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ANALYSING PHYSICAL-CHEMICAL PARAMETERS FOR PROCESSING DRIED MACKEREL AND COD PRODUCTS FOR CABO VERDE.

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This study focuses on the drying process of fish heads from different Icelandic species (lean and fat fish) which can be used in the Cabo Verdean market. The effects on sensory attributes (odour, appearance, flavour and texture), physico profile (pH, a_w, weight reduction and Total Volatile Basic Nitrogen (TVB-N)) and chemical composition (moisture, protein, sodium chloride and fat) were evaluated between heads of the Atlantic mackerel *(Scomber scombrus*) and Atlantic cod (*Gadus morhua*) before and after drying. This experience also allowed to develop a standard procedure and a processing guideline for the drying of fish in Cabo Verde. Cod and mackerel heads were dried following the Icelandic method of utilising geothermal energy in a drying chamber. During the drying the temperature, humidity and drying velocity were measured from the chamber readings. The test results showed that different factors, such as humidity, the rate and extent of water loss, the salt content, the time, the heat treatment temperature and the pH, can change the composition and quality of the final product. The protein, lipid content, TVB-N and salt content increased significantly after the drying process for both species. The protein in the cod head was 14.3% to 59.4% before and after drying and the mackerel head was 13.3% to 28.5% before and after drying. The lipid content of the cod head was 0.35% to 1.9% before and after drying, the mackerel head was 22.6% to 49.2% before and after drying. The TVB-N for the cod head was 13.05 mg N/100g to 218.1 mg N/100g before and after drying, the mackerel head was 20.2 mg N/100g to 27.9 mg N/100g before and after drying. Salt was used only for mackerel heads and was 1.07% before and 4.4% after drying. Sensory evaluation of the fatty fish after drying detected a strong rancid odor due to the high fat content of the mackerel. In the lean fish, blood was found in the flesh of the heads, which eventually accelerated the deterioration of some samples. However, in samples that had no blood, the flavour resembled traditional Icelandic dry fish.

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1 INTRODUCTION

In many parts of the world there is no access to refrigeration or ice. The absence of cold, places stress on the physical, chemical and biological processes that lead to spoilage. Reducing the moisture content through drying, smoking or curing results in a stable source of protein that can be transported to communities with limited access to fresh fish. Traditional methods in tropical countries include direct sun drying with the fish placed either directly on the ground or on mats or racks (Bremner, 2002).

The sea is an important source of economic growth for Cabo Verde, contributing to food security, employment, mobility of people and goods among others. The Strategic Sustainable Development Plan (PEDS) acknowledges that one of the vectors of Cabo Verde's dynamic integration into the World Economic System is the "Cabo Verde Maritime Platform" program, which is a platform for service provision in the Middle Atlantic. This programme marks the country's commitment to sustainable development of ocean and coastal areas. With the blue economy, the Government of Cabo Verde intends to develop fishing and aquaculture, blue energy, Blue Biotechnology and develop knowledge of the marine environment (Ministry of Finance the Cabo Verde, 2018).

Cabo Verde is a small island nation consisting of 10 islands and eight islets totalling 4,033 km^2 of land area and 965 km of coastline. Situated between 600 and 900 km off the West African coast, the country's Exclusive Economic Zone (EEZ) comprises 796,840 km^2 of ocean area (12nm-territorial waters 25,078 km^2, shelf area 3,768 km^2, inshore fishing area 5,697 km^2) (Facility, Global Environment, 2017). Fisheries products in Cabo Verde have great importance for the Cabo Verdean's diet both because of its good nutritional composition, and because it is inexpensive compared with other meat. Cabo Verde has no tradition of production or consumption of smoked fish (FAO, 2017). Literature, knowledge and experience on methods of drying in Cabo Verde are limited, there are few studies on methods of drying fish. This has been an obstacle for the Department of Inspection and Quality Control of Fishery Products in the evaluation and approval of companies interested in processing dried fish.

Drying fish, as is done in other countries, can be an effective method to extend the shelf life and add value to the product. Fishermen and fish vendors are working more closely with the government to improve food security and standards by working to ensure that restaurants buy more fish locally, and by establishing direct supply chains for hotels and restaurants to cater for tourists. Cabo Verde, like many small island developing states, sees its fishing communities, fish vendors, the commercial sector and the government working together to improve the fisheries sector (Facility, Global Environment, 2017).

Obtaining knowledge about drying fish heads in Iceland and adjusting this knowledge to drying fish heads in Cabo Verde can be an opportunity to improve the lives of local communities, create new job opportunities and improve economic conditions on the island. Drying of fish heads has not been done in Cabo Verde. Fish heads are usually discarded in the processing. In addition to this missed opportunity, discarding fish heads often has a direct financial and environmental cost. From experience gained in Iceland, drying fish heads can generate economic returns, it is beneficial to the company and a source of protein.

1.1 Goal

The main goal of this study is to determine if the drying process of fish heads of different species such as Icelandic cod and mackerel (lean and fat fish) can be used in Cabo Verde. Both species have potential for the Cabo Verdean market. The fat content of the mackerel fish is similar to the yellowfin tuna, one of the most consumed fish in Cabo Verde, besides being one of the species most used for canning in the largest fish company in the country, Frescomar. The cod fish has a chemical composition similar to that of small pelagic fish of Cabo Verde.

1.2 Objective

The study has the following specific objectives:

- To compare the physical and chemical parameters of dried fatty fish heads from mackerel and lean fish heads from cod and evaluate the quality assurance control in each processing step.
- Evaluate the sensorial quality of the raw material and the final product, in order to improve the quality and the taste of the product.
- To analyse the applicability of the drying process for fish heads in Cabo Verde
- To develop standard procedures and a processing guideline for drying fish heads in Cabo Verde.

2 LITERATURE REVIEW

2.1 Fishing in Cabo Verde

Fishing in Cabo Verde employs 4% of the active population (8,600 people), and is an important sector for the country's socio-economic development, with artisanal and industrial fisheries targeting large oceanic pelagic, coastal pelagic, demersal and lobsters. In the Exclusive Economic Zone (EEZ) both national and foreign fishing fleets are operating within the framework of Fisheries Agreements / Contracts (European Union, Japan, Senegal) (FAO, 2017).

Artisanal fishing is the oldest fishing practiced in Cabo Verde (Bulletim, 2016). It is practiced by 1,588 boats between 3 and 8 meters, driven by rowing, sailing or outboard, with an average of three fishermen per boat, operating from 97 landing sites. Industrial and semi-industrial fishing is practiced by about 122 vessels (118 semi-industrial and four industrial) with an average of 13 fishermen per vessel, 75% of these vessels are based in S. Vicente and Santiago. The artisanal fishery is the sector which contributes most to job creation and the supply of fresh fish to the population. In many communities, fresh fish is not always available to the population due to lack of preservation means, inadequate and irregular transportation system and high transport costs. The marketing of artisanal fishery products still faces several constraints due to the lack of ice which remains an unresolved problem in order to ensure the quality of the products. In the few communities where ice machines are to be found, they frequently do not work, so ice is not available. Many markets do not have refrigeration equipment in good working order. (FAO, 2017).

Coastal artisanal fisheries, however, exhibit particularly unsustainable catches because of the pressure exerted by a too large artisanal fleet on limited resources, compounded by the use of destructive and illegal fishing practices such as spear-fishing and lobster and conch collecting using scuba diving equipment. Studies indicate that the highly-targeted species such as the lobsters and sandy-bottom demersal have significantly declined. While there is a general agreement that the marine resource base in Cabo Verde is declining, the state of fisheries is described as still largely underexploited, depending on the source of information and the specific fisheries in question (Facility, Global Environment, 2017).

Most fish processing companies in Cabo Verde process only fresh, frozen, headless loins, and much of the fish come from national and international industrial vessels. Catches of fish in Cabo Verde mainly consist of tuna, small pelagic and demersal species. The total catch of artisanal fishing in Cabo Verde in the period 2007-2016 varied between 4000 and 4600 tons per year and the industry fishery in the period 2007-2016 varied between 4400 and 10000 tons (Figure 1).

