THE EFFECT OF THERMAL PROCESSING ON THE BIOCHEMICAL AND SENSORY ATTRIBUTES OF FISH

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ABSTRACT

The aim of this study was to develop and produce varieties of canned products from redfish and saithe fillets. Two different canning processes were used, not preheated and preheated, and the effect of these two canning processes was evaluated on the biochemical and sensory attributes of canned redfish and saithe fillets. Redfish fillets were canned in oil and brine (F0 6.52, 7.71) while saithe fillets were canned in oil and brine (F0 6.9, 8.6). Results showed that the protein content in the preheated canned redfish and saithe fillets in oil and brine was higher than the protein content in the not preheated canned redfish and saithe fillets in oil and brine. The protein content of preheated canned redfish fillets in oil and brine, canned saithe fillets in oil and brine was 17.4%, 16.8%, 18.5% and 17.6% respectively while the not preheated canned redfish fillets in oil and brine, canned saithe fillets in oil and brine had a protein content of 15.0%, 14.0%, 15.5% and 14.9% respectively. According to sensory evaluation, the preheated canned redfish and saithe fillets in oil and brine had a smoother texture than the not preheated canned redfish and saithe fillets in oil and brine.

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1. INTRODUCTION

Nigeria is a nation that depends solely on crude oil to drive its economy. The country has been doing well economically until recently, due to the crash in oil price globally. Agriculture has been identified as the key natural successor for growth beyond oil in Nigeria (PWC, 2016). Aquaculture is acknowledged as the fastest growing food production sector (FAO, 2016). This sector is a potential means of increasing the nation's fish production, to meet domestic needs. This is in line with the policy thrust of the Nigerian Federal Ministry of Agriculture and Rural Development on processing, to crowd private investments into the sector to deepen value addition and reduce waste (FMARD, 2016).

Fish is a major source of food for humans providing a significant portion of the protein intake in the diets of large proportion of people, particularly in developing countries like Nigeria. Nigeria is the largest fish consumer in Africa and among the largest fish consumers in the world with over 2.6 million tons of fish consumed annually (FMARD, 2013). Fish is said to be a cheap source of animal protein with little or no religious bias in terms of consumption, which gives it an advantage over other sources of protein, but fish is a very perishable commodity, and spoils more easily than other animal products. Therefore, unless measures are made immediately after harvest to preserve quality, fish will spoil rapidly leading to lost nutritional and economic value.

Fish processing methods currently used in Nigeria include chilling, freezing, drying, salting and smoking. However, the most affordable and widely used method of fish preservation is smoking. There are 160 registered fisheries product companies in the country, 29 of which are processing plants mainly for smoking of fish (FDF, 2017). Smoking of fish has been associated with some health problems such as ingestion of PAHs (Polycyclic Aromatic Hydrocarbons) which are carcinogenic and smoke inhalation during processing. There are currently no processing plants involved in the canning of fish in Nigeria, all the canned fish products in the country are imported from Ghana, Morocco and other countries.

The African catfish (*Clarias gariepinus*) and the tilapia (*Oreochromis niloticus*) are easily cultured in Nigeria and of great economic interest. They account for about 70% and 10% of aquaculture production in the country respectively (Atanda & Fagbenro, 2017). Nigeria with a current population estimated to be about 180 million has an annual demand of 2.6 million tonnes of fish. The local production is 800,000 tonnes and import about 800,000 tonnes of frozen fish, which adds up 1.6 million tonnes annually. This leaves a wide gap of about 1 million tonnes. The production of these species is becoming very popular in filling this wide gap for protein consumption in the country with some challenges especially with the marketing of medium sized or smaller fish. Smaller fish, about 40% of total production, are often smoked by farmers as means of preservation of raw materials and sold (Ikenweiwe *et al.* 2010). Introduction of canning as value addition can reverse the low profit margin of these fish farmers.

The canning process was developed to preserve food safely and for long periods of time. Once a food is packed into a can, the can is heated to an extreme temperature which kills all known microorganisms. However, this can become a viable solution to the problem of small or medium sized fish during production. This will introduce a higher quality and shelf stable product into the aquaculture market, and further expand the scope of the export market for foreign exchange. The development of canned fish products from these two commercially important species would substitute the sardines and such products imported into Nigerian market.

In this study, the fillets of redfish (*Sebastes marinus*) and saithe (*Pollachius virens*), two commercially important marine fish species in Iceland will be utilized for canning and then used as a reference for catfish and tilapia, the two commercially important freshwater fish species in Nigeria whose small sized or stunted size can be utilized for canning. Redfish and saithe are medium and lean fatty fish respectively that are similar to catfish and tilapia which are also medium and lean. Using fillets of redfish and saithe will inform ongoing experiments being carried out on the thermal processing of catfish and tilapia in Nigeria.

In a needs assessment study to determine the consumer acceptability of the canned fish products carried out across the geopolitical zones (south-south, south-east, south-west and north-central zones) in Nigeria in 2015, there were complaints about the dark skin of unfilleted canned catfish not been attractive, using fillets will fill up this gap.

1.1 Objectives

The aim of this project was to develop and produce varieties of canned products from redfish and saithe fillets using two different canning processes, not preheated and preheated. The objective is to investigate and evaluate the effects of these two different canning processes on the biochemical and sensory attributes of canned redfish and saithe fillets. The result of this study will be used as a reference for recommendations to fish processing plants in Nigeria on canned fish, with regards to biochemical properties and methods of sensory evaluation.

2. LITERATURE REVIEW

2.1 Thermal processing of fish

Processing of fish refers to the processes associated with fish and fish products between the time fish are caught or harvested and the time the final product is delivered to the customer. The central concern of fish processing is to prevent fish from deteriorating (FAO, 2005).

Thermal processing is a method of preserving food by heating in hermetically sealed containers to eliminate microbial pathogens at a given time and temperature. It was first done in the 18th century when Nicolas Appert packed food in wide mouth glass bottles, corked, heated and preserved them. However, it was in 1864, that Louis Pasteur made it clear that it was the heating process that killed the micro-organisms and extended shelf-life of food. Seafood was one of the first food types to be preserved by canning (Bitting, 1937).

In early 1918, aluminium alloy can for canning meat and fish products were introduced to replace tin containers due to the poor organoleptic qualities of foods packed in tin containers. These cans are now extensively used in European countries because of the availability of raw material and electricity and low production cost.

Metal cans are advantageous as packages due to availability in different sizes, their superior strength, high speed manufacturing and ease of filling and closing while the disadvantages are heavy weight, difficulty in reclosing and disposal. They are typically coated with an organic layer that protects the integrity of can from the effects of the food and prevents chemical reactions between the can's metal and the food. Acrylic and polyester coatings are currently used as first-generation alternatives to epoxy coatings and, more recently, polyolefin and non-BPA epoxy coatings were developed (LaKind, 2013).

To fulfil the technical and legal requirements, can coatings should withstand the production and sterilization processes, be universally applicable for all food and beverage types, prevent chemical migration into food in quantities that endanger human health, adhere to the can even after non-intentional deformation, resist aggressive food types and protect the metal of the cans, and preserve the food and maintain its organoleptic properties over several years (Whitaker, 2007).

2.2 F_0 value of canned products

The amount of heat treatment applied to a food product can be measured using the F-value-concept. This concept is practiced in canning plants, as part of HACCP System. The size and format of cans is of utmost importance for the speed of heat penetration. Temperatures to be achieved at the "cold point" of the can where the heat arrives last, are reached faster in small cans due to the shorter distance to the heat source than in large cans (Safefood, 2014).

Adequate thermal process lethality to kill the target organism should be given and the temperature at the cold spot which is the most inaccessible part of the food should be recorded by heat penetration (Banga *et al.* 1991). Time and temperature studies depend on characteristics of the product and container, geometry of the package and the type of heating medium.

Therefore, the F_0 value is the sterilization process equivalent to time, defined as the number of equivalent minutes at T= 121.1℃ delivered to a food container to make it commercially sterile and safe for consumption. Presently, the fish canning industry uses thermal processes that vary from F_0 = 2.5 minutes to F_0 = 20 minutes depending on the type of product and the technology used. Lower F_0 value yield microbial safe and shelf stable products without undue impairment of flavour, consistency, colour or nutrient content (Ababouch, 2000).

