CSIR COLLEGE OF SCIENCE AND TECHNOLOGY

USE OF IMPROVED SUN AND SOLAR DRYING METHODS TO PRODUCE DRIED ANCHOVIES (*Engraulis encrasicolus*) AND ATLANTIC BUMPER FISH (*Chloroscombrus chrysurus*) POWDER AND INCORPORATE THEM INTO NEW FOOD FORMULATIONS

ERNESTINA ASANTEWAA AYEH

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BY

ERNESTINA ASANTEWAA AYEH

Thesis submitted to the Department of Agro-processing Technology and Food Biosciences of the CSIR College of Science and Technology, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Food Science and Technology

AUGUST 2021

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this College or elsewhere.

Candidate's Signature ……..Date……

Name: Ernestina Asantewaa Ayeh

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of the thesis laid down by CSIR College of Science and Technology.

Principal Supervisor's Signature……Date……..

Name: Prof. Paa-Nii T. Johnson

Co-Supervisor's Signature……Date…….

Name: Prof. Wisdom Kofi Amoa-Awua

ABSTRACT

Open sun drying remains one of the cheapest and predominant methods of fish processing in Ghana. However, this method has always had challenges with contaminations from dust particles, blowflies as well as major postharvest losses. The aim of the study was therefore to use improved sun-drying and solar drying methods in the production of dried anchovies and Atlantic bumper fish powder and incorporate them into new food formulations. The fish samples were processed using the following: solar drying and sun drying on the bare ground, raised concrete platform (RCP) and raised concrete platform with netted drying racks (RCP+NDR). The samples were analysed for their microbiological and nutritional qualities. Consumer acceptability was also performed on fish fortified biscuit and instant cereal mix produced from the fish powder. Samples dried in the solar dryer had the fastest drying rate, lowest moisture content thereby the highest concentration of nutrients ($p<0.05$). Microbial quality of solar and RCP+NDR dried fish samples were comparable. Aerobic mesophilic count of the bare ground dried fish samples was the highest amongst all the samples with 5.89 $\log_{10}$ CFU/g for anchovies and 5.70 $\log_{10}$ CFU/g for Atlantic bumper fish. RCP+NDR dried fish samples proved to have better safety qualities than those sampled from the processing sites. Consumer acceptability of fish fortified biscuit and instant cereal mix showed that products with lower fish concentrations (5 % and 3 % fish powder respectively) were preferred. Traditional bare ground method of drying fish should be replaced with RCP+NDR since it produces safer products which meet regulatory requirements and have better nutritional and organoleptic qualities comparable to the solar dried fish.

KEY WORDS

Anchovy

Atlantic bumper fish

Dried fish fortified cereal products

Drying curve

Solar drying

Sun drying

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DEDICATION

To my family and loved ones

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LIST OF ACRONYMS

CSIR	- Council for Scientific and Industrial Research
FAO	-Food and Agriculture Organisation
FPP	- Fish Protein Powder
FRI	- Food Research Institute
GSA	- Ghana Standards Authority
ICMSF	- International Commission on Microbiological Specifications for Foods
RCP	- Raised Concrete Platform
RCP+NDR	- Raised Concrete Platform with Netted Drying Racks

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CHAPTER ONE

INTRODUCTION

This chapter introduces the study by giving the background information of the research, statement of the problem, hypothesis and justification of research. It also provides the objectives of the study, delimitations and limitations as well as the organization of the entire study.

Background to the Study

In recent years, demand for fish and seafood products has steadily increased because fish is now accepted as a major animal protein in many parts of the world. This development may be due to the greater understanding of the unique qualities of fish nutrients by consumers. It has been estimated that fish supplies 16 % of the total animal protein consumed worldwide (Food and Agricultural Organisation [FAO], 2018). This is especially the case in countries with low wages since it is more affordable compared to beef. In Ghana, fish contributes 60-70 % of the animal protein consumed. Total annual requirement for fish for the country is estimated at 880,000 metric tons (Frimpong & Adwani, 2015). Many studies have highlighted its nutritional properties, showing that apart from its rich protein content, fish contains essential micro-nutrients such as riboflavin, iron, calcium and fatty acids (omega-3) , which are essential for human health, especially during childhood (FAO).

Fresh fish is highly susceptible to spoilage since it contains up to 80 % water (Reza, Azimiddin, Islam, & Kamal, 2006). The main causes for rapid fish spoilage are the autolytic and microbial processes, which are initiated

immediately after the death of the fish, as well as during processing and sometimes storage (Anihouvi, Kindossi, & Hounhouigan, 2012). Fish is also often the source of food poisoning because of the presence of food poisoning microorganisms such as *Clostridium botulinum, Escherichia coli, Salmonella, Staphylococcus aureus, Vibro* species and *Bacillus cereus* (Saritha, Immaculate, Aiyamperumal, & Patterson, 2012). Processing of fresh fish into stable and safe products is therefore important to enhance quality and shelf-life.

