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NUTRITIONAL AND MICROBIOLOGICAL QUALITY OF SMOKED SARDINELLA (*SARDINELLA AURITA*) CANNED IN OLIVE OIL

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ABSTRACT

Round sardinella have an important role in food security due to their abundance, low purchase price and nutritional quality. Despite its economic and social importance in Senegal, the sardinella fishery faces a multitude of problems that could compromise the development of the sector, and the food and nutritional security of the people who consume it. The aim of this study was to contribute to the valorization of round sardinella by developing smoked canned sardinella and then improving its availability and creating added value. Fresh round sardinella purchased on the "Yarakh" fish landing ground (Dakar) were used for the cans production. Fresh round sardinellas are decontaminated by removing heads, scales and viscera, then trimmed by opening them in a "wallet" to wash them. The washed sardinellas are then salted brine (5%) before being smoked at 85°C. The smoked sardinellas are then stored in canning jars, before the olive oil is added. The canned sardinella were sterilized at 121°C for 20 min. The physico-chemical and microbiological characteristics of fresh and smoked canned sardinella were assessed. The chemical analysis showed an increase in proteins from 22.4 to 26.7% and lipids from 10.1to 13.1%, respectively, in fresh and canned sardinella. The canned sardinella had higher mineral values than the fresh sardinella, with iron, iodine, potassium and calcium contents of 2.51 mg/100 g, 0.07 mg/kg, 378 mg/100 g and 610 mg/100 g, respectively. For minerals, a significant increase ($p<0.05$) was noted in the iron content going from 1.78 to 2.51 mg/100 g, in the iodine content from 0.03 to 0.07 mg/kg and the calcium content increase from 382 to 611 mg/100 g. These nutrient values make smoked canned sardinella a potentially beneficial food and could be another way for preventing malnutrition through a dietary approach. The microbiological analyses showed that fresh and canned sardinella have a satisfactory microbiological quality according to the microbiological requirements for fishery and aquaculture products. The quality of the raw material and the use of good manufacturing practice during production can ensure the safety of canned products. The yield of smoked sardinella was 29.3% of fresh sardinella. Hopefully commercialization of smoked canned sardinella can lead to the increased availability of nutritious food in Senegal.

Key words: round sardinella, *sardinella aurita,* canned fish, iron, iodine, calcium, Senegal

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QUALITÉ NUTRITIONNELLE ET MICROBIOLOGIQUE D'UNE CONSERVE SARDINELLE FUMÉE (*SARDINELLA AURITA)* À L'HUILE D'OLIVE

RESUME

La sardinelle ronde joue un rôle important dans la sécurité alimentaire en raison de son abondance, de son prix d'achat et de sa qualité nutritionnelle. Malgré son importance économique et sociale au Sénégal, la pêcherie de sardinelles est confrontée à une multitude de problèmes qui peuvent compromettre le développement de la filière et la sécurité alimentaire et nutritionnelle des populations qui le consomment. Cette étude vise à contribuer à la valorisation de la sardinelle ronde par la mise au point de conserves de sardinelles fumées dans le but de contribuer à la disponibilité d'aliments nutritifs et de créer de la valeur ajoutée. Des sardinelles rondes fraiches achetées sur le quai de pèche *yarakh* (Dakar) ont été utilisées pour la production. Les sardinelles rondes fraiches ont été décontaminées en enlevant les têtes, les écailles et les viscères puis parées en les ouvrants en « portefeuille » pour les laver. Les sardinelles lavées sont ensuite salées dans une saumure (5% de sel) avant d'être fumer à 85° C. Les sardinelles fumées sont rangées dans des bocaux de conserve, avant d'y rajouter l'huile d'olive. Les conserves de sardinelle ont été stérilisées à 121° C pendant 20 min. Les caractéristiques physico-chimiques et microbiologique des sardinelles fraiches et des conserves de sardinelles fumées ont été évaluées. Les analyses chimiques ont montré une augmentation des protéines et des lipides passant respectivement de 22,4 à 26,7% et de 10,1 à 13,1% au niveau des conserves. Pour les minéraux une augmentation significative ($p<0,05$) a été notée sur la teneur en fer passant de 1,78 à 2,51 mg/100g, sur la teneur en iode passant de 0,03 à 0,07 mg/kg et sur la teneur en calcium passant de 382 à 610,7mg/100g. Ces valeurs en éléments nutritifs confèrent aux conserves de sardinelles fumées un grand intérêt nutritionnel et pourrait être un autre moyen de prévenir la malnutrition. Les analyses microbiologiques ont montré que les sardinelles fraiches et les conserves ont une qualité microbiologique satisfaisante suivant les exigences microbiologiques relative aux produits de la pêche et de l'aquaculture. La qualité de la matière première et les bonnes pratiques de fabrication lors de la production ont assuré la sécurité sanitaire des produits en conserve. Le rendement de la production de sardinelle fumée était de 29,3 % de la sardinelle fraiche. La commercialisation de la sardinelle fumée en conserve pourrait contribuer à l'accroissement de la disponibilité des aliments nutritifs au Sénégal.