Sterilization is applied to food products that undergo no additional preservation regimes such as chilling or freezing and have no preservation ingredients added to the product (sugar, salt, vinegar, acid, alcohol, lemon juice etc.). The effect of preservatives on pH will generally govern whether a product should be pasteurized or sterilized.

Sterilization is in most cases applied to foodstuffs which are stored at room temperature after processing without additional preservation. Without secondary preservation, the most lethal bacterial threat is the anaerobic organism *Clostridium botulinum*. Sterilization is essential to kill such bacteria at source, for this reason, *Clostridium botulinum* is chosen as the ideal bacteria to model the effectiveness of a sterilization procedure.

For sterilization processes, the spore of *Clostridium botulinum* is used to quantify the lethality of bacterial kill as it is the most heat resistant pathogenic organism. At a temperature of 121.1℃, 90% of the spore population is killed in 0.21 minutes. This time is known as the decimal reduction time (Ababouch, 2000).

Decimal Reduction Time (DT) is the time in minutes required at constant heating to reduce the number of surviving spores by a factor of 10 (90% reduction in population) which is also referred to as one logarithmic reduction.

In food industry, it has been decided that for sterilization it is necessary that a minimum of 12 log (or decimal) reductions of *Clostridium botulinum* spore population be achieved. This requirement is quantified as:

F_0 = [N^o Decimal Reductions] [D_T]

Target F_0 for *Clostridium botulinum* = $12 \times D_{121.1} = 12 \times 0.21$ mins = 2.52 mins (~3)

In practice as a safety issue the minimum target F_0 value is doubled to 6.

2.3 Canning of Fish in Nigeria

Canning of fish in Nigeria started in the late 80s. This was pioneered by a company named Jobitex Foods. This company started by importing canned sardine from Portugal and distributing it all over Nigeria in the late 70s. They later started processing and producing canned sardines along with other canned foods such as canned jollof rice, beans, local soups such as egusi and edikaikan. The company was quite popular not only in the Nigerian market but in other West African markets as well. Jobitex Foods lasted only for a decade and by the late 90s the company collapsed due to unfavourable business environment and a government policy that seems to favour importation of canned fish.

In 1988, the Nigerian Institute for Oceanography and Marine Research, a Marine Research Institute under the Nigerian Federal Ministry of Agriculture and Rural Development pioneered the canning of Tuna, Bonga, Sardinella and drift fish (*ariomma spp*) in Nigeria. This was made possible when the Japanese government provided the Institute a fishing vessel (M.V. Sarkim Baka) and a pilot processing plant. Nigerian entrepreneurs wishing to invest in fisheries were presented with this viable economic proposition with immense opportunities for local and export earnings but the government (Military government) policy of the day was not favourable (Ajayi & Tobor, 1991).

In 2014, Nigerian Institute for Oceanography and Marine Research (NIOMR) acquired a modern multi-purpose fishery and oceanographic vessel, RV Bayagbona, designed and built by NAVIMOR International, Poland. The vessel is capable of harvesting 70 tonnes of fish such as drift fish (*ariomma spp*) which when canned can serve as a substitute for the imported canned sardines.

NIOMR pioneered the thermal processing of catfish and tilapia in January 2014. The Institute got a grant from the Forum for Agricultural Research in Africa (FARA) in 2014 on an "Innovation platform for canning and marketing of canned catfish". The goal of the grant was to process small size catfish, canned with tomato sauce and oil, carry out a needs assessment and launch canned catfish innovation platforms across the six geopolitical zones in Nigeria. These launches started in 2015 in collaboration with stakeholders in the aquaculture value chain and it is ongoing. The aim of setting up these platforms is to have a fish canning industry in each of the six geopolitical zones in the country, to increase animal protein consumption, create jobs and reduce importation of canned fish.

2.4 Nigerian Imports and Consumption of Canned fish

Nigeria imports all its canned fish products from across the world. Countries imported from include; Morocco, Ghana, China, Thailand, Spain, Australia, Ireland, India, Bangladesh, Belgium, France, Brazil, South Africa, Singapore and United Arab Emirates (MMF, 2012). The canned fish species imported include sardines, herring, tuna and mackerel. The import of canned fish has been increasing from 804MT in 2000 to 23,455MT in 2010 (Figure 1). It is estimated to be 75,000MT in 2017. Import of canned sardines accounts for about 20% of the overall import of canned fish into the country.

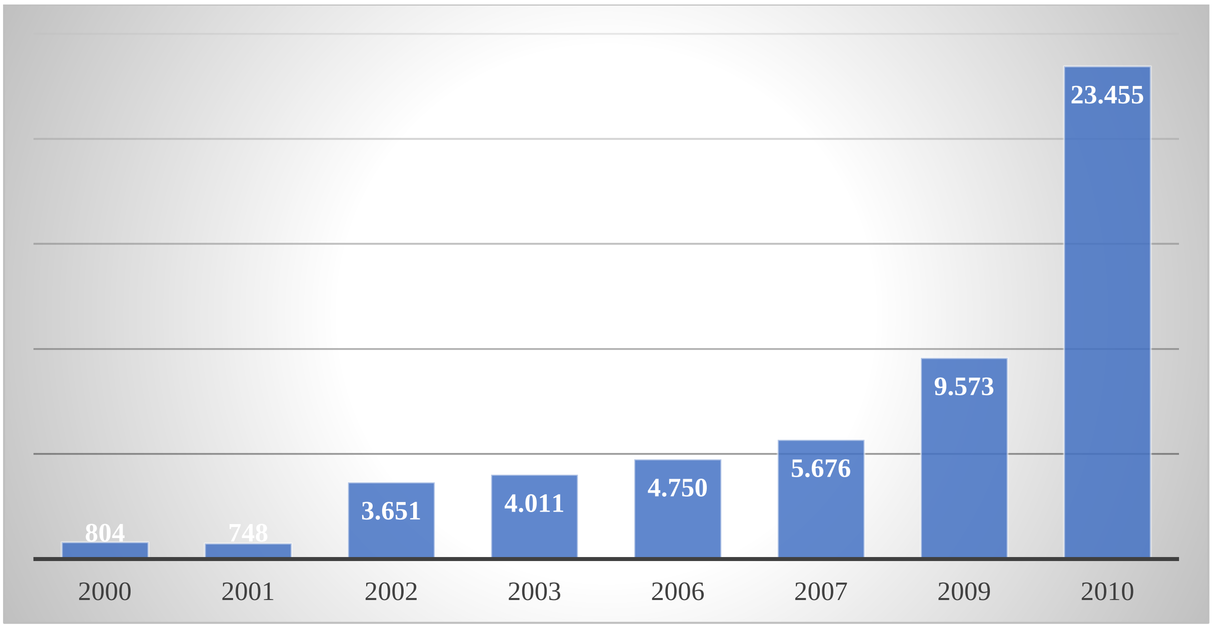

Figure 1. Imports of canned fish (tonnes) in Nigeria from 2000-2010
(Courtesy of the Moroccan Fishery Products Export on the World Market report.)

2.5 Quality changes during thermal processing

A major concern since the inception of the canning industry, is the effect of high temperature on the quality and nutrient retention in thermally processed food. Severe heat treatment and presence of certain catalysts in fish muscle favours lipid oxidation and hydrolysis resulting in off flavours and loss of nutrients. Heat treatment triggers browning (Millard reactions) which are a series of complex reactions between amino acids and sugars (Saguy & Karel, 1979).

2.5.1 Protein

Protein loss is mainly due to three possible reasons which are pre-cooking, diffusion into liquid and heat denaturation during thermal processing. It has been investigated that commercial thermal processing of canned fish products will not destroy significant amount of amino acids (Dunn *et al.* 1949). It was reported that a reduction of about 10-20% of the amino acids is in canned products. This decrease in amino acids in processed food is due to the heat sensitive nature of amino acids (Fellows, 1990).

Exposure to canning conditions do not significantly affect the dietary value of protein (Bender, 1972). Protein digestibility and available lysine are two recommended and frequently used indicators to assess the effects of heat treatment on the quality of food proteins. However, due to smaller level of available lysine in fish, the loss of lysine is less (Hurrel & Carpenter, 1977). It was found that there was only a small change in available lysine and protein digestibility in canned albacore subjected to heating in a batch steam retort (Seet & Brown, 1983).

