of storage tools was characterized with traders and depended on accessibility in the different markets of Yaoundé. The diversity of smoked fish was carried out by monitoring sixty-five (65) traders from the seven (07) markets of Yaoundé (Mfoundi, Etoudi, Mokolo, Briqueterie, Mvog-Mbi and Elig-Edzoa, Essos). This inventory was done three (03) days a week in 3 months with traders in each market. Specific information concerned: local names of smoked fish, storage methods and different strategies for limiting post-storage losses of smoked fish.

Establishment of the areas of origin of the diversity smoked fish present on the markets of Yaoundé

Some value chain actors were interviewed during the field study in each market to find out the fate of their aftermarket (smoked) products. Direct observations in the field and proximity surveys were based on: the target markets for their products and the distribution channels for each of their smoked products. The hydrographic network of the study area is very dense and essentially composed of the surface water stream that are rejected to river Mfoundi and its effluents. These ensure the natural drainage of runoff and surface water which is discharged into the Mfou river, which in turn discharges its water into the Nyong river. It is upstream of this last discharge point that the current catchment area for raw water intended for the production of drinking water for the inhabitants of the city of Yaoundé and its surroundings is found.

Alongside these rivers, the city has a few lakes and natural sub-artificial ponds whose waters are made dangerous to public health because of the discharge of water (Boulleys, 2006).

Inventory of pesticides used by traders to protect smoked fish during storage and their status

The inventory of conventional chemical pesticides used in the protection of smoked fish was made with 70 traders during the inspection of storage structures. After carrying out inventory on the conventional chemical insecticides in circulation in the study area, their status in Cameroon was determined using the list of chemicals registered in Cameroon (Minader, 2021). The active ingredients of these formulations have been classified according to their effectiveness as prescribed by the World Health Organization and the International Network on Pesticide Action (WHO, 2010; PAN International, 2013).

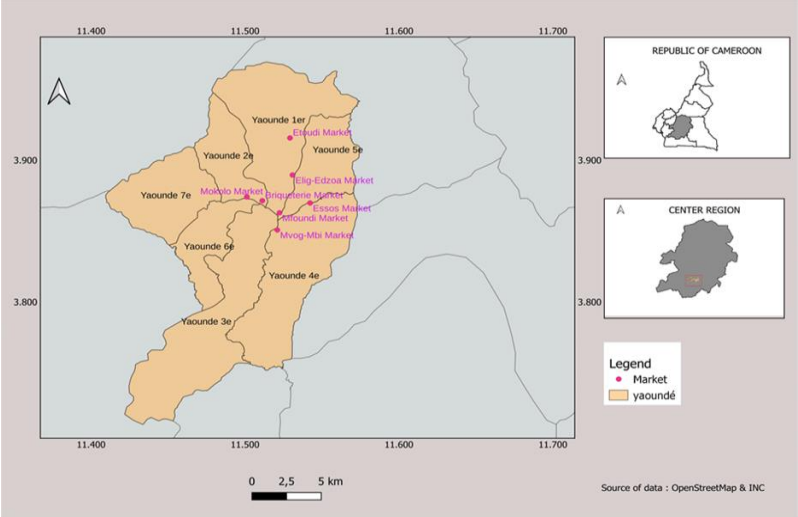

Figure 1. Map of smoked fish marketing areas surveyed as part of the study

Natural infestation of insect pests in in-vivo collections of smoked fish and observation of pest emergence in the laboratory

During inspection of storage tools, any insect present in the inspected tools was collected, preserved in 70% alcohol, then identified in the laboratory. 1000g of each sample of each smoked fish (Catfish, Kanga, Carp, Tilapia, Eel fish, redtail) attacked and untreated on the one hand and 1000g of each sample of (Catfish, Kanga, Carp) apparently not infested on the other hand have collected or even purchased from sixteen (16) merchants depending on availability. A total of 90 samples of smoked fish were purchased during this survey and brought back to the National Veterinary Laboratory (LANAVET), annex of Douala. Once at LANAVET, the infected samples were stripped to extract, count the larvae and adults of insect pests on the hidden forms of the various smoked fish as well as the galleries present on each smoked fish on the one hand. On the other hand, the samples of apparently not infested smoked fish were put under observation in the transparent glass boxes of 1200 ml of medium size (height of 15 cm and diameter of 10 cm), covered with a metal gauze lid (1 mm mesh) at ambient temperature and relative humidity in the storage room carried out with the thermo-hygrometer until the emergence of adults. The different pots were monitored every 2 days for 35 days. After this time, the pots were sieved and the various insect pests (remaining larvae and adults) identified and counted and the losses were assessed. This identification was made using the identification key for the beetle insect families and the n identification catalogs of products stored in tropical regions (Delobel and Tran, 1993; Halstead (1986).

Data analysis

Data on the mean values of storage tools and the different pesticides used were subjected to one-way Analysis of Variance (ANOVA I). To complete this analysis, the Duncan's multiple range test was used to group together the mean values that are nor significantly different with SPSS (16.0) software at the 5% level.