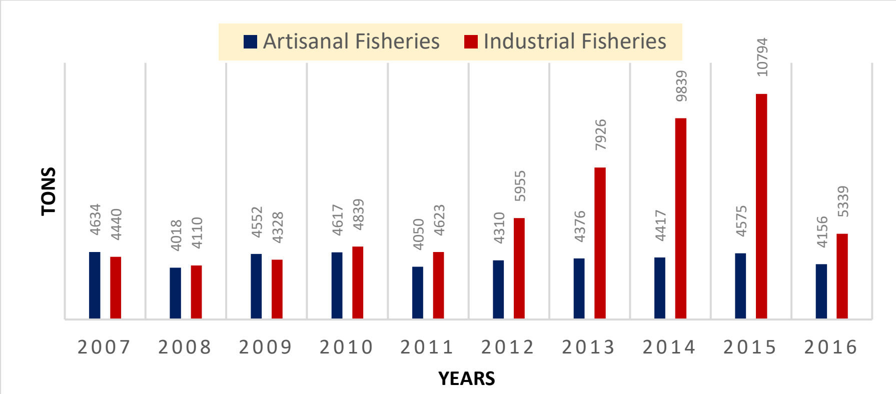

Figure 1- Total artisanal and industrial catches in Cabo Verde, 2007-2016.
Source: INDP, (FAO, 2017)

2.2 **Atlantic mackerel – *Scomber scombrus***

2.2.1 Biology and distribution

Atlantic mackerel is a fatty pelagic species, most abundant in cold and temperate shelf areas. They overwinter in deeper waters but move closer to shore in the spring when water temperatures range between 11° and 14° C. Its geographical distribution is mainly in the North Atlantic and the Mediterranean. Maturity is attained at an age of 2 or 3 years. Maximum fork length is 50 cm, on average 30 cm. It is mainly caught with purse seines, sometimes together with sardines. Surface catches are best when the summer thermocline is not deeper than 15 to 20 meters to prevent the mackerel from escaping into deeper water (Figure 2) (FAO, 2018a). Most of the spawning takes place within 10 to 30 miles from shore, but never in low-salinity estuaries.


Figure 2- Fish body profile and distribution map of mackerel
Source: Fishbase, 2018.

2.2.2 Chemical composition of the Atlantic mackerel

Chemical composition depends on the fish length and the stage of sexual maturity (Table 1). Fish of the older size-age group is the most valuable by the output of the edible part. The mass of Atlantic mackerel head decreases with the increase in the body length and as the mass of viscera enlarges (Russian Research Institute of Fisheries Ocenography, 2000). The different stages show the evolution of the size and weight of the trunk, viscera and mackerel heads during maturation.

Table 1- Length and weight of whole Atlantic mackerel and different parts.

Parameters	Size groups, cm			
	22 - 24	26 - 28	31 - 32	36 - 37
Length, cm	23	27	31	37
Weight, g	103	170	337	513
Mass composition %				
Body parts	Sex (stage of maturation)			
	Males females (II)	Males, females (II-III)	Males, females (III)	Males, females (III-IV)
Head	21	20.7	17.4	17.1
Viscera	8.7	9.1	9.8	11.4
Trunk	69.2	69	71	70.6

Source: (Russian Research Institute of Fisheries Ocenography, 2000)

Chemical composition of meat fluctuates highly depending on the physiological condition and the fish age. In the same catch, the fat and moisture content in the meat can fluctuate considerably because the mackerel spawns in different regions and the period of reproduction itself is stretched in time (Table 2). This fish is characterised by the fat content in the flesh length, fish of small sizes have the minimum fattiness (6%) and larger fish have a maximum fattiness up to 27% in the same period of catch (Russian Research Institute of Fisheries Ocenography, 2000).

Table 2- Chemical composition of Atlantic mackerel body parts(%)

Body Parts	**Moisture**	**Protein**	**Fat**	**Ash**
Head	61.3-66.6	12.3-15.3	14.1-19.5	4.6-5.0
Bones	56.7-61.0	15.3-18.4	14.8-20.0	5.4-6.4
Viscera	73.2-79.1	13.4-14.0	4.2-7.9	2.2-3.0
Liver	60.4-71.8	17.7-19.1	5.5-16.4	1.3-2.0
Roe	72.1-80.3	19.1	0.6-5.1	1.6
Testes	71.3-80.4	16.5	0.1-0.6	2.1

Source: (Russian Research Institute of Fisheries Ocenography, 2000)

2.3 **Atlantic Cod – *Gadus morhua***

2.3.1 Biology and distribution

Commercial name is "cod". Cod is benthopelagic lean fish, distributed in the North Atlantic and in the Arctic. Abundant in cold and temperate shelf areas. They overwinter in deeper waters but move closer to shore in spring when water temperatures range between 11° and 14°C. This species is widely distributed in a variety of habitats from the shoreline to well down the continental shelf, to depths over 600 m, but is mostly found within continental shelf areas between 150-200 m. The growth rate is rather high, the females growing slightly faster than the males. This can vary from one area to another. Three-year-old fish average 56 cm (males) and 59 cm (females); 5-year olds, 81 cm (males) and 85 cm (females). The species lives up to 20 years (Figure 3) (FAO, 2018a).

Figure 3- Fish body profile and distribution map of Cod Source: Fishbase, 2018

2.3.2 Chemical composition of the Atlantic cod

The relative output of Atlantic cod depends on the liver and gonads weight. As the increase of these body parts masses, the relative mass of the cod meat decreases. The mass of the liver fluctuates depending on on the fish condition, that is, on the feeding conditions as well as on the age; the larger the cod is, the greater is the weight of its liver. The minimum relative weight of the liver 1.9% was recorded in a cod with weight of 0.6 Kg, the maximum relative weight of 22.1% was found in a cod with weight of 3.5 kg.

By severing the head with a straight cut in a line perpendicular to the body, weight of the trunk comes to 52.5% and the head with pectoral fins is 31.5%. In such a dressing, part of the liver is also cut (about 20%). If the head is removed by a straight cut without the pectoral fins, about 7% of the liver is removed along with the head. In this case the output of the trunk is 61.6%, the head 27.5%. When the head is separated by a cut at an angle of 60°, the trunk constitutes 61.6% and the head 26.4%. In this method the liver remains intact. Separation of the head by two cuts slanting in relation to the plane of symmetry, starting behind the pectoral fins and terminating at the parietal bone, also does not touch the liver. Here the trunk constitutes 60.2% and head 25.7% (Table 3, 4) (Russian Research Institute of Fisheries Ocenography, 2000).

Table 3- Weight composition of Atlantic cod %

	Mass composition %		
	Head	Trunk (all)	Viscera
Small Fish (less than 1.5 kg)	17.1 - 22.9	62.6 - 71.6	5.4 - 10.8
	20.9	65.3	8
Large fish (more than 1.5 kg)	17.8 - 22.2	53.8 - 68.8	4.9 - 11.1
	20.3	64.5	8.1

Source: (Russian Research Institute of Fisheries Ocenography, 2000)

Table 4- Chemical Composition of the Atlantic cod individual body parts, %

Body parts	Moisture	Protein	Fat	Ash
Head	79.5	13.9	0.3	5.6
Flesh (weight less than 1.5 kg)	81.2	17.4	0.23	1.2
Flesh (weight more than 1.5 kg)	80.4	17.8	0.21	1.2
Liver	41	11	47	….

Source: (Russian Research Institute of Fisheries Ocenography, 2000)

2.4 Drying of fish heads

The drying process of fish is a well understood physical process (Bremner, 2002). Drying means that water is extracted from a substance, usually by heating. (Arason, 2003).

The theoretical drying is two processes (external and internal) happening concurrently, and the rate of drying is determined by the rate at which these two processes proceed.

1. ***External process:*** energy is transferred from the environment to the product to evaporate moisture from the surface. This process depends on the external conditions of temperature, humidity, pressure, flow of air and area exposed to the environment.
2. ***Internal process:*** moisture is transported via diffusion and capillary action to the surface of the product due to difference in concentration of dissolved substances, where it evaporates due to process 1 (Mujumdar, 2006).

Other factors that affect drying are the addition of heat, an increase in temperature, the removal of water, the addition of bacteriostatic compounds as occurs in drying, the addition of humectants, and pH changes. The phase of drying can last from minutes to hours, depending on the types of fish (lean or fatty), its preparation (salted or not salted), and the severity of the external drying conditions (Doe, 1998).

There are several different methods for drying which depend on different mechanisms. The most important ones with regards to drying of seafood are sun drying, solar drying, heat pump drying, freeze drying and osmotic dehydration (Nguyen, Arason, & Eikevik, 2013). Sun drying, as the name suggests, depends on using the sun to dry the product. While this is by far the cheapest method and still in use in many poorer countries it is not without its shortcomings. The dependence on weather, contamination from animals due to its need to be in the open and exposure to dust are the biggest issues (Immaculate, Sinduja, & Jamila, 2012). Solar drying also uses the sun directly but it differs from sun drying in that the process is done in an enclosed space. Solar energy is trapped within the space and utilised to dry the fish.

Heat pump drying is when hot air is created and utilised for the drying of fish. The process has been in use for several decades and is today extremely efficient in regard to power usage and drying quality. The main advantage is that it operates in closed spaces, sealed off from environmental contaminants, and can be operated over a wide range of temperatures; it is power efficient if configured correctly and not dependent on outside weather conditions. These advantages have made the process extremely popular, especially in countries that cannot depend on direct sunlight as the energy source (Gavrila, Ghiaus, & Gruia, 2008) (Butz & Schwarz, 2004).

Freeze-drying is a method that has been utilised for some time but still has not caught on in popularity as the costs behind the method are much higher than that of other methods. Not only are the running costs much higher but also the startup cost. Freeze-drying works by first freezing the product before changing the ice directly into vapour at both low pressure and temperature through a process called sublimation. This kind of drying offers the best quality with regards to the conservation of original sensory attributes such as flavor and aroma. Almost all of the water is removed, up to 98%, meaning that while transporting the product almost no water is being transported (Nguyen, Arason, & Eikevik, 2013).