2.5.2 Lipids

In marine fish, the lipid composition is highly unsaturated and hence oxidation during storage and processing is likely to occur, leading to quality loss (Pearson *et al.* 1977). However, normal processing procedure such as canning is unlikely to affect the nutritive value of oils adversely (Tarr, 1962). Lipid changes in cooked freshwater fish are least in fillets with high levels of lipids (Mai *et al.* 1978).

A general reduction in lipid content of canned and cooked foods with significant increase in free fatty acid (FFA) and phospholipids was noticed during canning of tuna while PUFA content did not vary with cooking or storage (Aubourg *et al.* 1990). A similar study on sardines showed a good deal of loss of fat during pre-cooking. Fatty acids were differently affected, with saturated fatty acid (SFA) and n-3 PUFA content increasing and a marked decrease in the MUFA and n-6 PUFA. Following sterilization there is a small intake of fat from the filling oil to fish and consequently an increase in lipid content in fillets but in fatty fish the fats diffuses into the fluid. During storage, a decrease in SFA and MUFA and an increase in n-3 PUFA and constancy in n-6 PUFA were noticed (Siriamornpun *et al.* 2008). Thermal processing resulted in an increase in free fatty acid content and in secondary oxidation in oil and brine canned sprat (Mahmood & Masoud, 2012).

2.5.3 Organoleptic quality

Fish muscle when subjected to heat treatment loses weight which can be attributed to denaturation. Excessive heating of fish can produce a toughening of texture. The breakdown of phospholipid and the production of free fatty acids in fish fillets were found to have a good relationship between protein denaturation and taste panel assessment of texture (Olley *et al.* 1969). Changes in texture are caused by loss of moisture, coagulation and hydrolysis of protein. Opacity of fish flesh increases during cooking due to thermal denaturation and precipitation of sarcoplasmic proteins.

The first quality impact by which consumers take a decision to purchase a product is its appearance, including colour. The most common type of discolouration are pigment degradation, browning reactions and oxidation of ascorbic acid. Free ribose accounts for much of the Maillard type of reaction when fish is heated in presence of carbohydrates. However, excessive heating produces considerable loss in the quality and organoleptic properties of foods (Hayakawa & Timbers, 1977).

Furthermore, these changes may be due to longer processing time employed for canned products to get equal lethality. Browning liquids are more intense in canned sardines processed for longer time than those with shorter processing time (Tanaka *et al.*1985). Retention of total colour can be used as a quality indicator to evaluate the extent of deterioration due to thermal processing. Salmon muscle colour whiten in the first 10 min of treatment followed by browning as heating progressed (Kong *et al.* 2007).

2.6 Microbial Safety of thermal processed products

Several reasons are responsible for microbial spoilage in thermally processed food, the important among them being, inadequate pre-processing, under processing, inadequate cooling and leaker infection (Frazier & Westhoff, 1998). To ensure commercial sterility, low acid foods are thermally processed. For maintaining sterility, primarily the container should be hermetically sealed, and the seal integrity should be guaranteed (Lopez, 1987).

A hygienic post-process treatment should be carried out and the products should be stored adequately. Thermal processed products should be stored at ambient temperature much below 30°C to prevent the outgrowth of thermophilic spores which may have survived the processing. The effect of storage temperature and storage time also are very important for fish products preserved in sauces which are acidic in nature and have corrosive action on the containers used (Lopez, 1987).

Safety of a sterilization process can be evaluated according to the lethality achieved and the microbiological risk alteration of the target microorganisms that survive the thermal treatment. Heat processing or sterilization is the most critical step during the manufacture of canned products that ensures the sterility of the product (Aubourg, 2001).

2.7 Product development: canning of redfish fillets and saithe fillets

The dietary habit all over the world and to the consumer preferences for fishery products could bring considerable structural changes in the fish processing industry. There is growing demand for "ready to cook" or "ready to serve" type fishery products, hygienically prepared and attractively packed convenience foods to match the changing needs of urban population. The fishery trade depends on optimization of raw material to produce higher percentage of value added products especially, processing of fish into a wide variety of products. One of such “ready to eat” fishery products is canned fish.

3. MATERIALS AND METHODS

3.1 Production of canned redfish fillets and saithe fillets

A canning process employed in Iceland where the fish in the cans are not preheated before sterilization and another canning process employed in Nigeria where the fish in the cans are preheated prior to sterilization were tested. Varieties of the canned redfish and saithe fillets will be produced in different packing medium such as in oil, in brine, in oil with smoke powder and in brine with smoke powder.

Twenty kilograms each of redfish and saithe fillets was purchased from HB Grandi, a fishing company in Reykjavik, Iceland. 115 g of fillets was weighed into sterilized cans. Oil (20 ml), brine (1%, 15 ml) and smoke powder (0.9 g) for six different varieties of canned products for each fish species was used as packing medium. Preheating was done at a temperature of 114°C for 15 minutes in an oven. Sterilization was performed at a temperature of 114°C for 40 minutes in an autoclave. Prior to sterilization, heat loggers were mounted in the center of the cans before sealing to determine the F_0 value (Figure 4).

Control of temperature and time of sterilization is essential to ensure the absence of undesirable microorganisms, such as *Clostridium botulinum*. Once sterilization was complete, cooling of canned products followed for thermal shock against unwanted microorganisms and the products quarantined for 14 days to ensure they have been processed correctly. The fish fillets were subjected to two different canning processes at a pilot processing plant at Matis Ltd, an Icelandic Food and Biotechnology Research and Development company in Reykjavik (Figure 2).

The varieties of canned fish fillets that will be developed and produced include: redfish fillets in oil not preheated, redfish fillets in oil preheated, redfish fillets in oil with smoke powder, redfish fillets in brine not preheated, redfish fillets in brine preheated, redfish fillets in brine with smoke powder, saithe fillets in oil not preheated, saithe fillets in oil preheated, saithe fillets in oil with smoke powder, saithe fillets in brine not preheated, saithe fillets in brine preheated and saithe fillets in brine with smoke powder (Figure 3).