Mots clés: Sardinelle ronde, *Sardinella aurita,* conserve de poisson, fer, iode, calcium, Sénégal

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INTRODUCTION

Senegal is a maritime country with abundant fish stocks, in the Atlantic Ocean [1]. Senegal is located in a zone of high biological productivity favoured by the presence of seasonal upwelling [2-4]. The fishing industry contributes 1.7% to the national Gross Domestic Product (GDP), generates nearly 200 billion franc of the French Colonies of Africa (CFA) annually and provides around 600,000 direct jobs and more indirect jobs, together representing 17% of the labour force [5,6]. Fishing is a major contributor to food security, with a per capita consumption of > 29 kg. Fish products provide more than 75% of the animal protein intake of the Senegalese population, both urban and rural [7,8] with over 70% of this consumption being small pelagic fish [7]. The socio-economic importance of fishing is linked to several factors, including the abundance of the resources and the dynamism of the fishery sectors. In addition, since the 1950s, fisheries policies have encouraged the development of small-scale fishing, with the motorisation of pirogues (canoes) and subsidies for fishing inputs [9,10]. Artisanal fishing primarily supplies local markets, and the both artisanal and industrial processing sectors [11, 12].

Over the last decade, the Senegal-Mauritania region has seen the emergence of an industrial fishery supplied mainly by sardinella [13]. This intensive fishing could seriously compromise food security in the West African sub-region [14]. As a result, despite the dynamism of the small pelagic market, the socio-economic situation of the artisanal fishing sector is becoming increasingly of concern, with yields and incomes falling and the living conditions of fishermen deteriorating [14-16].

This situation has suggested the need for a new way to add more value to sardinella. One such approach is to develop smoked canned round sardinella to provide the population more nutritious products that would increase the competitiveness of sardinella on the Senegalese market.

MATERIALS AND METHODS

Processing round sardinella into smoked canned sardinella

The round sardinella *(Sardinella aurita)* were bought from *Yarakh* fishing wharf (Dakar) the capital's busiest fishing site and one of the five sites that polarize around 80% of artisanal fishing activities in Senegal. The technique of sensory analysis of freshness criteria such as firm, brightly colored and shiny skin, clear and shiny bulging eyes, firm belly and red gills with a seaweed odor was defined for the selection of raw material at the fishing docks. A quantity of 14 kg of fresh sardinella was purchased for the production of smoked sardinella cans. Fresh round sardinella (*Sardinella aurita)* were prepared by removing the heads, scales with a knife and then gutting them by making an incision along the belly and removing the entrails. They were then trimmed by opening them into a “wallet” shape before being washed.