RESULTS

Characteristics of smoked fish traders in the different markets of the Mfoundi Division

The characteristics of smoked fish traders in the Center region vary according to the different markets (Table 1). The analysis of Table 1 shows that 80.3% are women while 19.7% are men, it should be noted that 100% of traders are women in the Mokolo, Elig-Edzoa and Essos markets. According to age group: 9.67% of traders are between [21-30], 33.12% between [31-40], 41.44% between [41-50] and finally 15.75% have an age > 50. The majority of traders surveyed are adults. As for the experience of traders,

it appears from Table 1 that the majority of traders have experience between [1-5] years, with a rate of 56%. 53.67% of traders have a primary level of education against 46.33% of traders that have a secondary education. Regarding the ethnic groups found in the various markets of Yaoundé, 41.52% are Beti, 32.88% are Bamoun and 25.59% are Fufulbe.

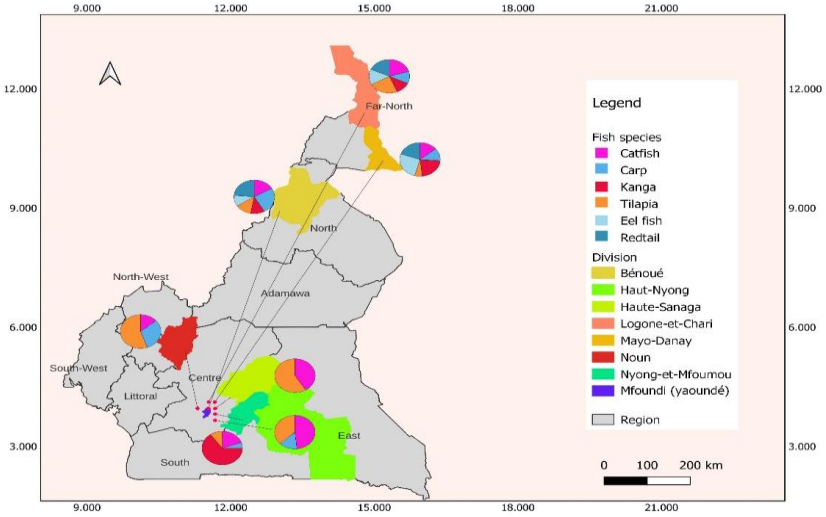

Figure 2. Zone of origin of smoked freshwater fish in Cameroon for Yaoundé Markets

Table 1. Sociodemographic characteristics of smoked fish traders in the different markets

Markets / Characteristics		Mfoundi	Mokolo	Briqueterie	Etoudi	Elig-Edzoa	Mvog-Mbi	Essos
Gender (%)	Male	33.33	00	60	50	00	14.3	00
	Female	66.67	100	40	50	100	85.7	100
Age (years) (%)	[21-30]	33.34	19.04	00	25	00	00	00
	[31-40]	33.33	38.11	10	25	00	28.57	50
	[41-50]	33.33	42.85	50	25	87.5	42.85	50
	> 50	00	00	40	25	12.5	28.57	00
Experience (years) (%)	[1-5]	55.55	57.14	00	50	62.5	42.85	100
	[6-10]	44.44	38.09	40	50	37.5	57.14	00
	>10	00	4.76	60	00	00	00	00
School level(%)	Primary	55.55	33.33	60	75	75	57.15	33.33
	Secondry	44.45	66.67	40	25	25	42.85	66.67
Type of traders (%)	Retailers	100	100	70	100	100	85.72	83.34
	Semi-wholesaler	00	00	10	00	00	00	00
	Wholesaler	00	00	20	00	00	14.28	16.66
Relationship with suppliers (%)	Family	44.45	14.28	00	00	00	00	00
	Wholesaler	00	38.09	00	00	50	00	00
	Fishmans	55.55	47.61	100	100	50	100	100
Ethnic groups (%)	Béti	44.44	61.91	00	50	00	62.5	33.33
	Bamoun	00	38.09	30	25	100	00	50
	Fufulbé	55.56	00	70	25	00	37.5	16.67

Storage facilities used for smoked fishes and duration of storage

The use of these storage tools also depends on the duration of storage of the smoked fish. With a view to protecting against attacks by insects and other pests, smoked fish are kept in various storage tools in the various markets of Yaoundé. Three (3) storage tools are used in different proportions in the seven markets (Mfoundi, Etoudi, Mokolo, Briqueterie, Mvog-Mbi, Elig-Edzoa, Essos) for the conservation of smoked fish (Jute bags: $F(58; 6) = 3.149$, $p<0.05$; cardboard: $F(58; 6) = 3.536$, $p<0.001$ baskets: $F(58; 6) = 3.459$ $p<0.001$) (Table 2). In the Essos market, cardboard are the tools most used in the storage of smoked fish (100%). On the various markets, 55.13% of traders use cardboards, 28.21% for baskets against 2.82% for jute bags. The most used tool for storage is cardboard (55.13%) with a storage duration of 5 weeks.

The ANOVA I showed a highly significant difference between the use of boxes by merchants F

(58; 6) = 3.536, p<0.001) and Baskets (F (58; 6) = 3.459, p<0.001) in the different market; concerning the jute bags, it showed a significant difference between their use in Yaoundé markets (F (58; 6) =3.149, p<0.05) (Table 2). The cardboard when it is filled, is sprayed with an insecticide formulation which has active ingredients on smoked fish during its storage, which will allow it to avoid being attacked quickly by insect pests.