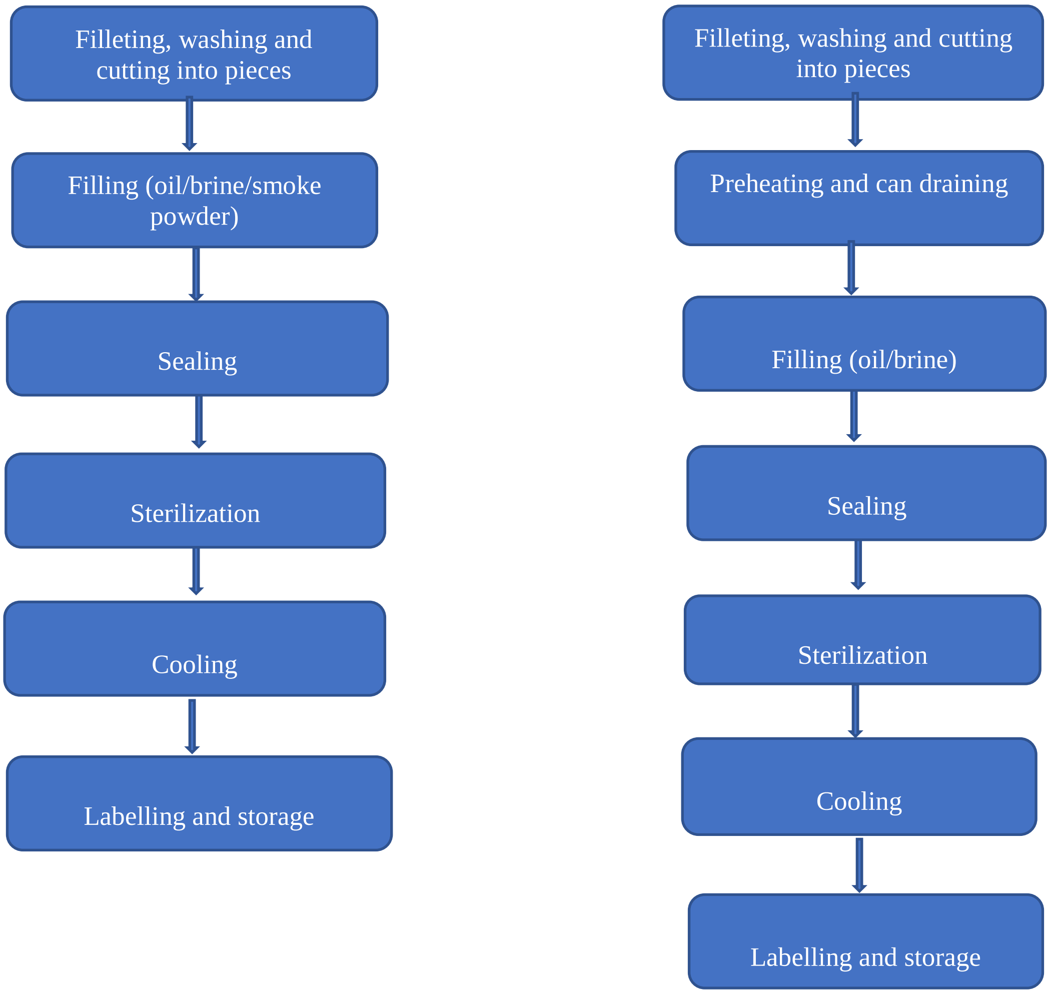

Figure 2. Flow chart of two different canning process

Redfish fillets in oil not preheated (RONP)	Redfish fillets in oil preheated (ROP)	Redfish fillets in oil with smoke powder (ROS)	Redfish fillets in brine not preheated (RBNP)	Redfish fillets in brine preheated (RBP)	Redfish fillets in brine with smoke powder (RBS)
Saithe fillets in oil not preheated (SONP)	Saithe fillets in oil preheated (SOP)	Saithe fillets in oil with smoke powder (SOS)	Saithe fillets in brine not preheated (SBNP)	Saithe fillets in brine preheated (SBP)	Saithe fillets in brine with smoke powder (SBS)

Figure 3. The 12 varieties of canned fish fillets produced

3.2 Determination of F_0 value for canned products

Temperature and time of sterilization was measured using heat loggers (by Maxim Integrated Products [model DS1922E]) with probes mounted in the center of the canned fish product and the F_0 value was calculated [$F_0 = T\text{-}121.1/10$ where T is temperature] (Figure 4).

Figure 4. Heat loggers mounted in the centre of canned fish products

3.3 Chemical evaluation

3.3.1 Protein content

Protein was determined by Kjeldahl method. The organic matter was digested by sulphuric acid in the presence of a catalyst. The reaction product was rendered alkaline, then the liberated ammonia was distilled and titrated with hydrochloric acids (ISO, 2005).

3.3.2 Lipid content

The sample was extracted with petroleum ether, boiling range 40-60°C. The extraction apparatus was 2050 Soxtec Avanti Automatic System (AOCS, 2017).

3.3.3 Moisture content

The sample was heated in the oven at 103°C+/-2°C for four hours. The percentage of moisture was calculated, and this corresponds to the weight loss (ISO, 1999).

3.3.4 Ash content

The sample was heated at 550°C in a furnace for 3 hours, and the residue weighed. The percentage of ash was calculated (ISO, 2002).

3.3.5 Sodium Chloride content

The salt content of the fresh and canned fish samples was determined by weighing 5g of sample into the extraction bottle, 200 ml of deionised water was added, mixed using the shaker for 50 minutes. 20 ml of nitric acid was then added to 20 ml of the supernatant and titrated with silver nitrate (AOAC, 2000).

3.4 Sensory evaluation

The aim of the evaluation was to describe the sensory characteristics of canned redfish and saithe fillets processed in six ways. Sensory evaluation of canned redfish and saithe was carried out at Matís. Six processing methods for both species were tested. Four trained panelists participated in the evaluation (ISO, 2014). They were instructed to describe the odour, appearance, flavour and texture of two samples of canned fish for each sample group, first individually and then the descriptions were discussed to reach a consensus on the results. The panelists were not given any information on the samples prior to the evaluation.

4. RESULTS

4.1 Canned fish products

Total of 144 cans of fish were processed with 12 varieties of canned redfish and saithe fillets (six varieties each). The average weight of each can was 128 g (net weight) and 88 g (drained weight). These 12 varieties of canned fish products are shown in Appendix I.

4.2 F_0 value for canned products

4.2.1 F_0 value for canned redfish fillets

The F_0 value for canned redfish fillets in brine was 7.71 while for canned redfish fillets in oil was 6.52 (Figure 5). The result was the mean of two F_0 values for canned redfish fillets in brine (F_0-brine 1 and F_0-brine 2) and canned redfish fillets in oil (F_0-oil 1 and F_0-oil 2). It was observed that the F_0 value in canned redfish fillets in brine (7.71) was higher than in canned redfish fillets in oil (6.52).

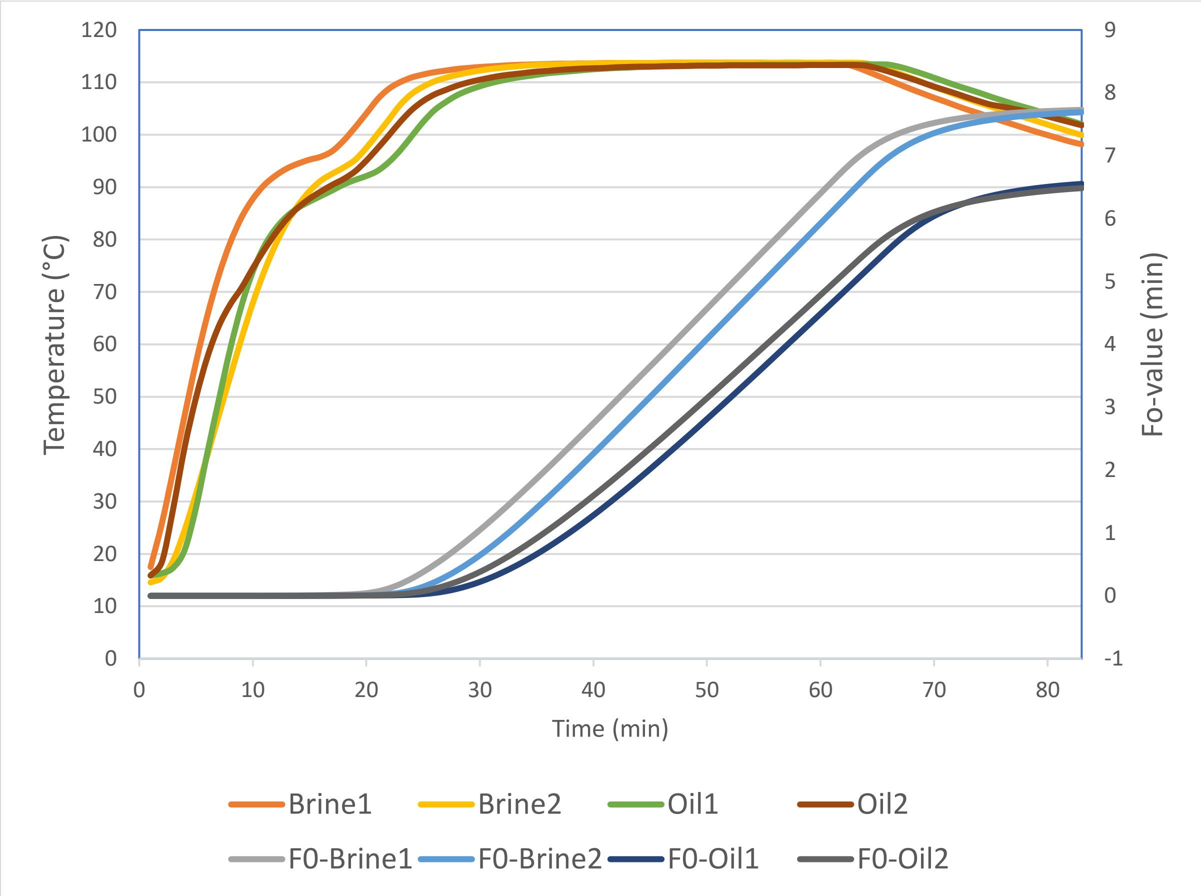

Figure 5. Chart showing the F_0 value for canned redfish fillets in brine and oil

4.2.2 F_0 value for canned saithe fillets

The F_0 value for canned saithe fillets in oil was 6.9 (F_0-oil 1) while for canned saithe fillets in brine was 8.6 (F_0-brine 1) (Figure 6). It was observed that the F_0 value for canned saithe fillets in oil (6.9) was lower than in canned saithe fillets in brine (8.6).