The preservation of foods by drying is based on the fact that microorganisms and enzymes need water in order to be active. In preserving foods by this method, one seeks to lower the moisture content to a point where the activities of food-spoilage and food-poisoning microorganisms are inhibited (Jay, 1996). The amount of available water in a food is measured by the water activity (abbreviated a*w*) (Martin & Flick, 1990). The general effects of a*w* on the relative rate of quality loss in food products can be seen in figure 4.

Chemical breakdown of nutrients contributes to spoilage of fish. Proper handling of fish, especially cooling of the raw material, is necessary as soon as it is harvested from its aquatic environment, this determines the nutritional properties and the quality of the fish product (Clucas, 1982). It is important to note that the raw material for drying must be fresh fish. Good product does not come from a bad raw material and drying never makes bad fish good (Arason & Arnason, 1992). It is common practice in some countries that fish is brined before being smoked and/or dried, to inhibit microbial and enzymatic activity (Chukwu, 2009); (Omadara & Olaniyan, 2012).

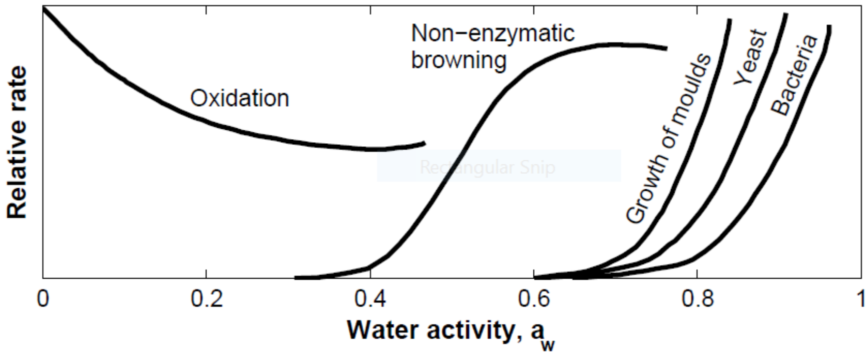

Figure 4- Relative rate of spoiling as a function of water activity.
Source: (Adapted from Chen & Mujumdar, 2009).

Full drying head of lean fish indoors is done in a rack cabinet or a conveyor-belt cabinet. The rack cabinet is the most common, with heads arranged in one layer on the racks where about 25 kg of heads can be arranged per square meter. The conditions of the drying air are: temperature should be 18-25°C, relative humidity 20-50% and air velocity about 3 m/s. The duration is about 24-40 hours. The water content of the heads at the end of this stage is about 50-55%. Secondary drying of semi-dried heads is conducted in drying containers of l-2m^3 volume with hot air blown through. The optimal conditions are: air temperature 22-26°C, humidity 20-50% and the air velocity in a full container is about 0.5-1 m/s. The water content of the cod-heads after drying is about 15%, or the water activity of the product must be lower than 0.6, which is achieved in about 3 days in the drying container (Arason, 2003).

2.5 **Brining of fish**

Brining serves three purposes; it firms the texture of the fish, provides seasoning or flavour, and acts as a preservative in some types and styles of smoked fish (Martin & Flick, 1990). Brining not only brings flavour but also reduces a_w in the product to prolong fish life and inhibit the growth of bacteria (ICAR-2017).

According to Martin and Flick (1990) when making brine, several principles should be kept in mind:

- To achieve a rapid and predictable salt penetration, use as pure a salt (NaCl) as possible. For example, calcium and magnesium, which are common salt impurities, hinder the proper penetration of salt into the fish tissues. Improper or delayed salt penetration can cause spoilage. In addition, these impurities may cause a chalky, bleached-out, unappetising, or unnatural colour that will detract from the appearance of the product. Scaled for reading at a temperature of 15°C.

- Salt used for brining should be fine texture so that it will dissolve quickly. Table salt has a suitable texture, but rock salt may take an inordinate amount of time to dissolve.
- Stirring or agitation of the brine will increase the rate at which the salt dissolves. Mechanical agitation by a pump, sparge, or propeller is highly recommended, but manual agitation with a paddle or stirrer could be employed. Agitation helps to dissolve the salt and also is useful during the brining process to maintain consistent absorption.

Numerous factors influence the rate that fish absorb salt. Among the most significant are:

- Fat content. As the percentage of fat increases, the rate at which the salt penetrates the fish flesh decreases. Consequently, fat content and the species of fish brined have a significant impact on brine concentration and brining time.
- Temperature control. The brining process should be performed so that the temperature of the fish and brine does not exceed 15°C at the start of brining. If the fish are between 3°C and 10°C at the start of brining, the temperature should be continuously lowered to 3°C or below within twelve hours (Martin & Flick, 1990).

2.6 **Sensory Evaluation**

Sensory evaluation is the scientific discipline that evokes measures, analyses and interprets human reactions to characteristics of food perceived through the senses of sight, smell, taste, touch and hearing. Scientific sensory evaluation methods must be performed under carefully controlled conditions in order to reduce the effects of the test environment, personal bias, and so on. It is extremely important to define the problem to be solved or what is to be measured. Sensory evaluation is qualitative: numerical data are collected to establish a relationship between product characteristic and human perception. It is critical to use proper analysis of the sensory data and interpret the result. The sampling system, methods and procedures for sensory evaluation must be very well defined to serve its purpose. In sensory evaluation, a sensory panel is established, with panellists or inspectors trained to perform sensory analysis with clear and descriptive guidelines (Martinsdottir, Schelvis, Hyldis, & Sveinsdottir, 2009).

To the consumer, the most important attributes of a food are its sensory characteristics (texture, aroma, shape, and colour). These determine an individual’s preference for specific products, and small differences between brands of similar products can have a substantial influence on acceptability. The rate and temperature of drying have a substantial effect on the texture of foods. Evaporation of water causes a concentration of solutes at the surface. High air temperature causes complex chemical and physical changes to the surface, and the formation of a hard-impermeable skin. This is termed case hardening. Food that has a high economic value due to its characteristic flavours are dried at low temperature. A second important cause of aroma loss is oxidation of pigments, vitamins and lipids during storage. The open porous structure of dried food allows access to oxygen. Drying also changes the surface characteristics of food and hence alters the reflectivity and colour (Fellow, 1988).

The role of sensory evaluation in the fish industry is to perform sensory analysis on daily production. Therefore, a sensory panel of trained inspectors should be established, usually within the company. To avoid errors in the sensory evaluation in daily quality control, it is necessary to follow well-defined grading systems or guidelines and standards. The assessors must be selected, trained and have clear and descriptive guidelines to produce reliable results from sensory evaluation. The Codex guideline for sensory evaluation of fish and shellfish in laboratories (Codex Standards, 1999) can be regarded as helpful for selecting and training panellists in the industry (Martinsdottir, Schelvis, Hyldis, & Sveinsdottir, 2009).

2.7 Hazard Analysis Critical Control Point (HACCP) Program

The basic underlying and fundamental program for the development of a functional and successful food safety program is the hazard analysis critical control point program, commonly referred to by its acronym, HACCP. A HACCP program provides the management of a food company or distributor with a systematic approach to evaluate products and processes for physical, microbiological, chemical, and allergenic hazards that might occur and pose a food safety hazard as well as direction to install corrective measures to prevent them from occurring. The creation of the HACCP plan utilises all of the departments and expertise of a company and the inherent knowledge of the products and processes. As the foundational program, the HACCP plan helps to determine which other supporting programs need to be developed (Clute, 2009).

The quality of smoked, cured and dried fish can be assessed using a range of physical, chemical, and organoleptic methods. Over the last 80 years, fish technologists and scientists have been endeavouring to draw some general rules from observation and experimentation on fish and fish products to control and predict their properties under a vast variety of circumstances. Over the past decade, the HACCP system has become internationally recognised as the system of choice, with respect to the prevention and control of food safety hazards (Bremner, 2002).

The responsibility for directing the development of the HACCP plan within the company usually is assigned to the quality control manager because, to implement a complete HACCP plan, this person must be able to recognise and evaluate the big picture. He or she must be able to view and understand the interaction between all of the components of the production and distribution flow, including major aspects such as the building structure, warehousing methods, processing line construction and sanitation, packaging, ingredients, and distribution methods, and many other nuances.

In preparation for the development of the HACCP plan, a HACCP team is formed. This should include employees from some or all of the various departments within the company, including production, maintenance, sales, warehousing, quality control, research and development, sanitation, microbiology, operations, purchasing, and accounting. Each represented department brings a unique perspective to the hazard evaluation and contributes to the development of a basic HACCP knowledge base within the company (Clute, 2009).

3 METHODOLOGY

3.1 Raw material

A total of 40 kg of mackerel heads and 20 kg of cod heads were supplied by the Sildarvinnslan fish processing company in Neskaupstad and by Visir in Grindavik, and kept in frozen storage at -24°C.