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The washed sardinella were filleted on a board. The sardinella fillets were washed and drained using a colander. The sardinella fillets are salted in a brine with a salt concentration of 5 % for 10 minutes, before being drained and hot-smoked at 85°C for 45 minutes in an industrial smoker (FRESSMANN) using coconut shells as a heat source. After smoking, the sardinella were left to cool in the smokehouse before being placed in 55 mm diameter metal cans, with two fillets per cans and adding olive oil purchased from the local market until the jar was completely full. The cans were sealed with a manual crimper (Sertinox S.C.I.M., Casteljoux, France) autoclaved using a high-pressure steam autoclave (Forestalk) at 121°C for 20 min, then cooled and stored at room temperature. This sterilization parameters were chosen in accordance with the recommendations of the French National Agency for Health Safety (ANSES) [17] for the production of canned food, which suggest sterilization values of 121°C capable of destroying *Clostridium botulinum* spores and toxin. In addition, a study conducted by Ndiaye et al. [18] on the optimization of sterilization scales during the production of canned food showed that a temperature of 121°C allows to destroy microorganisms linked to food deterioration

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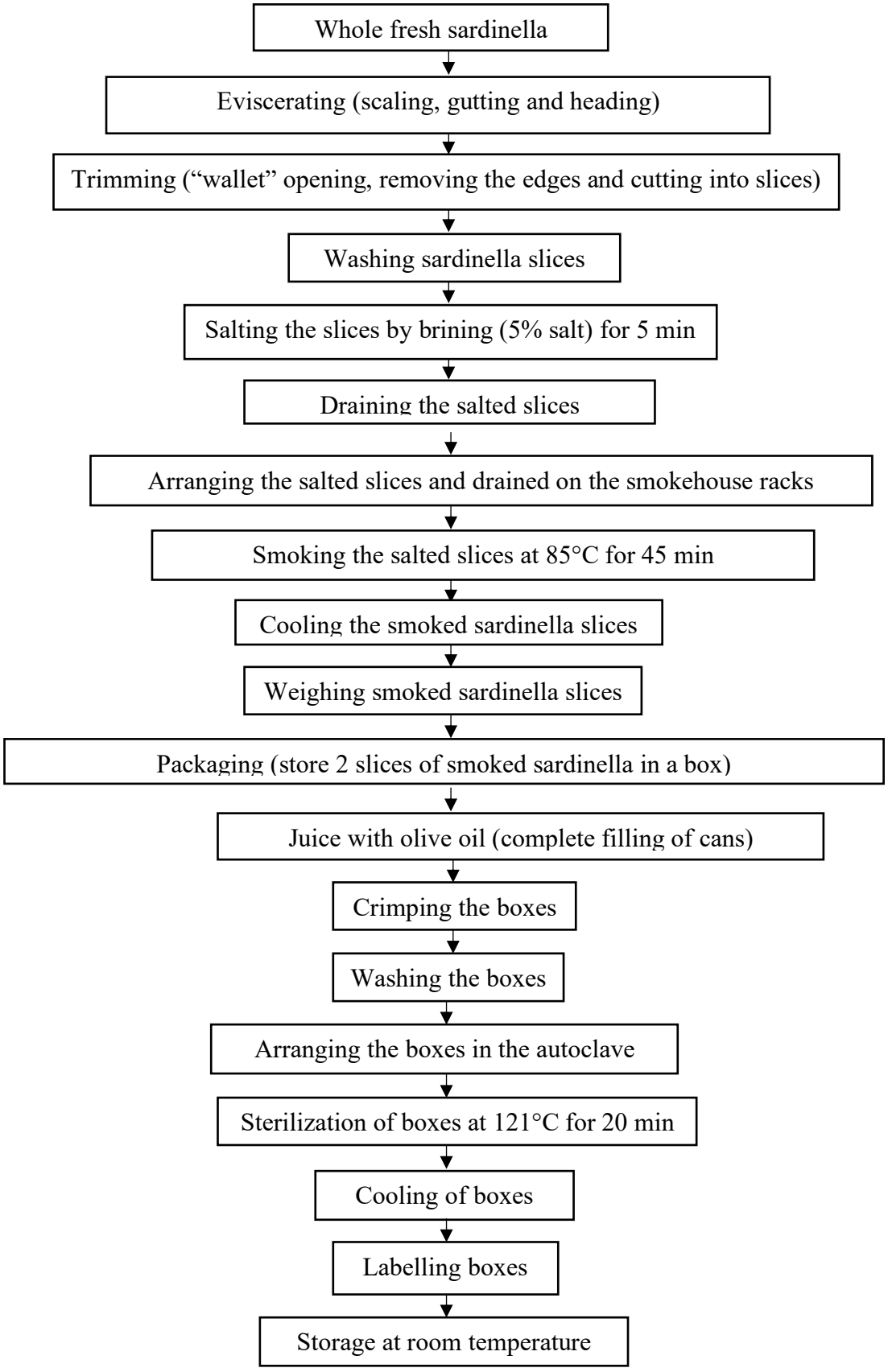