Table 2. Rate of storage tools used by traders according to markets and duration of storage of smoked fish

Markets	Storage tools (%)		
	Cardboards	Baskets	Jute bags
Mfoundi	25.93[a]	9.26[a]	20.37[b]
Mokolo	42.86[ab]	42.86[b]	00[a]
Briqueterie	90[ab]	00[a]	00[a]
Etoudi	75[ab]	25[a]	00[a]
Elig-Edzoa	37.50[a]	62.50[b]	00[a]
Mvog-Mbi	57.14[ab]	28.57[b]	00[a]
Essos	91.67[b]	8.33[a]	00[a]
F (58; 6)	3.536**	3.459**	3.149*
Traders %			
	55.13	28.21	2.82
Storage time (weeks)			
	5	3	1

*Values in the same column assigned by the same letter are not significantly different *p<0.05 or **p<0.001*

Diversity and quantity of smoked fish in terms of cartons in Yaoundé markets

The study counted in the seven markets, six species freshwater smoked fish, in all the markets inventoried; this is explained by the fact that these smoked fish are preferred by consumers. Among the smoked fish designated during three months of the study period, the catfish with 2,514 boxes of 50 kg are the most represented, followed by the Kanga, i.e. 492 boxes of 50 kg, and the least represented are the Eels fish with 30 boxes of 25 kg (Table 3).

The brick factory is the market that represents the largest number of sales of smoked freshwater fish in Yaoundé with 1,236 boxes sold, followed by Mokolo with 618 boxes. The Mfoundi market has the smallest quantity, 216 boxes of smoked fish.

Table 3. Relative abundance of boxes of smoked fish in the different markets

Markets	Quantity of smoked fish					
	Cardboards 50 kg			Cardboards 25 kg		
	Cat fish	Kanga	Red tail	Carp	Tilapia	Eel fish
Mfoundi	120	48	18	12	6	12
Mokolo	324	180	12	48	36	18
Briqueterie	984	144	48	60	0	0
Etoudi	36	24	0	12	0	0
Elig-edzoa	60	0	0	18	0	0
Mvog-Mbi	690	18	12	0	12	0
Essos	300	78	0	18	12	0
Total	**2 514**	**492**	**90**	**168**	**66**	**30**

Different insect pests' control of smoked fish during storage in markets

The different conservation methods observed among traders are natural, using salt, the sun and the freezer; and chemical by a mixture of salt + oil + water + insecticide (Rambo or DD Force with respectively active ingredient Permethrin 0,60% and Dichlorvos 1000 g/l EC) put in a perforated plastic bottle at the level of the lid which is sprinkled on the smoked fish (Table 3) Once sprayed, the smoked fish spend 4 hours in the sun and then 24 hours in storage before being placed on the counters. For longer storage, the DD Force with is sprayed directly inside the cardboard without mixing the product, before putting the smoked fish to protect them from harmful insects, thench tightly closed and stored in a dry place. The table 4 shows that in the 07 markets studied, (28.72%) traders use salt to preserve smoked fish. Regarding the chemical method, (14.10%) of traders use the formulation Oil + water + Rambo (24.36%) of traders use the formulation Oil + water + salt + DD Force strength insecticides for the conservation of smoked fish, therefore 100% of traders in the Mokolo and Briqueterie market use this product. It is observed that 4.87% of traders use the freezer to protect smoked fish against the attack by insect pests against 11.03% who expose them to the sun.

The ANOVA I showed a significant difference between the use of Sun (F (58; 6) = 37.288, p<0.05), the use of Rambo (F (58; 6) = 6.778, p<0.05), and the use of Freezer (F (58; 6) = 3.908, p<0.05) by traders as methods to control the attack of insect pests of smoked fish in the various markets of Yaoundé. However, this ANOVA I presented the highly difference between the use of the insecticide DD Force (F (58; 6) = 171.241, p<0.001), and the Salt (F (58; 6) = 71.739, p<0.001) by traders in different markets to protect the attack of insect pests (Table 4).

Table 4. Different insect pests control on smoked fish during storage in the markets

Markets	Insect pest control methods				
	Chemical control (%)		Physical control (%)		
	DD Force	RAMBO	Salt	Sun	Freezer
Mfoundi	00[a]	37.04[b]	3.70[a]	00[a]	14.81[ab]
Mokolo	49.21[c]	00[a]	49.21[c]	1.59[a]	00[a]
Briqueterie	50[c]	00[a]	50[c]	00[a]	00[a]
Etoudi	12.50[b]	37.50[b]	50[c]	00[a]	00[a]
Elig-Edzoa	00[a]	6.25[a]	00[a]	81.25[b]	00[a]
Mvog-Mbi	00[a]	11.90[a]	00[a]	4.76[a]	26.19[b]
Essos	00[a]	50[b]	16.67[b]	00[a]	00[a]
Total	24.36	14.10	28.72	11.03	4.87
F (58; 6)	171.241**	6.778*	71.739**	37.288*	3.908*

*Values in the same column assigned the same letter are significantly different *p<0.05 or **p<0.001*

Diversity of insecticide formulations used in Yaoundé markets and the level of harm associated with their active ingredients

Two commercial formulations of insecticides are used for the protection of smoked fish during storage by processors and traders in the various Yaoundé markets surveyed during the study. According to table 5, these insecticide formulations are made from 02 active ingredients (Dichlorvos and Permethrin) from DD FORCE and RAMBO. These two insecticides are from the Organochlorines and Pyrethroids family, belonging to toxicological class Ib (Highly hazardous) and II (Moderately hazardous). The application of insecticides is also done directly on surfaces, conservation tools or processing and storage areas.