3.2 Experimental Design

Before the beginning of the experiments, the mackerel were thawed at room temperature, for about 24 hours. The physicochemical parameters and sensory evaluation were performed on the raw material after brining and on the final product, and each analysis was done in triplicate. Figure 5 shows the processes that were performed to dry the heads of cod and mackerel.

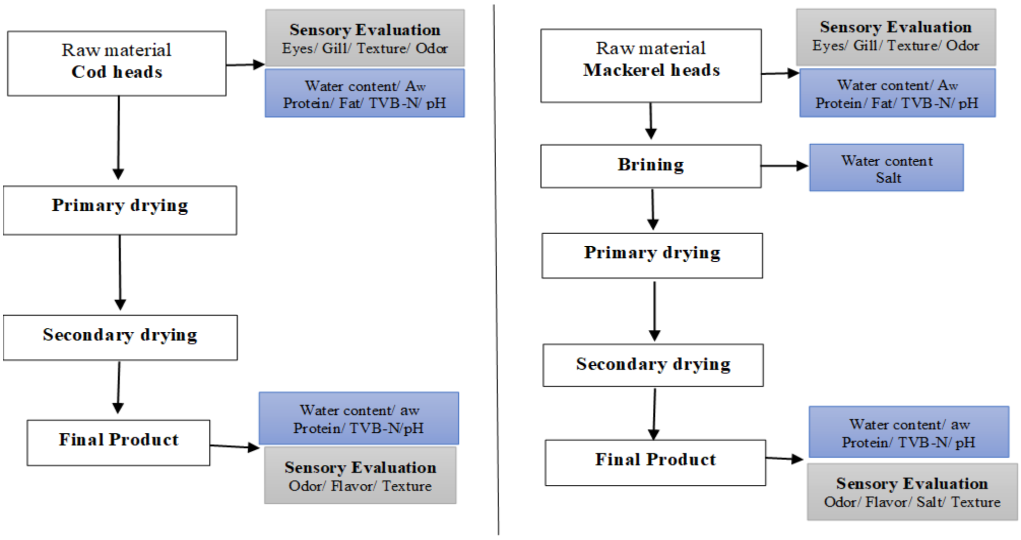

Figure 5- Flow diagram for physicochemical and sensory evaluation measurements of dried cod and mackerel heads.

3.2.1 Brining

After thawing, the mackerel heads were cut, washed for the removal of blood remnants in stainless steel fish washing tubs, labelled and weighed. The mackerel heads were placed in 8% brine for 60 minutes at 4°C. A 9 kg mix of brine was made with 740g of salt + 8 kg of water. After brining, the fish heads were arranged on racks and allowed to be drained at 0 °C (Figure 6). During the experiment, only the mackerel head sample was used for brining. The fresh cod samples were collected directly from the company Haustak, where they were washed, weighed, labelled and collected for physical-chemical analysis and sensory evaluation.

Figure 6- Heads of mackerel after being cut and washed (left) and mackerel heads placed on the shelves after brining in a cold room at temperature (right).

3.2.2 Drying heads

The drying experiment was performed at Haustak. To dry the heads of cod and mackerel, the company uses geothermal energy in the drying chamber. The type of primary drying used in this experiment was rack-dryer (Figure 7) (Arason, Thoroddsson, & Valdimarsson, 1992). Between 10 and 20% of the air passing over the racks is fresh air, the remainder being recirculated air which can be regulated. The drying heads are stacked on pallets, 15 to 22 racks on each. From 12 to 14 kg of fish can be accommodated per square metre of rack. The secondary drying of semi-dried cod heads was conducted in drying containers of 1-2m³ volume with hot air blown through (Figure 8). Both relative humidity and temperature were recorded during drying.

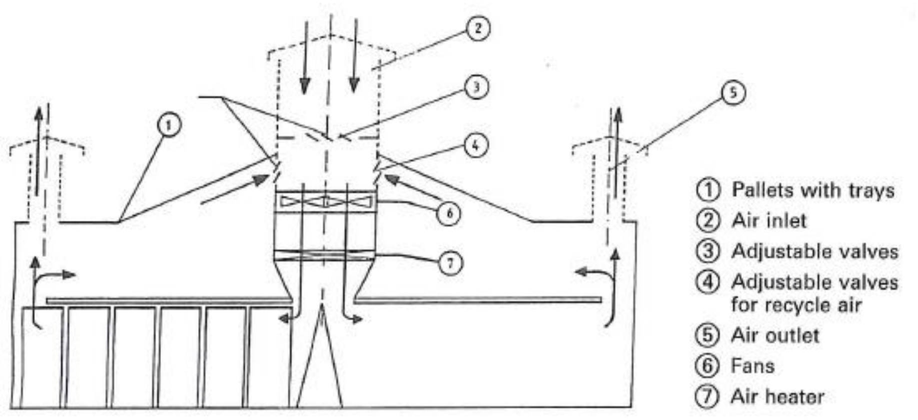

Figure 7 - Primary drying cabinet used for this experiment.
Source: (Arason, Thoroddsson, & Valdimarsson, 1992)

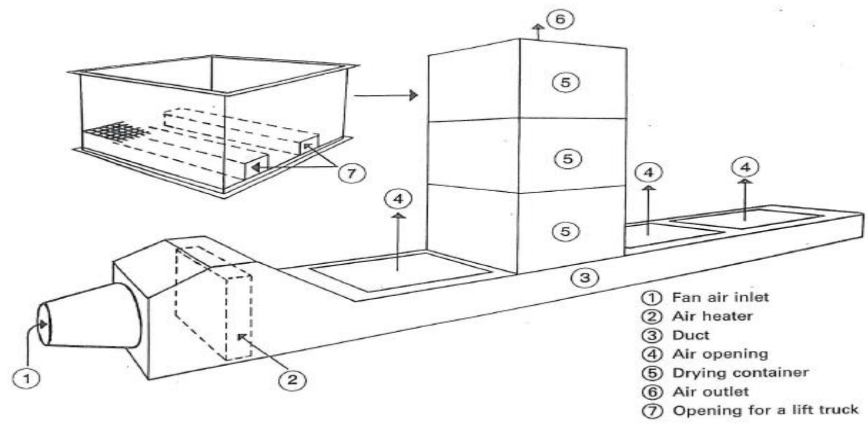

Figure 8- Secondary drying.
Source: (Arason, Thoroddsson, & Valdimarsson, 1992)

After arrival at Haustak, the fresh heads of cod and mackerel were arranged on drying racks (Figure 9). Racks with fish heads were placed into a primary dryer and dried for 100 hours. After primary drying, the products were placed in a container for secondary drying for 25 hours.

Figure 9 - Head of mackerel and cod arranged on shelves for drying.

3.3 Sampling

The samples of cod and mackerel were taken at different process stages (fresh raw material, sample after brining and after drying). The physical, chemical and sensory analyses were conducted at Icelandic Food Research and Biotech (Matis) in Reykjavik, Iceland. From the raw material and final product, three heads of cod and mackerel were collected for physico-chemical and proximate analysis, and five heads of each species for the sensory evaluation. Also three samples of mackerel heads were collected after brining for physical and chemical analysis. The samples were pulled and individually homogenised to get an homogenous sample. Measurements were done in triplicate.

3.4 Physicochemical parameters

Physicochemical parameters were performed on the raw material, after brining and on the final product and each analysis was done in triplicate.

3.4.1 Fat

Fat content was measured using the (AOCS, 1998). The method entails using petroleum ether to extract the fat from the sample in a 2050 Soxtec Avanti Automatic System. Approximately 5g of the sample is weighed and dried in an oven at 103°C ±2°C for one hour. A cup that collects the extracted fat is weighed before and after the extraction. The increase in the cup's weight corresponds to the amount of fat in the sample. For raw material samples approximately 5 g of sample was weighed into a porcelain cup containing fat free sand but following the previous protocol in every other way.

3.4.2 Protein

Crude protein content was measured using the (ISSO, 2005). Approximately 0.5 g of the sample is weighed and digested in H2SO4 using copper as a catalyst. After digestion the samples were placed in a distillation unit, 2400 Kjeltec Auto Sampler System. The acid solution is made alkaline by a 40% NaOH solution. The ammonia is distilled into 10% boric acid and the acid is simultaneously titrated with diluted H_2SO_4. The nitrogen content is multiplied by a factor of 6.25 to calculate the percentage of crude protein.

3.4.3 NaCl

Sodium chloride content was determined using the method according to (AOCS, 2000). By adding excess silver nitrate, soluble chloride is extracted with water containing nitric acid. The amount of chloride is then determined by Volhard titration. Approximately 0.5 g of the sample is weighed along with 25 ml of deionised water and 20 ml of nitric acid. The sample is then boiled and cooled down before titration.