Figure 1: Flow diagram of production of canned smoked sardinella

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Determination of nutritional quality

Nutritional characterisation was done on fresh fillets and smoked canned of round sardinella.

Moisture

The water content was determined according to Association of Official Analytical Chemists (AOAC) method 945.15 [19]. The sardinella samples were dried in an oven (GENEQ inc) at 105 ± 2°C until constant weight. Weight loss is calculated as the water content of the sample.

Protein

The protein content was determined using the Kjeldahl method (AOAC 2001.11), which consists of measuring the nitrogen in the product. The finely ground samples were hot mineralized with concentrated sulfuric acid in the presence of a catalyst. Nitrogen, after several transformation processes, produces ammonia which is distilled, recovered in a boric acid solution and titrated with a sulfuric acid solution. The nitrogen content was multiplied by a conversion factor (6.25) to find the protein content.

Fat

The lipid content was determined according to the Soxhlet Method (AOAC 2003.06) which consists of releasing the lipids by extraction using an organic solvent immiscible with water (N hexane), followed by evaporation of the solvent and weighing of the lipid extract after drying in an oven at 105°C.

Ash

The ash content was determined according to AOAC method 940.26. The sardinella samples were carbonized on a bunsen burner then incinerated in an oven at 600°C for 6 hours. The difference in weight with the test portion gives the ash content.

Carbohydrate

The carbohydrate content of sardinella is obtained by making the difference between the dry extract and the sum (proteins, lipids, ash).

Mineral

The mineral element contents (iron, zinc, potassium, iodine, calcium) were measured by Atomic Absorption Spectrophotometry flame mode and graphite furnace, with deuterium correction in flame mode and Zeeman effect correction in furnace mode (PERKINELMER), according to method 968.08 described in AOAC. After incineration of the samples and dissolution of the ashes in hydrochloric acid, the concentrations of the different minerals in the samples are determined from calibration curves established with a range of standard solutions characteristic of each element.

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Determination of microbiological quality

After six months' storage at room, the microbiological quality of fresh fillets and smoked canned round sardinella and were assessed their aerobic mesophilic flora (AMF) on Plate Count Agar (PCA) medium in compliance with ISO 4833-1: 2013, thermotolerant coliforms on crystal violet and neutral red bile agar (VRBL) according to ISO 4832, coagulase + staphylococci on Baird-Parker agar medium according to ISO 6888-1, and salmonella by the horizontal method with pre-enrichment in buffered peptone water (BPW), enrichment with Rappoport Vassiliadis broth with soy (RVS broth) and Muller-Kauffmann broth with Tetrathionate-novobiocin (MKTTn), followed by isolation on xylose-lysine-deoxycholate (XLD) agar deoxycholate (XLD) agar and Hektoen agar in accordance with ISO 6579-1. The values obtained were compared with the microbiological criteria defined by the Algerian Official Journal (JORA N°39/2017) relating to fishery and aquaculture products [20], in addition to the directives of the Directorate of Fisheries Processing Industries of Senegal which did not specify the microbiological requirements of canned fish.