Table 5. Diversity, toxicological class and level of harm associated with the active ingredients of the insecticide formulations used in the protection of smoked fish

Active ingredient	Trade name	Family	Toxicological class	Application
Dichlorvos[1,2,3] 1000 g/l EC	DD FORCE	Organophosphate	Ib	Insecticide
Permethrin[2,3] 0,60%	RAMBO	Pyrethrinoid	II	Insecticide

According to WHO, Ia : Extremely hazardous; Ib : Highly hazardous ; II : Moderately hazardous. According to PAN (2013), 1 : Lethal if inhaled ; 2 : Highly toxic to bees ; 3 : Long-term effect on human health

Origin of smoked freshwater fish present on the markets

The smoked fish sold in the seven markets surveyed come from 5 Regions of Cameroon according to the Divisions (Far North; Mayo-Danay, Logo-et-Chari), North (Benoué), Center (Haut - Sanaga, Nyong et Mfoumou), East (Haut-Nyong) and West (Noun) (Figure 2). It shows Mayo-Danay is the division that supplies the most smoked fish in Yaoundé markets (49.86%), followed by Bénoué (21.03%), Logone-et-Chari (10.06%). The other divisions supply a small quantity to Yaoundé markets, least of 10 % of supply of smoked fishes: Haut-Sanaga (1.13%), Nyong and Mfoumou (3.38%), Haut-Nyong (7.45%) and Noun (7.45%). Whatever the different freshwater smoked fish, the Far North Region supplies the various markets of Yaoundé in very large quantities for a rate of 70.89% than the other 04 Regions of Cameroon. According to Figure 2, the smoked fish (Eel fish and redtail) sold in the various Yaoundé markets come only from the Far North and North regions of Cameroon.

Insect pests emerged *In vivo* collections of smoked fish according to origin and number of galleries identified

Two species of insect pests have emerged from in-vivo collections of infected freshwaters smoked fish brought back from seven markets in Yaoundé and observed in the laboratory: *Dermestes maculatus* (Coleoptera: Dermestidae) and *Necrobia rufipes* (Coleoptera: Cleridae) these insects have varying densities depending on the species of smoked fish and the markets in Yaoundé (Table 6).

Table 6. *Necrobia rufipes* and *Dermestes maculatus* of the different *in vivo* collections of smoked fish according to the origin and the number of galleries identified

Smoked attacked fish	Insect pest		Extraction of insects by sampled market							Galleries counted
			Mfo undi	Mokolo	Briqueterie	Mvog-Mbi	Etoudi	Elig-Edzoa	Elig-Edzoa	
Catfish	*N. rufipes*	Larvae	03	06	00	03	05	00	02	86
		Adults	01	04	02	02	03	06	00	
	D. maculatus	Larvae	08	15	06	06	13	07	09	
		Adults	02	06	04	02	07	03	01	
Carp	*N. rufipes*	Larvae	00	02	06	00	03	07	00	69
		Adults	00	01	03	00	00	02	00	
	D. maculatus	Larvae	06	07	06	02	05	12	06	
		Adults	02	04	00	00	01	00	01	
Kanga	*N. rufipes*	Larvae	00	06	00	00	00	00	00	43
		Adults	00	01	02	00	00	00	00	
	D. maculatus	Larvae	07	12	08	03	06	03	03	
		Adults	02	03	00	00	03	00	00	
Tilapia	*N. rufipes*	Larvae	00	00	00	00	00	08	00	25
		Adults	01	02	00	00	00	02	00	
	D. maculatus	Larvae	06	05	02	02	00	13	00	
		Adults	02	02	00	00	00	04	00	
Eel fish	*N. rufipes*	Larvae	00	00	07	00	00	00	00	13
		Adults	00	00	03	00	00	00	00	
	D. maculatus	Larvae	05	02	02	00	00	00	00	
		Adults	00	00	00	00	00	00	00	
Red tail	*N. rufipes*	Larvae	00	01	00	00	00	00	00	11
		Adults	00	01	00	00	00	00	00	
	D. maculatus	Larvae	02	03	10	02	00	00	04	
		Adults	00	00	04	00	00	00	00	

Of the five fish species brought back, five individuals per infested fish species were taken from traders, i.e. 25 in total for observation of the larvae and adults of insect pests in the hidden forms of each smoked fish. *D. maculatus* is the most abundant insect in every market and in every smoked fish. The Mokolo markets had the highest number of larvae (15) and adults (08) of *N. rufipes* followed by Briqueterie (13) larvae and adults (10) than the other markets. Catfish is the smoked fish with the highest number of insect pests (25) larvae and (20) adults of *N. rufipes* and (72) larvae and (26) adults of *D. maculatus*. Overall, the populations of *D. maculatus* are higher with 221 larvae and 54 adults of *D. maculatus* than those of *N. rufipes* with 65 larvae and 37 adults. The Catfish is the smoked fish that filled the largest number of galleries (86).