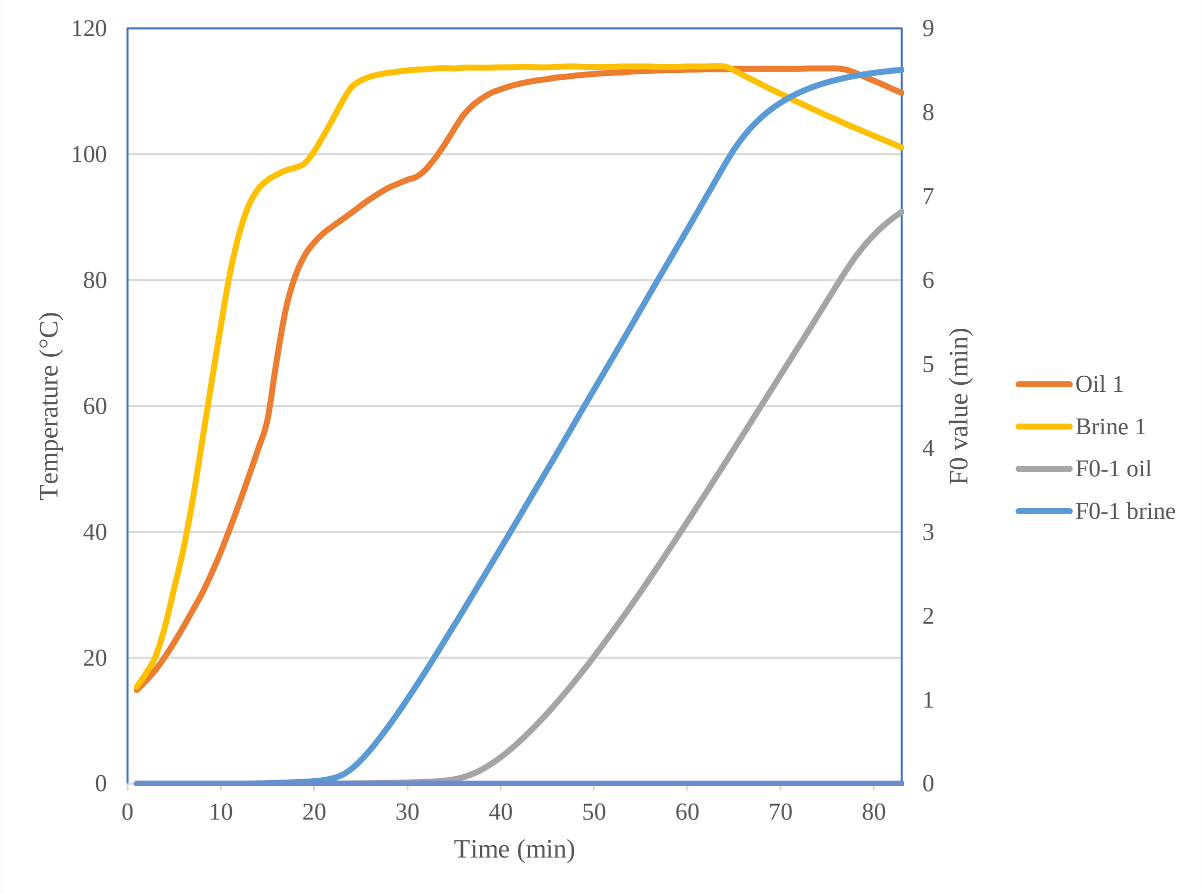

Figure 6. Chart showing the F_0 value for canned saithe fillets in oil and brine

4.3 Chemical evaluation of canned products

Changes in the proximate composition of the raw fish fillets to the canned fish fillets with a packing medium of oil and brine processed in two different ways was observed. There were differences in the protein, lipid, moisture, ash and salt content of the not preheated canned fish products compared to the preheated canned fish products (Table 1-5).

4.3.1 Protein content of canned products

The protein content of the raw redfish and saithe fillets with their canned fillets from the two canning methods was determined (Table 1).

The protein content of raw redfish fillets was 17.2% but decreased to 15.0% in canned redfish fillets in oil not preheated (RONP) while it increased to 17.4% in canned redfish fillets in oil preheated (ROP). In canned redfish fillets in brine not preheated (RBNP), it was 14.0% but was 16.8% in canned redfish fillets in brine preheated (RBP). The protein content of raw saithe fillets was 18.9% but decreased to 15.5% in canned saithe fillets in oil not preheated (SONP) while it increased to 18.5% in canned saithe fillets in oil preheated (SOP). In canned saithe fillets in brine not preheated (SBNP), it was 14.9% but was 17.6% in canned saithe fillets in brine preheated (SBP).

Table 1. Protein content (%) of raw redfish and saithe fillets with their canned fillets from the two canning methods.

Protein content (%)			
Raw redfish fillets	**17.2**	**Raw saithe fillets**	**18.9**
Redfish fillets in oil not preheated (RONP)	**15.0**	**Saithe fillets in oil not preheated (SONP)**	**15.5**
Redfish fillets in oil preheated (ROP)	**17.4**	**Saithe fillets in oil preheated (SOP)**	**18.5**
Redfish fillets in brine not preheated (RBNP)	**14.0**	**Saithe fillets in brine not preheated (SBNP)**	**14.9**
Redfish fillets in brine preheated (RBP)	**16.8**	**Saithe fillets in brine preheated (SBP)**	**17.6**

4.3.2 Lipid content of canned products

The lipid content of the raw redfish and saithe fillets with their canned fillets from the two canning methods was determined (Table 2).

The lipid content of raw redfish fillets was 4.7% but increased to 18.9% in canned redfish fillets in oil not preheated (RONP) while it also increased to 19.7% in canned redfish fillets in oil preheated (ROP). In canned redfish fillets in brine not preheated (RBNP), it was 7.6% but was 4.1% in canned redfish fillets in brine preheated (RBP). The lipid content of raw saithe fillets was 0.9% but increased to 14.8% in canned saithe fillets in oil not preheated (SONP) while it also increased to 15.6% in canned saithe fillets in oil preheated (SOP). In canned saithe fillets in brine not preheated (SBNP), it was 0.6% but was 1.3% in canned saithe fillets in brine preheated (SBP).

Table 2. Lipid content (%) of raw redfish and saithe fillets with their canned fillets from the two canning methods.

Lipid content (%)			
Raw redfish fillets	**4.7**	**Raw saithe fillets**	**0.9**
Redfish fillets in oil not preheated (RONP)	**18.9**	**Saithe fillets in oil not preheated (SONP)**	**14.8**
Redfish fillets in oil preheated (ROP)	**19.7**	**Saithe fillets in oil preheated (SOP)**	**15.6**
Redfish fillets in brine not preheated (RBNP)	**7.6**	**Saithe fillets in brine not preheated (SBNP)**	**0.6**
Redfish fillets in brine preheated (RBP)	**4.1**	**Saithe fillets in brine preheated (SBP)**	**1.3**

4.3.3 Moisture content of canned products

The moisture content of the raw redfish and saithe fillets with their canned fillets from the two canning methods was determined (Table 3).

The moisture content of raw redfish fillets was 77.5% but decreased to 65.3% in canned redfish fillets in oil not preheated (RONP) while it also decreased to 61.2% in canned redfish fillets in oil preheated (ROP). In canned redfish fillets in brine not preheated (RBNP), it was 77.3% but was 78.9% in canned redfish fillets in brine preheated (RBP). The moisture content of raw saithe fillets was 78.7% but decreased to 68.4% in canned saithe fillets in oil not preheated (SONP) while it also decreased to 64.4% in canned saithe fillets in oil preheated (SOP). In canned saithe fillets in brine not preheated (SBNP), it was 83.5% but was 80.6% in canned saithe fillets in brine preheated (SBP).

Table 3. Moisture content (%) of raw redfish and saithe fillets with their canned fillets from the two canning methods.

Moisture content (%)			
Raw redfish fillets	**77.5**	**Raw saithe fillets**	**78.7**
Redfish fillets in oil not preheated (RONP)	**65.3**	**Saithe fillets in oil not preheated (SONP)**	**68.4**
Redfish fillets in oil preheated (ROP)	**61.2**	**Saithe fillets in oil preheated (SOP)**	**64.4**
Redfish fillets in brine not preheated (RBNP)	**77.3**	**Saithe fillets in brine not preheated (SBNP)**	**83.5**
Redfish fillets in brine preheated (RBP)	**78.9**	**Saithe fillets in brine preheated (SBP)**	**80.6**

4.3.4 Ash content of canned products

The ash content of the raw redfish and saithe fillets with their canned fillets from the two canning methods was determined (Table 4).