3.4.4 Water activity (a_w)

The a_w was measured using water activity meters (Aqua Lab Series 3 and Series 4, Decagon Devices, USA). The measurement plate of each device will be filled with a sample and placed within until finished. Most enzymes are inactivated at a_w <0.85. Water activity less than 0.75 bacterial growth is inhibited but some yeast and moulds may grow. Water activity less than 0.6 all growth is inhibited (Professional Whitepapers Series, 2014).

3.4.1 Moisture content

The moisture content was measured using the ISO 6496-1999 method in which approximately 5g of the sample is weighed and put into an oven operating at 103°C ±2°C for 4 hours (ISSO, 1999) After 4 hours the sample is cooled down in a desiccator and then re-weighed. The amount of weight lost during the 4 hours correspond to the amount of moisture in the sample.

3.4.2 Weight reduction:

The weight of the samples were taken in the beginning (raw material), after brining , after primary drying and after secondary drying (Figure 10). The mass balance was expressed as percentage and was calculated after drying in relation with the weight of the head from raw material. Yield was calculated as follows:

$$Head\ yield\ (\%) = \frac{head\ weight\ after\ primary\ drying\ x\ 100}{fresh\ head\ weight}$$

$$Head\ yield\ (\%) = \frac{head\ weight\ after\ secondary\ drying\ x\ 100}{fresh\ head\ weight}$$

Figure 10- Weighing samples after drying, Cod head (left) and mackerel head (right).

3.4.3 Temperatures:

Temperature was measured from the chamber readings.

3.4.4 Humidity:

Relative humidity values were measured from the chamber readings.

3.4.5 Drying velocity:

Airflow were measured from the chamber readings.

3.4.6 Total Volatile Basic Nitrogen (TVB-N)

A steam distillation method was used, described by (Malle & Poumeyrol, 1989), for the TVB-N determination. The measurements were performed on the raw material and final products. For the extraction, 100 g of mackerel and cod heads were mixed with 200 ml of 75% aqueous trichloroacetic acid solution, homogenised in a blender for 1 min. and then filtered through Whatman no. 3 filter paper. The distillation was performed using a Kjeldahl-type distillatory (Struer TVN). Into a distillation flask, 25 mL of filtrate was transferred and 6 mL 10% NaOH was added. The distillate went into an Erlenmeyer flask containing 10 mL 4% boric acid and placed under the condenser for the titration of ammonia for 4 minutes. The boric acid solution turned green when alkalinized by the distilled TVB-N, which was titrated with aqueous 0.0372

N sulphuric acid solution (H_2SO4) using 0.05 ml graduated burette. Complete neutralisation occured when the colour turned grey/pink on the addition of a further drop of sulphuric acid. The results were expressed as mg N/100 g.

3.4.7 Acidity (pH)

The pH of fresh and dried samples was measured by the method of (Bragadottir, Reynisson, Thoraninsdottir, & Arason, 2007), 5 g of fresh samples measured directly while 5 g of dried samples were mixed with 20 ml of deionised water, stirred for 5 mins prior to measurement with combined electrode SE 104- Mettler Toledo, Knick Berlin Germany, and connected to a portable pH meter Portamess 913, Knick, Berlin, Germany.

3.5 **Sensory evaluation**

The aim of the evaluation was to describe the quality of mackerel- and cod heads in raw materials and in the final product. Sensory evaluation of mackerel- and cod heads was carried out at Matís ohf.

Three trained panellists, specialising in evaluation of freshness and spoilage characteristics of different fish species, participated in the evaluation (ISO, 2014). They were instructed to describe the odour, appearance, texture and flavours of the fish heads verbally. Five heads were evaluated for each species before and after drying. They were placed in a bowl and presented to the panellists as one sample. The cod and mackerel heads after drying were evaluated after steam cooking and served to the three experienced panelists who described the sensory attributes. Figure 11 shows the characteristics of cod and mackerel heads after drying.

Figure 11- Dried mackerel and cod heads used for sensory evaluation

3.6 **HACCP**

HACCP is a two part system. The first part focuses on defining the nature of the product being produced and developing a flow diagram which details each operational step in the process. Understanding the nature of the product is essential to determining the potential food safety hazards. Important aspects to know include the intended use (i.e., raw ready-to-eat; raw ready-to-cook; cooked ready-to-eat); method of distribution and marketing (i.e., refrigerated, frozen, etc.) and intended consumer. This does not mean that food should be safer for one segment of the population than another. It does recognise, however, that some segments of the population are more vulnerable than other segments. The second part of HACCP consists of applying the seven principles (Clute, 2009).

3.6.1 Conduct a hazard analysis (Principle 1)

The purpose of hazard analysis is to develop a list of hazards that are of such significance that they are reasonably likely to cause illness or injury if not effectively controlled. Consequently, in the context of HACCP, the word "hazard" is always limited to safety. In HACCP, there is no hierarchy among the principles in terms of importance. All seven principles are equally important and must ultimately be integrated into an overall plan.

3.6.1 Determine the critical control point (Principle 2)

A critical control point (CCP) is defined as a step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level. Examples of CCPs could include thermal processing, chilling, testing ingredients for chemical residues, product formulation control and testing the product for metal contamination.

3.6.2 Establish critical limits (Principle 3)

A critical limit is a parameter, established at CCPs, which targets conditions essential for the production of safe food. It can be a maximum and/or minimum value to which a biological, chemical or physical parameter must be controlled at a CCP to prevent, eliminate or reduce to an acceptable level the occurrence of a food safety hazard. Failure to achieve the critical limit means that the CCP is not in control and the food being produced must be considered unsafe.

3.6.3 Establish monitoring procedure (Principle 4)

Monitoring is a plan of observations or measurements to assess whether a CCP is under control and to produce an accurate record for future use in verification. Monitoring at CCP is done to determine whether or not the critical limit(s), established for each CCP, is being met. Monitoring serves three main purposes: first, it is essential to food safety management in that it facilitates tracking of an operation. If monitoring indicates that there is a trend toward loss of control, then action can be taken to bring the process back into control before a deviation from a critical limit occurs. Second, monitoring is used to determine when there is a loss of control and critical limit deviation occurs at a CCP, i.e., exceeding or not meeting a critical limit. Third, it provides written documentation for use in verification.

3.6.4 Establish corrective actions (Principle 5)

When there is a deviation from established critical limits, corrective action is necessary. As recommended by (NACMCF, 1998), corrective actions are predetermined components of a written HACCP plan.

3.6.5 Establish verification procedures (Principle 6)

Verification is defined as those activities, other than monitoring, that determine the validity of the HACCP plan. Of the seven principles, this one inevitably proves to be the most challenging for trainers to teach and for students to understand. Perhaps part of this lies in the fact that in the evolution of HACCP this principle was the last to be developed and as a consequence it attempts to deal with several problematic issues that had become evident. The activities (other than monitoring) that determine the validity of the plan include:

1. Evaluating whether the facility's HACCP system is functioning according to the written plan.

2. Determining (initial validation) if the plan is scientifically and technically sound, that all hazards have been identified, and that if the HACCP plan is properly implemented these hazards would be effectively controlled. This includes determining if CCPs have been properly identified and that the critical limits which are scientifically valid for hazards are being controlled. Equipment calibration is also part of validation.
3. A subsequent validation (sometimes referred to as revalidation) is necessary if there is an unexplained system failure; a significant product, process, or packaging change occurs; or a new hazard is recognised.
4. A periodic comprehensive verification should be conducted, even if there have been no substantive changes to the plan.

3.6.6 Establish record-keeping and documentation procedures (Principle 7)

Generally, records maintained for the HACCP system should include (Clute, 2009):

1. Summary of the hazard analysis, including rationale for determining hazards and control measures.
2. The HACCP plan:
   a) Listing of the HACCP team and assigned responsibilities
   b) Description of the food, its distribution, intended use, and consumer
   c) Verified flow diagram
   d) HACCP plan summary Table.

4 RESULTS

4.1 **Massa balance (yield)**

In this experiment, the final water content after the primary drying for cod head was 24.4% (about 75.6% weight loss), and the mackerel head was 47.1% (52.3% weight loss) during 100 hours. The total drying time for the heads were about 125 hours and the yield for the cod head after drying was 23,5%, and for the mackerel heads were 45% (Figure 12).

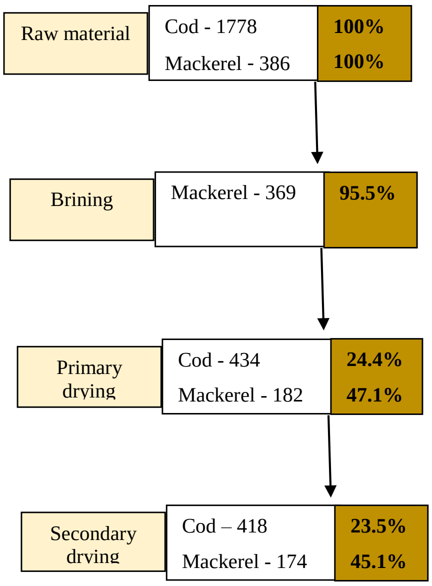

Figure 12- Mass balance for drying of cod and mackerel heads. Percentage yield figures are given for each step.