Diversity of insect pests emerged from in-vivo collections of smoked fish and their numbers over 35 days in the laboratory

The damage due to the activities of insect pests is materialized by the numerical importance of *D. maculatus* and *N. rufipes* obtained after 35 days of observation (Table7). These parameters vary according to the collections of smoked fish and their origin. *D. maculatus* is the most recorded pest in the different collections with 336 larvae and 107 adults against 152 larvae and 45 adults for *N. rufipes* on the 1000g of apparently healthy smoked fish collected from Yaoundé market traders. Generally, *D. maculatus* and *N. rufipes* infested all smoked fish collected. The most infested smoked fish are Catfish with 182 larvae and 54 adults, followed by Kanga with 86 larvae and three adults for *D. maculatus*; and *N. rufipes* more infested the catfish with 60 larvae and 22 adults against 38 larvae and 20 adults for the Kanga and finally 26 larvae and 03 adults for the carp (Table 8). The Briqueterie market is the locality which recorded the highest number of larvae (45) and adults (20) for *N. rufipes* and *D. maculatus* with regard to larvae (93) and adults (32), monitoring of the Mokolo market with (26) larvae and (9) adults for *N. rufipes*, and (57) larvae and (16) adults for *D. maculatus*. Catfish and Kanga are the smoked fish with the highest number of *N. rufipes* and *D. maculatus* in the various markets of Yaoundé.

Table 7. Diversity of insect pests emerged from *in-vivo* collections of smoked fish and their numbers over 35 days in the laboratory

Smoked fishes	Catfish				Carp				Kanga			
	Insect pest				Insect pest				Insect pest			
	N. rufipes		*D. maculatus*		*N. rufipes*		*D. maculatus*		*N. rufipes*		*D. maculatus*	
Markets	Larva e	adults	Larvae	Adults	Larva e	Adults	Larvae	Adults	Larvae	Adults	Larvae	Adult s
Mfoundi	05	2	24	9	00	00	07	02	13	09	10	05
Mokolo	17	5	33	08	00	00	10	04	09	04	14	04
Briqueterie	23	11	52	12	09	02	16	08	13	07	25	12
Elig-Ndzoa	03	00	17	05	00	00	10	02	00	00	00	00
Mvog-Mbi	00	00	08	03	02	00	06	02	00	00	12	02
Essos	02	00	27	10	03	00	05	00	00	00	10	01
Etoudi	10	03	13	05	04	00	11	07	03	00	04	00
Total	60	22	182	54	26	3	68	23	38	20	86	30

DISCUSSION

The study in the seven markets selling smoked freshwater fish in the city of Yaoundé made it possible to identify the demographic data of traders in each market surveyed. The market study revealed that women represent the sex that exercises the most in the marketing of smoked freshwater fish (Table 1), this work corroborates with the work of (Mufutau et al., 2018) carried out in the dried fish market in Kwara State, Nigeria and (Peyieno et al., 2023) which showed that women are more involved in the processing and marketing of smoked fish in the localities of Mouanko, Manoka and Youpwé of the Central Camroun estuary.

The strong use of cardboard and baskets as storage tools (Table 2) could be explained by the fact that this storage tool has a dual functionality because it is considered as a storage and sales tool for traders. Despite the short duration of storage, traders report the presence of pests in their stock, this result is similar to (Tamgno et al., 2020b) which showed that baskets are the storage tools most used by fishermen and traders. smoked fish traders in Bamendjing and Mapé, West Cameroon region. This result also corroborates with the work of (Tekou, 2018, Tamgno 2019) who identified five storage tools used by fishermen/processors of the North of the Dja Biosphere Reserve, East Cameroon; and that of (Chegué, 2020) in the various smoked fish marketing markets of Youpwé, Mouanko and Manoka, Littoral-Cameroon.

Poor storage systems used by some dried fish vendors could also pose a risk of infestation. The level of infestation of smoked fish with *D. maculatus* and *N. rufipes* can be directly related to the duration of fish storage (Table 6), as smoked fish sellers do not buy new stock until the old stock is completely eliminated. This observation is consistent with the work (Adler et al., 2015), who reported that long storage periods allow insects more time to reproduce and consume the fish.

The use of a varied range of synthetic insecticides in the protection of smoked fish in the different commercialization markets of Yaoundé (Table 5) would testify to the difficulty that certain traders have in succeeding in the practice of storage. Regarding the trade names of these insecticides, none is registered in Cameroon (Minader, 2021; Ngamo et al., 2020). The insecticide formulations in circulation and used in the protection of smoked fish in Yaoundé markets (Table 4) belong to toxicological classes Ib and II, these classes are the most harmful both for the environment and for the consumer; this result is almost similar to the work done in West Region of Cameroon which showed the toxicological class Ia, Ib and II of the insecticides used (Fopa, 2019). These formulations are made from several active ingredients. The active ingredient of RAMBO, permethrin, although approved in Cameroon with the recommendation to wear personal protective equipment, is prohibited from production and sale in the European Union and the United States of America (Minader, 2021; Ngamo Tinkeu et al., 2020). Dichlorvos 1000 g/l EC and Permethrin 2.3 0.60%, two active ingredients used in the protection of smoked fish in Yaoundé markets testifies to the ignorance of traders. In some markets, for longer storage, the DD Force is sprayed directly inside the carton without mixing the product, before putting the smoked fish to protect them against insect pests, then tightly closed and stored in a dry place (Table 5). Babarinde et al. (2015); Abolagba et al. (2015), Mufutau, (2012); Adesina et al. (2016); Akpotu et al. (2016) have suggested the use of plants as an alternative to the use of toxic materials such as vehicle oil and synthetic chemicals to protect dried fish.