Production yields for smoked, canned sardinella in olive oil

The yield for the production of canned firm sardinella was determined using 3 kg of fresh sardinella to carry out the various unit operations such as scaling, gutting, brining and smoking for the production of smoked canned sardinella. This process was carried out in triplicate. The yield was determined according to the equation below:

$$\text{Production yields (\%)} = \frac{\text{weight of sardinella obtained after smoking}}{\text{weight of fresh round sardinella}} x100$$

Statistical analysis

Physico-chemical analyses were performed in triplicate and results are expressed as mean ± standard deviation. Differences between variable means were compared using a one-way analysis of variance (ANOVA), with multiple comparison procedures by calculating Fisher's Smallest Significant Difference (FSD) using XLSTAT version 2013 software (Addinsoft Sarl, Paris-France). The significance level was set at $p < 0.05$.

RESULTS AND DISCUSSION

Nutritional quality

The nutritional value of fresh sardinella and canned smoked sardinella are shown in Table 1. There was a significant decrease ($p=0.002$) in the moisture content of the smoked canned sardinella compared to the unprocessed raw sardinella. This reduction in water content may be due to the brining which causes the transfer of

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water contained in the flesh of sardinella fillets to the brine against the transfer of salt to the flesh. Hot smoking drained the water contained in the sardinella fillets. The reduction in humidity combined with the reduction in water activity by salt and the bacteriostatic effect of smoking helps to reduce the microbial load of cans. The moisture content of fresh sardinella found in this study was lower than those found by Depo *et al.* [21] and Barakat *et al.* [22] respectively, of 76.5% and 72.1% on smoked catfish and round sardinella, respectively.

The protein content in fresh sardinella was higher than the 17.2% found by Mujinga *et al.* [23] in fresh red mullet (*Scorporena porcus*). A significant increase ($p<0.0001$) of protein content of smoked canned sardinella was observed. This may be due to the loss of water from the muscles, during the smoking process. For smoked canned sardinella, the protein content was higher than the 20.7% found by Chabi *et al.* [24] for smoked horse mackerel. These high protein values show the potential of this smoked canned sardinella to contribute to the alleviation of malnutrition and increased food security in Senegal.

The fat content increased significantly ($p<0.0001$), probably due to the olive oil. These results were lower than the 15.7% and 20.3% found by Roberta et al. [25] on matrinxa (*Brycon amazoniens*) and sardine (*Hemiodus unicamculatus*), respectively, canned with soybean oil. These fish lipids are the main sources of polyunsaturated fatty acids in the human diet and olive oil is a major source of monounsaturated fatty acids. The consumption of fish is believed to reduce the risk of cardiovascular disease, cognitive decline and dementia in elderly subjects [26, 27].

There was a significant increase ($p<0.001$) in the iron content of the canned products. This value was higher than those show for the nutritional value of canned sardines (*Sardina pilchardus*) (1.97 mg /100 g) and canned tuna (*Thunnus thynnus*) (1.3 mg/100 g) in the Ciqual food composition table [28] and the West African food composition table [29], respectively. This high iron content of smoked canned sardinella suggests the potential to contribute to the prevention and management of iron deficiency and anaemia in children and women of childbearing age in Senegal.

The results also showed that smoked canned sardinella contained 1.98 mg /100 g of zinc, 378 mg /100 g of potassium and 611 mg /100 g of calcium. These values for zinc, potassium and calcium were much higher than the 0.76 mg/100 g, 229 mg/100 g and 11 mg/100 g, respectively, found in canned tuna (*Thunnus thynnus*) [29]. Thus, the smoked canned sardinella may be a good source of these important minerals.

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Microbiological quality

Microbiological quality of fresh and smoked canned sardinella are shown in Table 2. The AMF value in the canned product was a concern, the heat treatment should have led to a greater reduction of CFU.

For thermotolerant coliforms, coagulase + staphylococci and salmonella the microbiological analysis showed that the fresh and smoked canned sardinella were not contaminated and met the standards of the Algerian Official Journal (JORA N°39/2017) for fishery and aquaculture products.