4.2 Temperature, time and humidity

The temperature used for drying depends on the characteristics of the food, if the temperature is too high, the surface of foods becomes hard and inhibits the diffusion of water, instead if drying is at low temperature, it reduces the risk of spoiling the food. The method of drying cod and mackarel heads was divided into two phases, primary dried and subsequently processed through secondary step in drying containers. The conditions used in this experience for primary drying cod and mackerel heads were: air temperature between 24-28°C, airspeed of 1.5-2 m/s and air humidity about 32%. For the second drying the conditions were: air temperature between 27-29°C, airspeed of 1.5-2 m/s and air humidity about 18% (Figure 13).

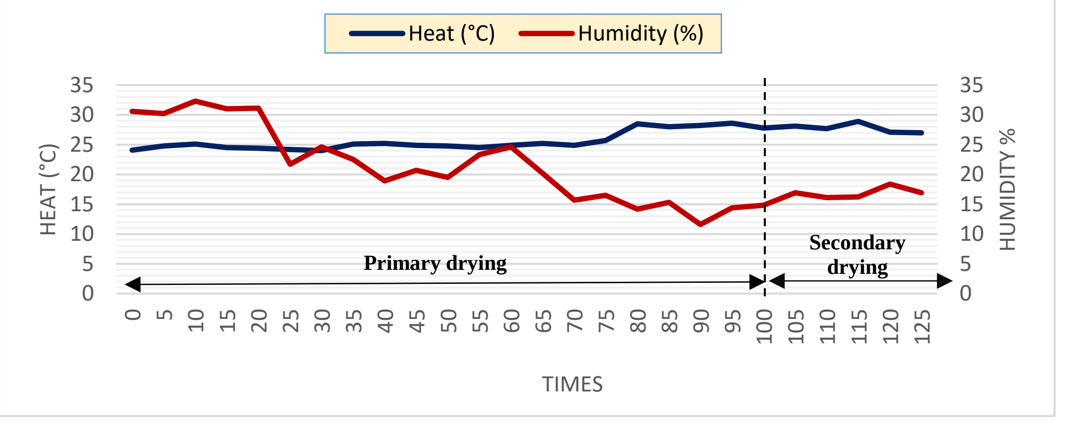

Figure 13- The temperature and humidity used for cod and mackerel heads changes with time in the chamber drying. The drying is conducted in two stages, primary drying and secondary drying.

4.3 Moisture content and water activity

The moisture content of fresh samples was 84% for cod heads and 59% for mackerel heads. After drying, the moisture content of cod heads decreased to 11% and mackerel to 7.8%. The a_w for fresh mackerel heads was 0.98 and for cod heads 0.99, after drying the a_w decreased to 0.60 on mackerel heads and 0.5 on cod heads. Figure 14, shows the relationship between moisture and water activity in dried cod and mackerel heads.

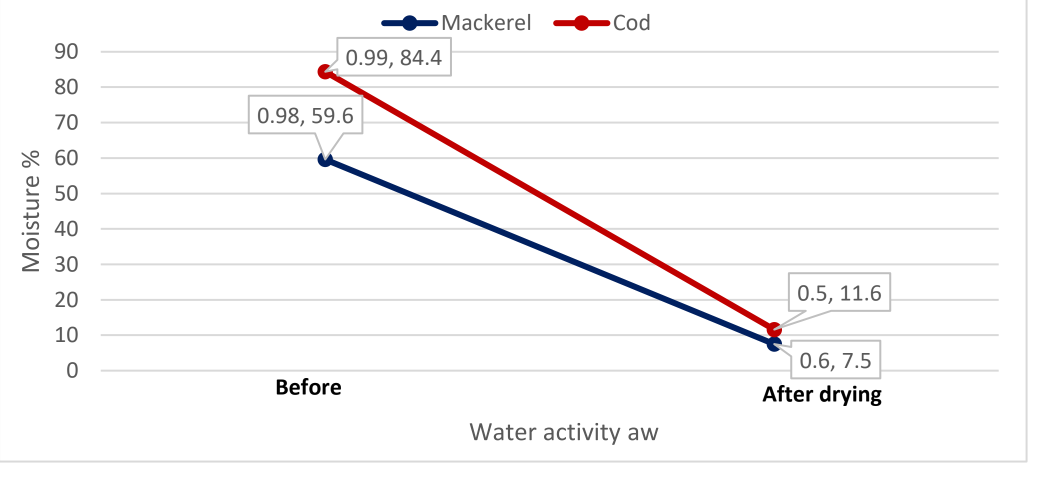

Figure 14- Relationship between moisture and water activity before and after drying of cod and mackarel heads.

4.4 Lipid content

In relation to the cod heads, the lipid content results were low; in the fresh head samples it was 0.3%, and after drying it was 1.5%. For fresh mackerel head it was 21% and after drying the lipid content increased to 49% (Table 5).

Table 5- Lipid content, before and after drying cod and mackerel heads.

	Mackerel		Cod	
Samples	Fresh head	Dried head	Fresh head	Dried head
A	22.2	49.3	0.3	1.9
B	23.6	49.6	0.4	1.3
C	21.9	48.6	0.3	1.3
Average	**22.6**	**49.2**	**0.3**	**1.5**
Stdev	**0.9**	**0.5**	**0.1**	**0.3**

4.5 Protein

The protein content between fresh cod and fresh mackerel heads was similar 14% for cod heads and 13% for mackerel heads. After drying, the protein content of the cod heads was 59.4% and for the mackerel heads it was 28% in Table 6.

Table 6 - Protein, before and after drying cod and mackerel heads.

	Mackerel		Cod	
Samples	Fresh heads	Dried head	Fresh heads	Dried head
A	13.6	28.9	14.3	59.4
B	13	28	14.9	57.8
C	13.4	n.d	14.6	n.d.
Average	**13.3**	**28.5**	**14.6**	**58.6**

4.6 NaCl

The salt content of dried mackerel heads was found to have increased by about 4.4% relative to fresh cod heads after brine 2.2%, as a result of evaporation of the water. The salt content of fresh mackerel heads before brine was 1.07%. The moisture content after the brine, decreased from 59.6% to 57.9%, and after drying to 7.5% (Figure 15).

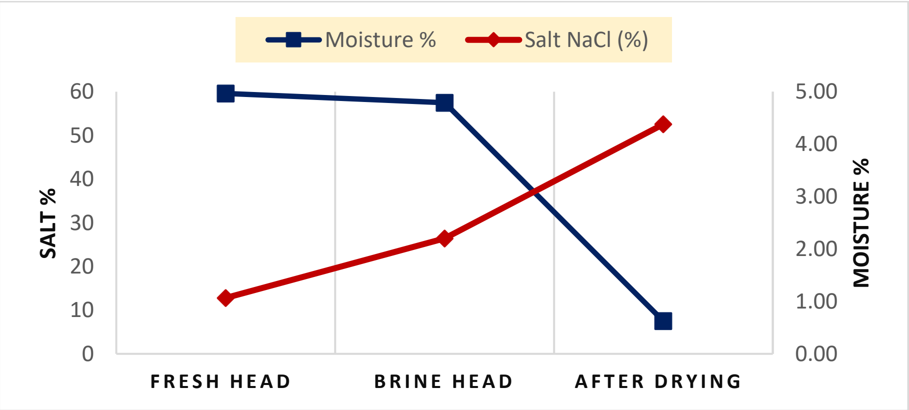

Figure 15- Relationship between salt content and moisture content in different drying step of mackerel heads.

4.7 TVB-N

The mean values of TVB-N found for fresh samples and sample after drying can be seen in the table. Despite the differences found between the fresh sample and the sample after drying, the highest values of TVB-N were obtained in the samples after drying. The TVB-N value of the dry groups in the mackerel heads was 27.9 mg N/100g and cod heads 218,1 mg N/100g. Among the fresh samples, the value of the mackerel heads was 20.2 mg N/100g and in the heads of cod 13 mg M/100g.

Table 7- TVB-N, before and after drying cod and mackerel heads.

	Mackerel		Cod	
Samples	Fresh heads	Dried head	Fresh heads	Dried head
A	21.1	32.6	12.4	223.8
B	19.6	28.5	13.7	n.d.
C	19.9	22.6	n.d	212.4
Average	**20.2**	**27.9**	**13.05**	**218.1**

4.8 pH

The pH was analysed only in the raw material and the pH of the fresh cod heads was 6.41 and for the fresh mackerel heads were 6.78, respectively.

4.9 Sensory evaluation

According to the description of the panels, for the fresh samples of the mackerel and cod heads, no deterioration characteristic was detected (Table 8). After drying, the sensory characteristics changed, between samples. Both heads, cod and mackerel, presented alterations, as shown in Table 9.

Table 8- Results of sensory evaluation analysis of fresh heads.