The number of emergence of larvae and adults on fish species (Table 6) is similar with the work of Folorunso et al. (2006) which suggests that there was a greater presence of adults and dermestid larvae which developed in *C. gariepinus* than in the others fish species. The harmful insects emerged from the collections belong to two families: Dermestidae and Cleridae and an order, that of the beetles (Table 6 and 7), similar to the smoked fish collections of the Dja Biosphere Reserve (Tekou, 2018), also at the three markets (Ipata, Idi-ap, Gbugbu) famous for their sale

of dried fish in the state from Kwara in Nigeria (Mufutau et al., 2018). The presence of galleries in differents smoked fish brought back from the markets testifies to the degree of infestation of insect pests on smoked fish (Table 6). It appears that after 35 days of storage (Table 7), a large number of larvae and adults of *D. maculatus* were observed on *C. gariepinus* than on the other species of fish smoked in the laboratory. These results corroborate with the work of (Tamgno et al., 2020b) which indicates when the beetles reproduce on smoked fish until it is reduced to powder, there is practically nothing left but the skin and the bones. The heavy infestation of insect pests and the corresponding economic damage caused to dried fish have been recognized worldwide (Mufutau, 2012). The likelihood of insect pest cross-infestation on smoked fish was high (Babarinde et al., 2016a). The use of botanicals to control Dermestes species is not new especially in developing countries where these botanicals are cheaply available. Several scientists (Fasakin and Aberejo, 2002; Akinwumi et al., 2006, Nowsad et al., 2009; Akinwumi and Fesobi, 2010; Babarinde et al., 2016a) have reported the bioefficacy of different plant formulations against *D. maculatus*. Essential oils extracted from aromatic plants are volatile complex mixtures with high insecticidal and antimicrobial activity to fight against the attack of food pests (Ngamo Tinkeu et al., 2007; Sameza et al., 2016).

CONCLUSION

This study highlighted the presence of stock insect pests and determined the storage tools, chemicals and damage caused by *D. maculatus* and *N. rufipes* on smoked fish in the major marketing areas of the city of Yaoundé. The results of this study showed the existence of *D. maculatus* and *N. rufipes* in the stocks of freshwater smoked fish from the Far North, North, East, Center and West Regions of Cameroon. The test and observation in the laboratory revealed that *D. maculatus* is the insect pest that most infests smoked freshwater fish taken from the various markets and that the infestation leads to substantial, economical weight losses. In general, the susceptibility depends on the stage of development of the insects and the species of smoked fish, but the larval stage of *D. maculatus* is more destructive than its adult stage. The storage methods, which are generally rudimentary packaging from craftsmen, are unsuitable and favor breakage during handling and then during storage; pest infestation and development. To limit food losses due to *D. maculatus*, synthetic chemicals are used in the seven markets of Yaoundé. Most of these very dangerous products are not approved in Cameroon and can be potential sources of poisoning for consumers. The research for phytopesticides based on essential oils of aromatic plants currently use as bioinsecticides can make it possible to propose new product to traders, suppliers and fishermen for the protection of treated fish during storage in the place of chemicals.

Conflict of interest

The authors declare that there is no conflict of interest.

Acknowledgements

The authors are grateful to the National Veterinary Laboratory Douala-Annex for the welcoming to the laboratory and providing the necessary equipment to complete this work.

REFERENCES

Abolagba, O. J., Akise, O. G., & Orukpe, J. D. (2015). Effects of pirimiphos methyl and common salt (NaCl) on the prevention of *Dermestes maculatus* from smoke-dried *Clarias gariepinus* (Burchell, 1822). *Nigerian Journal of Agriculture, Food and Environment, 11*(1), 73-77. https://www.researchgate.net/publication/362317860

Adesina, J. M., Jose, A. R., & Rajashekar, Y. (2016). Bio-efficacy of *Clerodendrum capitatum* (Willd) Schumachet. Thonn. (Lamiales: Verbenaceae) against *Dermestes maculatus* De Geer, 1774 (Coleoptera: Dermestidae) larvae infestation on smoked catfish *Clarias gariepinus* (Burchell, 1822) (Siluriformes: Clariidae). *Brazilian Journal of Biological Sciences, 3*(5), 37-44. https://dx.doi.org/10.21472/bjbs.030504

Adler, C., Katamssadan, T. H., Nukenine, E. N., & Stahler, M. (2015). Bio-efficacy of *Azadirachta indica* A. Juss oil extracted from sun- and shade-dried seeds against two stored-product beetles. *International Journal of Biosciences, 7*(2), 135-151. https://dx.doi.org/10.12692/ijb/7.2.135-151