The ash content of raw redfish fillets was 1.0% but increased insignificantly to 1.1% in canned redfish fillets in oil not preheated (RONP) while it also increased to 1.4% in canned redfish fillets in oil preheated (ROP). In canned redfish fillets in brine not preheated (RBNP), it was 0.9% but was 1.0% in canned redfish fillets in brine preheated (RBP). The ash content of raw saithe fillets was 1.0% but increased to 1.3% in canned saithe fillets in oil not preheated (SONP) and also 1.3% in canned saithe fillets in oil preheated (SOP). In canned saithe fillets in brine not preheated (SBNP), it was 1.1% but was 1.0% in canned saithe fillets in brine preheated (SBP).

Table 4. Ash content (%) of raw redfish and saithe fillets with their canned fillets from the two canning methods.

Ash content (%)			
Raw redfish fillets	**1.0**	**Raw saithe fillets**	**1.0**
Redfish fillets in oil not preheated (RONP)	**1.1**	**Saithe fillets in oil not preheated (SONP)**	**1.3**
Redfish fillets in oil preheated (ROP)	**1.4**	**Saithe fillets in oil preheated (SOP)**	**1.3**
Redfish fillets in brine not preheated (RBNP)	**0.9**	**Saithe fillets in brine not preheated (SBNP)**	**1.1**
Redfish fillets in brine preheated (RBP)	**1.0**	**Saithe fillets in brine preheated (SBP)**	**1.0**

4.3.5 Sodium Chloride content of canned products

The salt content (sodium chloride) of the raw redfish and saithe fillets with their canned fillets from the two canning methods was determined (Table 5).

The salt content of raw redfish fillets was 0.3% but increased to 0.6% in canned redfish fillets in oil not preheated (RONP) while it also increased to 0.8% in canned redfish fillets in oil preheated (ROP). In canned redfish fillets in brine not preheated (RBNP), it was 0.4% and also 0.4% in canned redfish fillets in brine preheated (RBP). The salt content of raw saithe fillets was 0.3% but increased to 0.6% in canned saithe fillets in oil not preheated (SONP) also increased to 0.6% in canned saithe fillets in oil preheated (SOP). In canned saithe fillets in brine not preheated (SBNP), it was 0.4% and also 0.4% in canned saithe fillets in brine preheated (SBP)

Table 5. Sodium chloride (salt) content (%) of raw redfish and saithe fillets with their canned fillets from the two canning methods.

Salt content (%)			
Raw redfish fillets	**0.3**	**Raw saithe fillets**	**0.3**
Redfish fillets in oil not preheated (RONP)	**0.6**	**Saithe fillets in oil not preheated (SONP)**	**0.6**
Redfish fillets in oil preheated (ROP)	**0.8**	**Saithe fillets in oil preheated (SOP)**	**0.6**
Redfish fillets in brine not preheated (RBNP)	**0.4**	**Saithe fillets in brine not preheated (SBNP)**	**0.4**
Redfish fillets in brine preheated (RBP)	**0.4**	**Saithe fillets in brine preheated (SBP)**	**0.4**

4.4 Sensory evaluation of canned products

The panels' detailed descriptions of the twelve varieties of canned fish is shown in Appendix II. The summary of their descriptions is given below:

The canned redfish (not smoke flavoured) generally had a weak flavour. The brine samples were characterised by a canned fish odour, a trace of odour and flavour of dried fish, and a trace of paint odour (not rancid). The redfish in oil had no dried fish flavour or rancid flavour. It had a slightly sweet oil odour and less paint and dried fish odour than the brine samples.

Canned saithe in brine had a canned fish odour and the preheated samples had some dried fish odour and flavour. Two panellists detected a TMA like off flavour in the preheated samples. Samples of saithe in oil had less dried fish flavour and had no dried fish odour. The smoke flavoured fish, both redfish and saithe, had a mild smoke odour and flavour which masked, at least to some extent, dried fish odour and flavour of the fish. The smoke flavoured samples were generally saltier than other samples.

Using oil instead of brine generally lessened the dried fish odour and flavour of the fish and made the fish slightly less stiff and dry. Preheating the fish did not seem to have a big effect on its odour or flavour. There however might be some effect of preheating on the texture. The preheated redfish samples seemed to be slightly less dry than the non-preheated samples. The apparent effect on saithe was different since the preheating seemed to result in more mealy texture of the saithe.

All samples were very stiff and dry but fish in oil a little less than fish in brine. Most of the smoked flavoured samples were however less stiff and dry. They also had a mild smoke flavour and salty flavour which seemed to mask off notes detected in other samples. The salty taste indicates more salt content in the smoked samples which could improve the water holding capacity of the samples and result in softer and juicier fish. None of the cans were filled to the top with liquid (brine or oil). The fish which was not covered in liquid tended to be stiffer than fish covered in liquid.

5. DISCUSSION

5.1 F_0 value of canned products

In the fish canning industry, a sterilization process is effective when $F_{0\ 121} = 2.5$. The F_0 value at this temperature (121°C) and time (2.5 minutes) ensures that there is a twelve (12) log reductions in the spore population of *Clostridium botulinum* which is the most heat resistant pathogenic organism present in the canned fish. Canned fish subjected to such treatment are stable at ambient temperatures and therefore considered commercially sterile.

In the present study, the F_0 value for canned redfish fillets in oil and brine was 6.52 and 7.71 respectively while the F_0 value for canned saithe fillets in oil and brine was 6.9 and 8.6 respectively (Figure 5 and 6). It was observed that the F_0 value in both species where the packing medium was oil (6.52 and 6.9 respectively) was lower compared to when the packing medium was brine (7.71 and 8.6 respectively). Oil serves as an insulator and slows down heat penetration compared to brine hence the difference in their F_0 values (Ansar *et al.* 2005).

This result compares with a study carried out by Ansar *et al.*, (2005) on the canning of sardine at different lethality values of F_0 5, 7 and 9 in retort pouches and aluminum cans. In a similar study, an F_0 value of 7 minutes was used when assessing the fatty acid composition of yellowfin tuna (*Thunnus albacares*) and sardine (*Sardina pilchardus*) canned in three different ways in brine, sunflower oil and olive oil (Mesias *et al.* 2015). The result obtained falls within the limit of F_0 5 to 20 recommended for fish and fish products (Frott & Lewis, 1994).

5.2 Chemical evaluation of canned products

The protein content in raw redfish and saithe fillets was 17.2% and 18.9% respectively but decreased after not-preheated canning of fillets of both species in oil and in brine while it increased in the preheated canning of fillets of both species in oil and in brine. These results show that the preheated canned redfish and saithe fillets in both packing medium had a higher protein content than the not preheated canned redfish and saithe fillets. Similar observation was made in the protein content of thermally modified tilapia (Dhanya *et al.* 2010) and in variation in the quality of raw and canned Indian mackerel (George, 1987). This increase in protein content may be due to the reduction in water content during thermal processing in the preheating process that involves draining of water from the preheated fish which may have concentrated the protein in the fish.

The lipid content of redfish and saithe fillets before canning was 4.7% and 0.9% respectively. An increase in the lipid content was observed in both the not preheated and preheated canned redfish and saithe fillets in oil but slightly more in the preheated canned fish products, this is probably due to the oil used in the cans. There was just a slight difference in the lipid content of both the not preheated and preheated canned redfish and saithe fillets in brine. This increase in lipid content could be attributed to reduction in moisture content. It was reported that there was an increase in lipid content in a study on the utilization of tilapia by canning and also in studies on the canning of pink perch (Santha, 2004; Suresh, 1984).

The moisture content of redfish and saithe fillets before canning was 77.5% and 78.7% respectively, their moisture content decreased in both the not preheated and preheated canned redfish and saithe fillets in oil, though the reduction was more in the preheated canned redfish and saithe fillets. This could be attributed to changes during heating decreasing the water holding capacity of the fish muscle and as a result muscle loses its tenderness (Devadasan, 2001). In contrast, the moisture content increased in both the not preheated and preheated canned redfish and saithe fillets in brine. The later result, an increase in moisture content, contrasts with a similar study on brine packed mackerel and pink perch whose moisture content decreased from 70.22% for mackerel and 75.55% for pink perch to 68.01% and 75.10% respectively (Naik *et al.* 2014).