The AMF contamination in fresh sardinella was lower than 117 x10^5 CFU/g obtained by Kaffine *et al.* [30] with smoked horse mackerel or the 7.69 x 10^5 CFU obtained by M'handi [31] for sardine *(Sardina pilchardus*). For canned fish, the level of AMF contamination was higher than the results obtained by Dagnon *et al.* [32] who observed an absence of AMF in smoked tuna. With regard to thermotolerant coliforms, similar results were obtained by Kaffine *et al.* [30] and Degnon *et al.* [32] for smoked horse mackerel and smoked tuna, respectively. This level of contamination of these hygiene indicator pathogens shows compliance with good production practices and the effectiveness of sterilisation in reducing the microbial load. Staphylococci and salmonella as required by the regulations were absent for both fresh and smoked canned. Similar results were obtained by Lalami and Chadir [33] for canned tuna. This reflects both good quality raw material and the heat treatment.

Round sardinella are cited as one of the most spoilable seafood products due to their chemical composition that favours the proliferation of micro-organisms, which favors the proliferation of micro-organisms and enzymatic reactions [34]. This spoilage involves a range of chemical, physical and microbiological processes that can impact on nutritional, sanitary and sensory quality. Post-harvest losses of fish products due to the degradation of their organoleptic and nutritional quality in developing countries, particularly in Africa, have been estimated at over 70% [35]. Considered a fragile commodity, that is, highly degradable especially when handled at ambient temperature, rapid canning is a means of preserving round sardinella to extend their shelf life and also make them available to those without access to fresh fish.

Production yields for smoked canned sardinella

For the production yield, the results showed that 3 kg of fresh sardinella gave 0.88 kg of smoked sardinella fillet intended for the production of cans, that is, a production yield of 29.3%. This was lower than the 35% obtained by Ndiaye and Diei-Ouadi [36] 70 % by Cyprian *et al.* [37] and 78% by Asamoah [38] (78%) for smoked sardinella, smoked sardines and smoked Mackerel, respectively. This difference in yield could

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be linked to the species, the weight of the fish (larger fish give higher yields), the smoking time but also the smoking technique which is generally carried out on whole fish which are just gutted.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

Canning of gutted round sardinella is a way to valorise round sardinella, the fishing sector of the species and possibly revitalize the industry involved in the processing of sardinella. However, special attention should be given to the quality of the raw material and the processing conditions that may compromise the nutritional and health potential of these cans. Further studies on the effectiveness of heat treatment, the presence of chemical contaminants, and microbiological stability could be considered to improve the health quality and control the shelf life of canned smoked round sardinella.

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Conflict of interest

The authors have no conflicts of interest to declare

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Table 1: Proximate composition of fresh and canned smoked sardinella

Parameters	Fresh sardinella	Canned smoked sardinella	p-value	Significant
Water (%)	65.4± 0.01	58.1 ± 0.02	0.002	Yes
Protein (%)	22.5 ± 0.01	26.7 ± 0.03	<0.001	Yes
Carbohydrate (%)	0.05 ± 0,01	0.05 ± 0.01	1	No
Fat content (%)	10.1 ± 0.01	13.1 ± 0.1	<0.001	Yes
Ash (%)	2.15 ± 0.01	2.15 ± 0.01	0.842	No
Iron(mg/100g)	1.78 ± 0.01	2.51 ± 0.03	<0.001	Yes
Zinc (mg/100g)	4.8± 3.4	1.98 ± 0.02	0.452	No
Iodine (mg/kg)	0.03 ± 0.01	0.07 ± 0.01	0.003	Yes
Potassium (mg/100g)	398 ± 0.3	378 ± 0.3	<0.001	Yes
Calcium (mg/100g)	382 ± 0.3	611± 0.1	<0.001	Yes

Table 2: Microbiological content of fresh sardinella and canned smoked sardinella

Parameters	Fresh sardinella	Reference values	Canned smoked sardinella	Reference values
Aerobic Mesophilic Flora (AMF) (CFU/g)	5.8×10^3	$<10^6$	1.9×10^3	$<5.0 \times 10^3$
Thermotolerant coliforms (CFU/g)	<10	<10	<10	<10
Coagulase + staphylococci (CFU/g)	<10	$<10^2$	<10	$<10^2$
Salmonella (/ 25 g)	Absence	Absence	Absence	Absence

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