Akinwumi, F. O., Fasakin, E. A., & Adedire, C. O. (2006). Progeny inhibiting effects of four plant products against the leather beetle and the copra beetle on smoked African mudfi sh. *Journal of Biological Sciences*, 6 (6): 1023-1028. https://dx.dio.org/10 3923/jbs.1023.1028

Akinwumi, F. O., & Fesobi, M. E. (2010). Effect of some plant-based insecticides on the nutritive value of smoked catfish, *Clarias gariepinus* (Pisces: Clariidae). *African Journal of Food Science* 4 (4): 143 -147. https://academicjournals.org

Akpotu, O. J., Oniye, S. J. & Abolude, A.D. (2016). Yusuf. Comparative study of the toxicity of oils from seeds of *Citrullus colocynthis* and *Citrullus vulgaris* on larvae of *Dermestes maculatus*. *Aquaculture Engineering and Fisheries Research,* 3 (1). 6-12. https://dx.dio.org/10.3153/JAEFRI7002

Babarinde, O.O.R., Pitan, G.O. & Olatunde, M.O. (2015). First report of toxicity of *Xylopia parviflora* (A. Rich.) Benth (Annonaceae) root bark's essential oil against cowpea seed bruchid, *Callososbruchus maculatus* Fabricius (Coleoptera: Chrysomelidae: Bruchinae). *Natural Product Research,* 29 (4). 349-352. https://www.cabi.org/ac/20123255840

Babarinde, S.A., Adebayo, T.A., Usman, L.A., Ameen, O.M., Akinyemi, O.A., Onajole, O.T., & Adekale, O. (2016a). Preservation of smoked African catfish, Clarias gariepinus Burchell against *Dermestes maculatus* De Geer (Coleoptera: Dermestidae) using neem seed oil-iodized salt mixtures. *Agriculturae Conspectus Scientificus*. 81(4), 235e240. https://www.cabi.org/ac/20173238211

Babarinde, S.A., Sunnie-Ododo, M.O., Aknbi, W.B., Oyegoke, O.O., Tijani, R., & Olaobaju, S. F. (2016b). Comparative susceptibility of two developmental stages of hide beetle (*Dermestes maculatus* Degeer, 1774) to ginger (*Zingiber officinale* Roscoe) essesntial oil. *Journal of Saudi Society for Agricultural Sciences*. https://dx.doi.org/10.1016/JJSSAS09003

Beramgoto, A. (2019). Des pesticides utilisés pour la conservation des poissons fumés, tchadinfo.com. 9, p 52.

Bouleys, P. (2006). Contribution à la maitrise de l'hygiène et l'assainissement dans les établissements classés de Yaoundé. Mémoire de Master spécialisé, Université de Yaoundé.

Delobel & Tran. (1993). Les Coléoptères des denrées alimentaires entreposées dans les régions chaudes. ORSTOM/CTA (Faune tropicale XXXII): France, p 424.

Fasakin, E.A., & Aberejo, B.A. (2002). Effect of some pulverized plant materials on the developmental stages of fish beetle, *Dermestes maculatus* Degeer in smoked cat fish, *Clarias gariepinus* during storage. *Bioresource Technology* 85 (2): 173-177. https://dx.doi.org/10.1016/S0960-8524(02)0058-5

Fopa, N. (2019). Poissons fumés et contraintes liées au stockage à l'Ouest-Cameroun. Mémoire de stage d'insertion professionnelle. Master professionnel, Université de Douala, Cameroun, 94. 53-64.

Gamane, K. A., Micha, J.C., & Tidjani, A. (2016). Démarche Assurance Qualité dans le secteur de production du poisson transformé au Tchad. *Revue Scientifique et Technique Forêt et Environnement du Bassin du Congo*. https://revue.riffeac.org/index.php?journal=RSTBC

Geden, C.J., & Hogsette, J.A. (2001). Research and extension needs for integrated pest management for Arthropods of veterinary importance. Proceedings of a workshop in Lincoln, Nebraska, 12–14 April 1994, Center for medical, agricultural, and veterinary entomology USDA-ARS, Gainesville, Florida.

Halstead, D. G. H. (1986). Keys for the identification of beetles associated with stored products. Introduction and key to families. *Journal of Stored Products Research, Vol. 22*, no. 4, 163-203.

Ikenweiwe, N.B., Bolaji B.O., & Bolaji, G.A. (2010). Fabrication and performance assessment of a locally developed fish smoking kiln. *Ozean Journal of Applied Sciences*, 3(4), 363e369. https://scholar.google.com/citations?user=2XUjaCAAAAAJ

Maliki, D. (2020). Poissons et poison dans nos assiettes CENOZO (Journalisme d'investigation en Afrique de l'Ouest), 694.

Minader (Ministère de l'Agriculture et du Développement Rural) (2021). Commission nationaled'homologation des produits phytosanitaires et de certification des appareils de traitement au Cameroun. Liste des pesticides homologués le 04 Mars 2021, p 1.