The ash content of redfish and saithe fillets before canning was 1.0% for both species. There was a slight but insignificant increase in the not preheated and the preheated canned redfish and saithe fillets in oil and in brine.

The salt content of redfish and saithe fillets before canning was 0.3% for both species. There was an increase in the not preheated and the preheated canned redfish and saithe fillets in oil but a slight insignificant increase in the not preheated and the preheated canned redfish and saithe fillets in brine.

5.3 Sensory evaluation of canned products

The canned redfish and saithe fillets in brine were all characterized by a canned fish odour, a trace of odour and flavour of dried fish, and a trace of paint odour (not rancid) while the canned redfish and saithe fillets in oil were all characterised by no dried fish flavour or rancid flavour, it had a slightly sweet oil odour and less paint and dried fish odour than the brine samples. It was observed that using oil as the packing medium instead of brine lessened the dried fish odour and flavour of the fish and made the fish slightly less stiff and dry. The canned redfish and saithe fillets in oil and in brine with smoke powder were all characterized by a mild smoke odour and flavour which masked, at least to some extent, the dried fish odour and flavour of the fish. This will be quite interesting for consumers of fish in Nigeria who are used to the smoke flavour in smoked fish.

Preheating does not seem to have any effect on the odour and flavour of the canned fish products, but it seems to have some effect on the texture. It was observed that preheated canned redfish fillets were slightly less dry than the not preheated canned redfish fillets while the preheated canned saithe fillets had a mealier texture than the not preheated canned saithe fillets.

This could also be attributed to the low F_0 value that has been reported to yield canned products without undue impairment of flavour, texture, consistency, colour or nutrient content (Ababouch, 2000). Research has also shown that when accurate time and temperature conditions are employed during thermal processing, the retention of most of the fish constituents remains at an acceptable level provided high quality raw material is employed.

6. CONCLUSIONS

This research shows that different canning processes influence the nutrient content and sensory attributes of canned redfish and saithe fillets. The protein content of the preheated canned redfish and saithe fillets in oil and in brine was higher than the not preheated canned redfish and saithe fillets in oil and in brine. The preheated canned redfish and saithe fillets had a smoother texture than the not preheated canned redfish and saithe fillets. The low F_0 value may have contributed to the retention to an acceptable level of most of the fish constituents and sensory attributes.

7. RECOMMENDATIONS

- This research needs to be replicated in Nigeria using catfish and tilapia.
- Precooking or preheating before sterilization seems to be an ideal process for canning.
- To enable proper filling of cans with fish and allow the packing medium of oil or brine to cover the fish and be evenly distributed, I recommend testing flakes of fish for canning against fillets.

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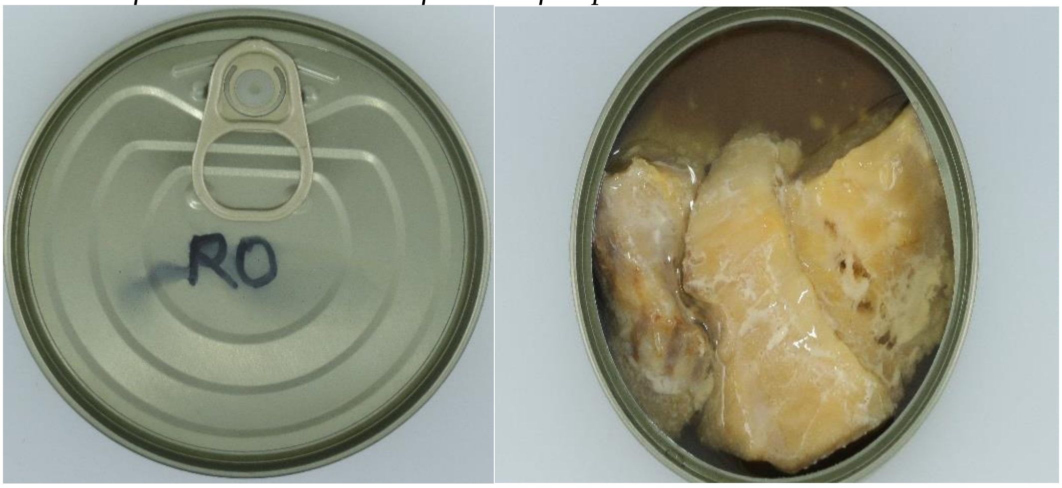
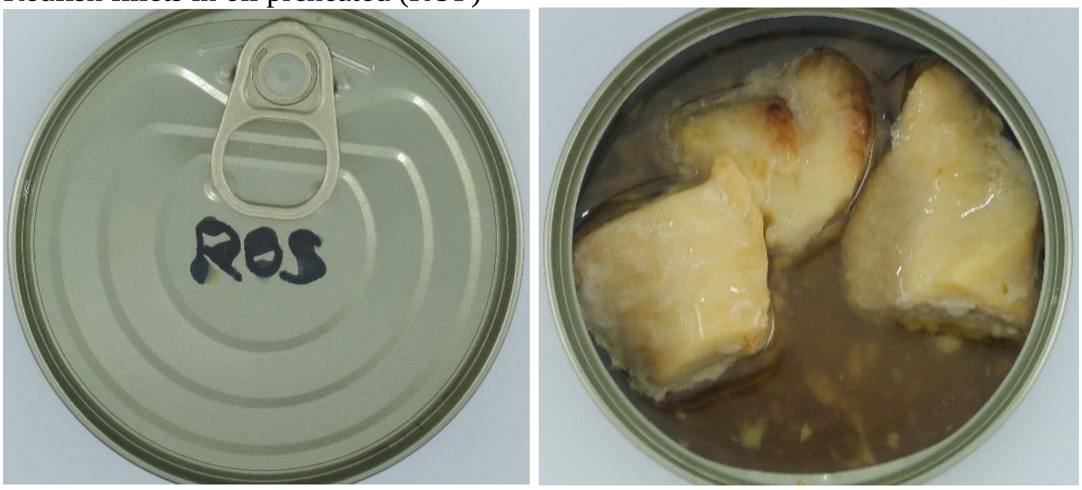
APPENDIX I

Pictures of the twelve varieties of canned fish products

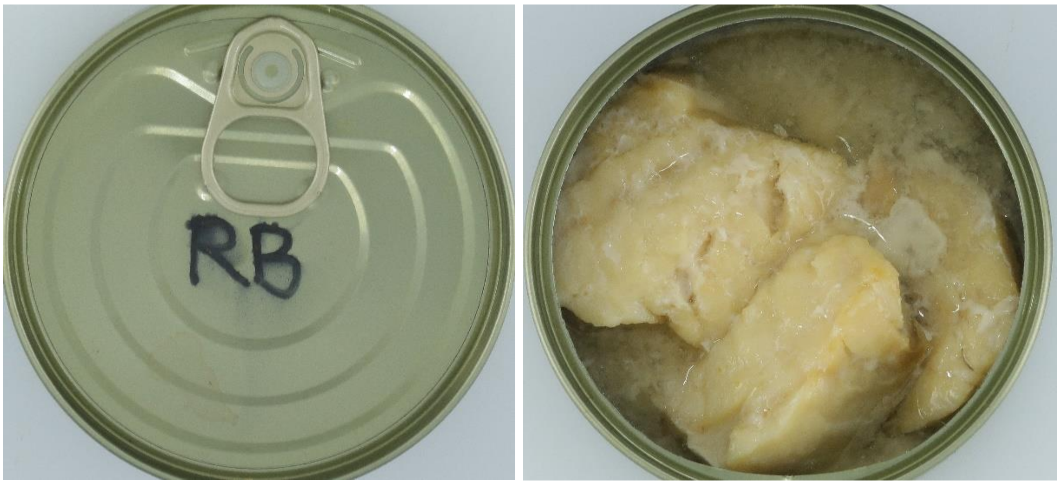


Redfish fillets in oil not preheated (RONP)

Redfish fillets in oil preheated (ROP)