Raw material		
	Mackerel heads	**Cod heads**
Odour	Fresh odour, blood, metallic, fish oil.	Very fresh odour.
Appearance	Fresh appearance, bright and shiny skin, dark red/dark brown colour of blood.	Very fresh appearance, bright and shiny skin, convex and clear eyes, fresh gills, transparent slime on gills.

Table 9 – Results of the panels for the cod and mackerel heads after drying.

Final product - dried heads		
	Mackerel heads	**Cod heads**
Odour	Rather heavy odour, rancid if smelled from cut and very rancid when opened at the back of the head (front end of loin).	Spoilage odour (TMA odour, sour and putrid) was detected on the heads but differed much in strength between heads and parts of the head. Two of the heads seem to have been from fish which were badly bled, and they had more spoilage odour than the other three heads. Spoilage odour was very well detectable in the gills and where blood was seen but not at the top of the heads.
Appearance	Shiny and without defects, no yellow colour.	The appearance was very different between heads. Some had much blood and others less. The heads with more blood were more yellow in colour than heads with less blood. The appearance of the gills also differed between heads, and gills from heads with more blood looked more spoiled than others. A difference was also seen between heads in how much of the loin part of the fillet was left in the head. Some had been cut transversally so that small parts of the loins were still present in the head. In other heads these parts of the loins had been cut off with the fillets.
Flavour	Could not be evaluated due to rancid odour	The panellists tasted the loin parts in one head. The flavour of the flesh close to the skin was similar to traditional Icelandic dried fish, without salt flavour and without spoilage flavour. However, the flavour close to the gills had obvious spoilage flavour.
Texture	Could not be evaluated due to rancid odour	Very dry and tough.

4.10 **HACCP**

During the development of the HACCP plan for drying fish head in Cabo Verde, two CCPs were identified. First in the receiving step of the raw material and secondly in the cold storage before processing. Table 10 shows the description of the drying process of the mackerel heads step by step, Table 11 shows the Hazard Analysis at all stages of the drying heads and Table 12 shows the HACCP Plan Form for fish processing dry heads in Cabo Verde.

Table 10 - Description step by step for drying of mackerel heads in Cabo Verde

	Process description for drying of mackerel heads in Cabo Verde
Receiving	Fresh mackerel heads are received on ice and are re-iced before cold storage if necessary. The quality of the raw material is evaluated at reception. If the freshness of the raw material is questionable it is put on hold for further evaluation before being allowed to enter processing. Samples of every lot are tested for histamine and the mackerel cannot enter processing until test results show histamine level below 50ppm.
Cold Storage	Fresh mackerel heads are stored on ice in a cold storage at 0°C until processed. If the mackerel is stored for more than one day the quantity of ice is monitored and the fish re-iced if necessary.
Washing	The fish heads are washed for the removal of blood remnants in stainless steel fish washing tubs. Water temperature is kept under 4°C by adding ice into the wash water. Washing takes less than 10 minutes
Brining	The fish heads are placed in 8% brine solution for 60 minutes. The final salt concentration of the fish is approximately 1%. Temperature of the fish and brine is kept below 15°C.
Racking	After brining, the fish heads are arranged on racks and allowed to drain overnight at 0 °C, before thr drying process.
Primary Drying	Racks with fish heads are placed into a primary dryer and dried for 24 to 40 hours at 18-25°C. Air speed in the dryer is kept at 3 m/s and the humidity of air entering the drying chamber is between 20-50%. The water content of the mackerel at the end of primary drying is between 50 and 55%.
Secondary Drying	After primary drying, the products are placed in a container for second drying for 3 days at 22 to 26°C. The air speed is kept at 0.5 to 1 m/s and the humidity of air between 20 and 50%. The water content of the mackerel at the end of drying is about 15% and the water acidity around 0.6.
Packing and labelling	The final product is packed into gunny sacks of size 960x640 cm. After packing the sacks are labelled: . Common name . Scientific name of the species . Name and address of producer . Storage conditions . Weight . Expiration date . License number, . Lot number . Export authorisation number . Country of origin
Final product storage	Final product is stored in a dry and clean place until shipped.

Table 11- Hazard analysis of dry head fish processing in Cabo Verde.

Firm name:	**Product description: Mackerel**				
Firm Address	Method of storage & distribution: **Dried mackerel heads**				
	Intended use & Consumer**: The ordinary consumer, people in general or the public**				
Processing Step	List all potential **biological, chemical and physical** food safety hazards that could be associated with this product and process	Is the potential food safety hazard **significant** (introduced, enhanced or eliminated at this step? **(Yes/no)**	**Justify the decision** that you made in column 3	What **control measure(s)** can be applied to prevent, eliminate or reduce this significant hazard?	Is this step a **Critical Control Point? (yes/no)**
Receive Raw Material	Histamine	YES	Likely to occur/	Time/temperature Checking incoming fish to ensure that they are not at an elevated temperature at time of receipt and, Performing sensory examination of incoming fish to ensure that they do not show signs of decomposition.	YES
	Parasite	NO	Not likely to occur		
	Pathogenic bacteria	YES	Has temperature abuse microorganism occurred	Control by temperature; Use clean ice. Ice a soon possible. Temp. 1-5°C. Use clean water	NO
Cold Storage	Histamine formation	YES	Temperature can increase, if don't have ice	Cover with Ice	YES
Washing	Contamination of Bacteria	NO	Not likely to occur		
Brining	*C. Botulinum* Toxin	NO	Not Likely to occur		
Primary Drying	Pathogenic bacteria growth	NO	The product is heated before consumption. *Staphylococcus aureus* contamination prevented by PRP		
Second Drying	Pathogenic bacteria growth	NO	Not likely to occur		
Package	None Identified				
Storage	None identified				

Table 12- HACCP Plan Form for dried head Mackerel in Cabo Verde

HACCP Plan Form Product: **Dried Mackerel Heads**

Critical Control point	Significant Hazard	Critical Limits for each Control Measure	Monitoring				Corrective Actions	Verification	Records
			What	How	Frequency	Who			
Receiving	Histamine	Temperature <4°C	Temperat ure	Thermomet er	Every receiving lot	Receiving manager	Add ice to the product; If the temperature > 4 C, test product for histamine, limit 50 ppm. Destroy all affected product, if any fish exceeds 50 ppm histamine.	Verification if the thermometer is calibrated. Thermometer Check daily in ice slurry. Review corrective action record. Daily raw receiving Monitoring record	Received record form
Cold Storage	Histamine formation	All fish covert in ice	Quantity ice	Visually	Every morning	Storage manager	Then add ice and measure temperature the fish. If temperature is more than 7°C, test for histamine. Destroy all affected product if any fish exceeds 50 ppm histamine.	Review record every day thermometer calibrated monthly	Quality storage record

5 DISCUSSION

5.1 Massa balance (yield)

The removal of water in any drying process involved the combination of evaporation of water from a surface together with the movement of the water from the interior of the material being dried. The process of water movement and heat transfer were inter-related. Heat was needed to provide the change of state from liquid water to water vapor, which evaporated from the surface of the fish during drying (Jason & Peter, 1973). The yield of water content was higher in the head of cod than in the head of mackerel because mackerel is a very fat fish and the water outlet is slower. According to (Dore, 1993) a fat, firm fish will take longer to dry to a specific level than a leaner, softer fish, even though fatty fish has less water to remove. The variation in the percentage of fat is reflected in the percentage of water, since fat and water normally constitute around 80 % of the fillet of the fish (FAO, 2001).

It can be understood that lipids played an important role as a limiting factor in the drying steps either by replacing the aqueous phase reducing water transfers or acting as a physical barrier to heat transfer that causes evaporation and diffusivity of water. According to Arason *et al.,* 1992, the optimum conditions for the drying time for cod heads is about 120 hours and the yield is 21.2%. For small pelagics with a fat content of less than 5%, the total drying time is about 80 hours and the yield is 20%.

5.2 Moisture content and water activity

The main constituent of fish flesh is water, which usually accounts for about 80% of the weight of a fresh white fish fillet. Whereas the average water content of the flesh of fatty fish is about 70%, individual specimens of certain species may at times be found with a water content anywhere between the extremes of 30 and 90% (FAO, 2001).

The moisture content and water activity during the drying process decreased due to the effect of heat. The moisture is removed from the surface of the product by evaporation. Heat is required to evaporate the moisture. Too much heat too soon, however, hardens the outer surface and traps moisture in the flesh (Dore, 1993). According Arason *et al*, 1992, the a_w falls more rapidly when the water content is below 30% in the drying process.

The change of a_w during drying is not controlled by internal diffusion processes. The evaporation rate from the surface, at which the fish is dried, is controlled by external factors such as air, air temperature and humidity. The a_w at the surface of the fish during the constant rate of drying phase will remain close to 1.0, because the air within the boundary layer near the surface will be saturated (i.e., 100% relative humidity) at the surface temperature of the fish, which will be below the surrounding air due to evaporative cooling occurring. When diffusion processes within the fish start to control the rate of moiture flow to the surface, the constant rate phase ends, and the surface of the fish starts to dry out (Doe, 1998).