Mufuta, A. A., Barakat, O., & SoliuSegun, O. O. (2018). Impact de l'infestation de *Dermestes maculatus* Degeer sur la perte de marché du poisson séché dans l'État de Kwara, au Nigeria. *Aquaculture et Pêche*, 170-173. https://dx.doi.org/10.1016/j.aaf.2018.06.001

Mufutau, A.A. (2012). Evaluation of the efficacy of neem seed oil (NSO) extract for the control of *Dermestes maculatus* Degeer, 1774 (Coleoptera: Dermestidae) in *Clarias gariepinus* (Burchell, 1822) (Pisces: Claridae). *Munis Entomology and Zoology*, 7(2), 1188e1194. https://www.researchgate.net/publication/266021985

Ndrianaivo, E.N., Cornet, J., Cardi, M., Razanamparany, L. & Berge, J.P. (2016). Stockage des poissons fumés et ou séchés : cas de *Oreochromis niloticus*. *Fihasaly malgache, Afrique Science*. 254– 265. https://www.afriquescience.info

NEPAD. (2013). Annual Review on International Partnership for African Fisheries Governance and Trade (PAF) (Nouveau partenariat pour le développement de l'Afrique (NPCA) et Agence de Planification et Coordination du NEPAD). 30 p. Agriculture familiale et lutte contre la pauvreté, Commission de l'Union Africaine & 2014. Cadre politique et la stratégie de réforme de la pêche et de l'aquaculture en Afrique ;30(3): p 25-26.

Ngamo, T.L.S., Ngatanko, I., Ngassoum, M.B., Mapongmetsem, P.M., & Hance, T. (2007). Use of Essential Oils of Aromatic Plants as Potectant of Grains During Strorage. *Agricultural Journal* 2 (2): 204-209. https://tropiculture.org

Ngamo, T.L.S., Ngatanko, I., Tamgno, B.R., Watching, D., Madou, C., Ayiki, E. N. Goudoum, A., & Ngassoum, M.B. (2020). Highly Hazardous Pesticides (HHPs) Registered and Its Use in Sub-Saharan Africa. *Journal of Agricultural Sciences and Technology*. 344-350. https://dx.dio.org/10.17265/2019.06.003

Nowsad, A. K. M., Mondal, R., & Islam, M. R. (2009). Effectiveness of neem, garlic and red chili against adult dermestid beetle in sun dried fish. *Progressive Agriculture* 20 (1 & 2): 133-142. https://doi.org/10.3329/pa.v20i1-216865

OMS. (2010). The WHO recommended classification of pesticides by hazard and guidelines to classification: Wissenchaftliche Verlagsgesellschaft mbH, Stuttgart, Germany, p 83.

PAN International. (2023). PAN International List of Highly Hazardous Pesticides (PAN List of HHPs). Harmburg/Germany, p 36.

Peyieno, M.J., Tekou N. H., Yantcho, T. L.F., Tamgno, B.R., Leng, M., & Tchoumbougnang, F. (2023). Relative abundance of smoked fishes and the diversity of pests associated with their deterioration during storage. *International Journal of Innovation and Applied Studies.* https://www.ijias.issr-journals.org/

Sameza, M.L., Tchameni, S.N., Ekoue, J.D.A., Jazet, P.M.D., & Tchoumbougnang, F. (2016). Growth inhibition of the stored fish (*Ethmalosa frimbiata)* fungus *Aspergillus flavus*, exposed to extracted essential oils from *Callistemon citrinus* and *Ocimum canum*. *African Journal*. https://doi.org/10.5897/QJMR20168028

Tamgno, B. R., Chegue, P.J., Tchoumbougnang, F., & Ngamo Tinkeu, L.S. (2021). Evaluation of factors of loss on stocks of smoked fish in three subdivisions of the Cameroon maritime coastal zone in Littoral region. *Journal of Entomology and Zoology Studies*. 37-44. https://doi.org/10.22271/j.ento.v9.i3a.86 87

Tamgno, B. R., Tekou, N. H. Nyamsi, T.N.L. Mouamfon, M., & Ngamo T. L.S. (2020a). Insectes ravageurs des poissons fumés au cours du stockage et dégâts occasionnés dans la boucle Nord de la Réserve de Biosphère du Dja (Est Cameroun). *International Journal of Chemical and Biology Sciences*. 14(2): 528-538. https://dx.doi.org/ 10.4314/ijbcs .v14i218

Tamgno, B.R., Tekou, N.H., Nyamsi, T.N.L., Mouamfon, M., & Ngamo, T.L.S. (2019). Contraintes de stockage du poisson fumé dans la boucle Nord de la Réserve de Biosphère du Dja. 26ème Conférence Annuelle des Biosciences, du 26 au 30 novembre 2019, Maroua, Cameroun, Poster 28, Sécurité alimentaire. Book of abstract of Cameroon Biosciences Society.

Tamgno, B.R., Fopa, N,. & Ngamo, T.L.S. (2020b). Les insectes ravageurs des poissons fumés et le statut des insecticides chimiques utilisés dans leur protection au cours du stockage dans la Région de l'Ouest-Cameroun (Afrique Centrale). *International Journal of Innovation and Scientific Research*. 50(1):71-81. http://www.ijisr.issrjournals.org/

Tekou, N.H. (2018). Contraintes de stockage du poisson fumé dans la boucle Nord de la Réserve de Biosphère du Dja. Mémoire de stage, Institut des Sciences halieutiques, Université de Douala, p 64.

Read online :	Scan this QR code with your smart phone or mobile device to read online.