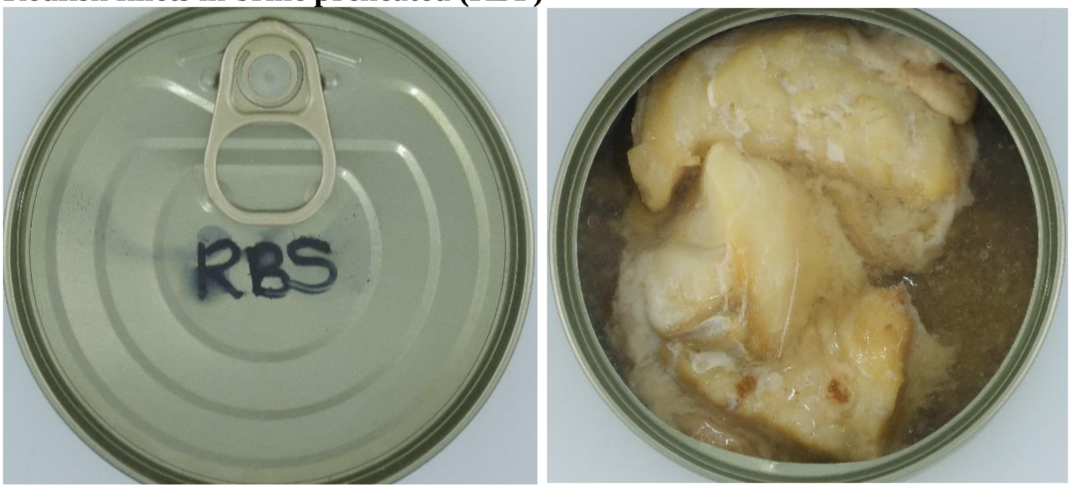


Redfish fillets in oil with smoke powder (ROS)

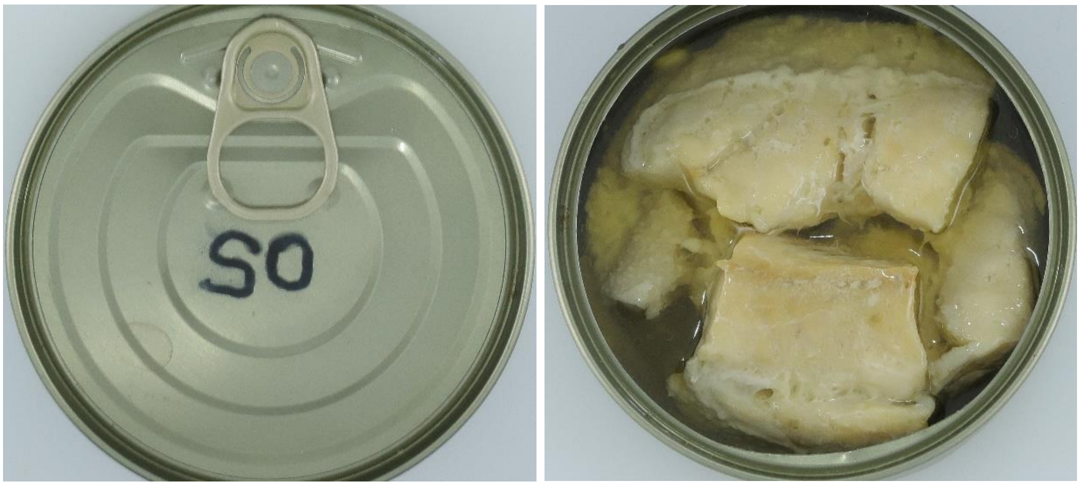


Redfish fillets in brine not preheated (RBNP)

Redfish fillets in brine preheated (RBP)



Redfish fillets in brine with smoke powder (RBS)



Saithe fillets in oil not preheated (SONP)

Saithe fillets in oil preheated (SOP)

Saithe fillets in oil with smoke powder (SOS)

Saithe fillets in brine not preheated (SBNP)

Saithe fillets in brine preheated (SBP)

Saithe fillets in brine with smoke powder (SBS)

APPENDIX II

Panels' description of the twelve varieties of canned fish products

Sensory characteristics of redfish fillets in oil not preheated (RONP)

Characteristics	Description
Odour	Oil odour, slightly sweet, canned fish odour.
Appearance	More fish covered, compared to the brine samples.
Flavour	Rather flavourless, less flavour of dried fish than in the brine samples, slightly sweet.
Texture	Very stiff and dry but less dry than the brine samples. The fish standing out of the oil is stiffer than fish covered in oil.

Sensory characteristics of redfish fillets in oil preheated (ROP)

Characteristics	Description
Odour	Some paint odour (not rancid), more in the can with less oil.
Appearance	Different amount of fish in the two cans. Less oil than in RONP. Some dark stains.
Flavour	Similar to group RONP but maybe a little stronger flavour and saltier, no dried fish flavour.
Texture	Very stiff but a little less dry than group RONP.

Sensory characteristics of redfish fillets in brine not preheated (RBNP)

Characteristics	Description
Odour	Different odour from the cans, canned fish odour, a trace of dried fish and paint odour (but not rancid).
Appearance	Very different appearance between cans, red brown spots in one can, cans not full.
Flavour	Very weak flavour, a trace of dried fish flavour and bitter, a small trace of rancid flavour.
Texture	Very stiff and dry.

Sensory characteristics of redfish fillets in brine preheated (RBP)

Characteristics	Description
Odour	Paint (not rancid), metallic.
Appearance	Cans only half filled, fish not covered in brine looks dry, some dark spots.
Flavour	Dried fish flavour, a trace of rancid flavour.
Texture	Very stiff and dry, perhaps slightly less dry than RBNP.

Sensory characteristics of redfish fillets in oil with smoke powder (ROS)

Characteristics	Description
Odour	Oil odour most apparent, a trace of smoke odour.
Appearance	To little liquid. Fish stands out of liquid.
Flavour	A moderate salty flavour, oil, a trace of metallic flavour and smoke flavour as aftertaste, no dried fish flavour or other off-flavour.
Texture	Stiff in first bite but less dry and mealy than group RBS.

Sensory characteristics of redfish fillets in brine with smoke powder (RBS)

Characteristics	Description
Odour	Smoke odour, some difference between cans.
Appearance	To little liquid. Fish stands out of liquid.
Flavour	Slight smoke flavour, some difference between bites and/or cans, dried fish, slightly sour but smoke flavour masks other flavour to some extent.
Texture	Stiff in first bite, dry and mealy.

Sensory characteristics of saithe fillets in oil not preheated (SONP)

Characteristics	Description
Odour	Oil odour, slightly sweet and sour, metallic odour, no dried fish odour.
Appearance	Different amount of fish and oil in the two cans. More oil than was of brine in the brine samples.
Flavour	Weak dried fish flavour, sour flavour, oil flavour, bitter aftertaste, slightly saltier then the previous saithe samples.
Texture	Stiff and dry but softer and less dry than SBNP.

Sensory characteristics of saithe fillets in oil preheated (SOP)

Characteristics	Description
Odour	Similar to SONP, a weak frying odour.
Appearance	Can is not filled with fish and oil.
Flavour	Very similar to SONP but less bitter aftertaste.
Texture	Stiff and dry but more mealy texture than of SONP.

Sensory characteristics of saithe fillets in brine not preheated (SBNP)

Characteristics	Description
Odour	Fish odour, odour of cold fish which has be stored for some time (not spoiled odour).
Appearance	Very little fish and liquid in the cans. Some amount of precipitations in the liquid.
Flavour	Some dried fish flavour, trace of bitter, very little salt.
Texture	Very stiff and very dry but less dry than the RBNP.

Sensory characteristics of saithe fillets in brine preheated (SBP)

Characteristics	Description
Odour	Canned fish, metallic, slight dried fish odour.
Appearance	More of fish than in SBNP, the brown muscle is very dark.
Flavour	Dried fish, a trace of bitter, two panellists detected an off-flavour (TMA like).
Texture	Very stiff, very dry and mealy, more mealy texture than of SBNP.

Sensory characteristics of saithe fillets in oil with smoke powder (SOS)

Characteristics	Description
Odour	Oil and smoke odour.
Appearance	To little liquid. Fish stands out of liquid. Some white precipitations.
Flavour	Salty flavour, smoke and oil flavour, aftertaste of smoke and oil, no dried fish flavour.
Texture	Much softer and juicier than all other samples tested, slightly mealy when chewed.

Sensory characteristics of saithe fillets in brine with smoke powder (SBS)

Characteristics	Description
Odour	Smoke odour.
Appearance	To little liquid. Fish stands out of liquid.
Flavour	Moderate smoke flavour and salty flavour, a trace of dried fish flavour.
Texture	Very stiff in first bite but a lot less dry than other samples of saithe tested (still rather dry).