5.3 Lipid content

The lipid content was higher in mackerel head than in cod head because cod fish is a typical lean species of the cod family. The lipid content of the muscle is always low, usually below 1 per cent, and seasonal fluctuations in lipid content are noticeable mainly in the liver, where the bulk of the fat is stored (Dore, 1993).

Contrary to what happens in lean fish, mackerel is a fatty fish that stores lipids in fat cells distributed in the body tissues (FAO, 2001). Probably this increase in fat content is linked to the decrease in water content and the rate of drying, affected by heat, humidity, the flesh characteristics of the product (species, texture, thickness) as well as by velocity of the air.

The fat content of the mackerel are very unstable and are influenced by oceanographic conditions. Variability of external factors, such as size of the stock, ocean temperature, feed conditions, feed availability and competition for feed with other species, such as herring, may negatively affect the biological condition of the mackerel, and hence affect the quality and stability of the initial raw material intended for further processing. Moreover, the heavy feeding period and the variation in muscle lipid content, as well as variation in biological conditions may lead to great fluctuations in the quality of mackerel (Romatowska, Karlsdottir, Gudjonsd, Kristinsson, & Arason, 2016).

5.4 **Protein**

The amount of protein in fish muscle is usually somewhere between 15 and 20%, but values lower than 15% or as high as 28% are occasionally met with in some species. The water in fresh fish muscle is tightly bound to the proteins in the structure in such a way that it cannot readily be expelled even under high pressure. After prolonged chilled or frozen storage, however, the proteins are less able to retain all the water, and some of it, containing dissolved substances, is lost as a drip (FAO, 2001).

The protein after the drying process increased in both species, however, a more significant increase was observed in relation to the cod head. According to (Zdzislaw, Bonnie, & Fereidon, 1994), protein in the dried tissues are affected by different factores, that is the rate and extent of loss of water and the accompanying concentration of the mineral components in the tissues, the action of salt, the time and the temperature of heat treatment, the autolytic and bacterial proteolytic activity, the pH of the tissues and the interactions with lipid oxidation products. During the drying of fish, about 70%-80% of the moisture in the fish is evaporated leaving nutrients in its most natural form. For instance, the nutritional value of a kilogram of dried fish is the same as approximately five kilograms of fresh fish (Jonsson, et al., 2007).

5.5 **NaCl**

The salt content during the drying process increased with the decrease in moisture content, because the salt removed part of the moisture from the flesh of the fish. (Martin & Flick, 1990) reported that during the brining procedure several phenomena occur; the water migrates from the fish tissues because of osmotic pressure. This water loss causes some weight loss but will favourably affect the texture of the fish. The salt concentration in the tissues increases with soaking time. The use of salt content in the mackerel head, is to impart flavours and increases the shelf life of the fish, because the fat of mackerel is so high, salt helps to prevent oxidation, the fish's rancidity and preserving the quality of the fish (Ásbjörn Jónsson personal communication).

In salting fish, the salt should not be too finely grained because fine-grained salt dissolves rapidly in the muscle fluids causing a too-fast withdrawal of moisture from the surface tissue. As a consequence, a rapid protein denaturation and cogulation occur, presenting further penetration of the salt into the fish and giving rise to a condition known in the trade as "salt burn". Denaturation by salt, just like denaturation by heat, results in a decreased extractability of fish muscle proteins. Heavily salted fish loses much water, its texture is tough, and the flavour is much less developed than, for example, in fatty herring salted with a low amount of salt (Zdzislaw, Bonnie, & Fereidon, 1994).

5.6 pH

The pH value is an indicator of the degree of freshness or spoilage of food. The pH of the fresh cod and mackerel heads were quite neutral. The high pH favours microbial growth and that most bacteria will grow best at neutral pH 7 although they can still tolerate ranges from pH 5 (acidic) to pH 8 (basic) (Nester, Anderson, Roberts, Pearsall, & Nester, 2007).

5.7 TVB-N

In this study, higher TVB-N content was detected in the samples after drying, compared to the raw material. The value of TVB-N in fresh cod and mackerel heads were within the acceptable range of 20-35 mgN / 100g. In a study by (Eysteinsson, 2016), using the warm indoor drying method, with high temperatures and longer processing time, increased the rate of TVB-N in the final products. According to Commission Regulation (EC) No 2074/2005, the TVB-N content limit for species of the Gadidae family of which cod belongs is 35 mg nitrogen / 100 g of flesh. This is the reason for a much higher level of TVBN in dry products than in fresh produce. First, there is more amount of TVB-N in the dry product than in fresh produce because the TVB-N is measured in dry material. Secondly the trimethylamine oxide (TMAO) is a production of trimethyloxide (TMA) which includes amino compounds. In cod there are much more TMA than in mackerel. That is why the TVB-N value in cod is much higher. So, in dry products, TVB-N at 214 and even 300 is usual, and causes no harm for the consumer. The process drying also has an effect, so high value of TVB-N causes no harm for the consumer.

5.8 Sensory evaluation

According to the description of the panel, for the fresh samples of mackerel and cod heads, both appearance and odour indicated that the cod heads were very fresh. The mackerel heads were also fresh, no rancidity or frozen storage odour were detected, and the odour was fresh. The dark red/dark brown colour is normal for frozen mackerel.

After drying, the appearance of the mackerel heads was shiny and without defects, but a strong rancid odour was detected in the flesh, as would be expected for fish with so high fat content. Since the mackerel heads were evaluated fresh and without rancid odour before drying, it is likely that the rancid odour has developed during the drying of the heads.

The dried cod heads differed in freshness level and quality. The top parts of the loins were present in some heads but not in others. Blood in flesh seems to have accelerated spoilage in the heads, since heads with more blood were evaluated more spoiled than heads with less blood. Spoilage odour was obvious in the gills, especially in heads with more blood. The cod heads were evaluated very fresh before drying which indicated that spoilage has developed during the drying procedure. However, flesh without blood had no spoilage flavour and reminded of traditional Icelandic dried fish.

5.9 HACCP

In this experiment it was possible to acquire knowledge with the professional experts from Iceland on the drying of heads of lean and fat fish and to adjust this knowledge to the drying of fish heads in Cabo Verde. Guidelines were developed to be used as tools to support the

Department of Inspection and Quality Control of Fishery Products in approving new companies interested in processing fish drying.

5.10 Project applicability in Cabo Verde

Fishery products are the food most consumed by Cabo Verdeans and by all social classes in the country. The drying of fish heads, besides being a project of an innovative product, can be an effective method to overcome the lack of ice, extend the shelf life of the product and the high transport cost in Cabo Verde. One of the advantages of drying fish heads is that reducing the weight and volume of the fish reduces the costs of transport and with decreasing packaging facilitates storage. With the reduction of the weight of 50% to 80% occurs a concentration of nutrients in the remaining mass, i.e., proteins, lipids, carbohydrates, etc., and are in greater quantity per unit weight in dry products, than products fresh. In most cases this does not require refrigeration, which also greatly reduces costs. It is an inexpensive process and maintains the physical and chemical characteristics of the product.

In the case of Cabo Verde, the sun drying also can be applied as a option, taking into account the high cost of electricity in the country, although the method of drying in the sun is not the most appropriate due to the high risk of contamination of the product, as was stated previously.

Considering the overexploitation of some fish species in the country, this project can be applied to poorly exploited fishery resources and thereby alleviating pressure on target species traditionally most exploited. Besides that, because of the low diversification in fish processing and conservation methods, the techniques performed within the scope of this study can successfully be adopted to improve the fish processing, knowledge and experience in the country.

The process of drying fish may be one of the strategies to develop fishing within the context of blue economy. The Blue Growth and Coastal Fisheries initiatives are niches to be explored, particularly with regards to the introduction of good fishing practices and product conservation along the whole chain, minimising post-harvest losses, increasing added value and diversifying the supply of fish for consumption.

6 CONCLUSION AND RECOMENNDATION

The quality of dried products depends on the condition of the raw material, drying processes and conditions, packaging and the storage conditions. Dry fish heads can be a good opportunity to improve the lives of local communities and the country. Small-scale fisheries feed diversified and spatially extensive networks of supply and trade that connect production with consumers, adding significant value and generating important levels of employment (the value chain). Drying fish heads in Cabo Verde can also generate new export markets, new opportunities and new horizons for the fishing sector. The study indicated that dried cod and mackerel heads are a good source of protein and lipids, thus constituting a healthy food. Drying lean fish, according to the results of the physicochemical analysis, is better, easier, preserves the product for a longer time and the risk of oxidation is less than for fatty fish. Fatty fish are not generally suitable for salting and drying but are usually brined or smoked. These products are usually dried to about 30% of their raw material weight. According to (Dore, 1993), the smokers as well as curers need to be able to assess the oil content of fish they are smoking, partly because salt does not penetrate oily flesh as quickly or evenly as it enters lean tissue. For future research, I recommend the following studies: stable storage conditions (relative humidity and temperature), storage period and amino acid studies and mineral composition of fish heads before and after drying.

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