Fishing and fish processing (mainly smoking and drying) are the most common means of livelihood in coastal towns in Ghana. Fish, depending on the species, is either smoked, fried, fermented or sundried in the open for the improvement of its sensory quality and preservation. Anchovy (*Engraulis encrasicolus*) is one of the pelagic fishes mostly sun-dried or smoked in these areas. Open air sun-drying is a highly economical traditional method of processing and preserving foods in Ghana. However, it is largely carried out under unhygienic conditions exposing the food to dust, flies, rodents, and adverse weather conditions. This also facilitates microbial contamination of the food thus compromising the quality and safety of the food; subsequently leading to losses and health risks. (Akinola & Bolaji, 2006; Alonzo & Alexie, 2015).

Globally, the loss of fish caught due to poor handling, processing, and distribution has been estimated at 10 % by Davies and Davies (2009). However, losses during small-scale fish processing are said to be particularly high and figures as high as 40 % are sometimes reported. This waste also translates into huge financial losses and reduction in the quantity of available

fish supplied for human consumption, thereby threatening food security (Akintola & Fakoya, 2017).

The drying operation, even though a very ancient practice for food preservation, presently continues to be an important industrial process of treatment for diversified food products. Much innovation and technological advancements have led to better drying processes, which are more efficient and allow a better preservation of the organoleptic and nutritional qualities (Guine, 2018). In view of this, some countries have developed inexpensive and user-friendly improved platforms and racks for sun drying of fish. This helps to reduce microbial contamination to a minimum by providing a covering for the fish against flies, dust etc. and reduce human contact during drying. Overall, small fishes are rich in micronutrients and its frequent consumption in everyday diets, contributes to the intake of multiple micronutrients and proteins from a meal (Abbey, Glover-Amengor, Atikpo, Atter, & Toppe, 2017).

The Ghanaian diet largely consists of starchy staple foods like cassava, yams, bananas and cereals (rice, maize, millet, sorghum), with fish being central in the local cuisine serving as a complementary addition (Nti, 2008; FAO, 2010; Kawarazuka & Béné, 2011; Weichselbaum, Coe, Buttriss, & Stanner, 2013). There is however an increasing shift towards quality and safe ready- to -eat snacks or convenience foods (Staatz & Hollinger, 2016). The incorporation of fish powder as a form of fortifying snacks such as biscuits, waffles and instant cereal mix for infants can therefore be exploited. This will go a long way to reduce micronutrient deficiency that persist amongst the

population especially amongst children under five years and pregnant women (Hasselberg *et al*., 2020b).

Statement of the Problem

Sun-drying remains one of the ancient and predominant methods of fish processing in Ghana. The availability of the sun's energy for food processing makes this method one of the cheapest. Sun -drying processing of fish thereby serves as a means of livelihood for many processors in Sub-Saharan Africa. However, the traditional open air-drying method of processing mainly involves drying the fish on the bare ground. This exposes the fish to flies, dust, rodents and other agents which serve as a conduit for microbial contamination. The contamination may not be limited to spoilage microorganisms, but to growth and multiplication of pathogenic bacteria, which raises concerns about the safety and quality of sun-dried fish. This is particularly important since subsequent processing may not eliminate such microbial hazard. In addition, whilst being dried using the traditional method, fish is exposed to adverse weather conditions and this leads to huge revenue losses to the fish processors, who happen to be mostly women.

Even though solar drying has been proven to produce safer and better quality dried fish, the cost of construction may not be affordable to low income fish processers, as research has shown. This has resulted in the continual usage of the traditional sun-drying processing. A research by Sankat and Mujiaffar (2004) showed that some limitations of sun-drying can be eliminated or reduced by raising the drying fish rack off the ground on wooden frames. This allows air to circulate in all directions, thus facilitating

water evaporation from both sides and reducing contamination from dust. However, there is limited information of such approaches being used for fish processing in Ghana. There is therefore the need to investigate an alternative means of processing fish by sun drying with improved, cost effective and user friendly technologies.

Low value/ underutilized fishes (especially small pelagic fishes) are usually used for fish meal production to feed livestock. They are also used in some indigenous foods. With the increasing demand for convenience foods cutting across income groups, these low value/underutilised fishes may be converted to highly valuable products that are rich in micronutrients (Arason, Shaviklo, Thorkelsson, Sveinsdottir, & Rafipour, 2011b; Shaviklo, 2016). However, despite widespread recognition of their nutritional values, few examples exist on the use of dried fishes and their powders in food product development.

Purpose of the Study

The objective of the study was to use improved sun-drying and solar drying methods in the production of dried anchovies (*Engraulis encrasicolus*) and Atlantic bumper fish (C*hloroscombrus chrysurus*) powder and incorporate them into new food formulations.

Research Objectives

1. To compare the effects of the use of solar- drying and two improved sun-drying methods (raised concrete platform and netted racks) on the proximate composition of dried anchovies and Atlantic bumper fish.

2. To assess the effect of solar-drying and the two improved sun-drying methods on the microbiological safety of dried anchovies and Atlantic bumper fish.
3. To develop new food formulations using dried anchovies and Atlantic bumper fish powder and assess their consumer acceptability.

Hypothesis

Ha: Improved sun- drying method of fish, using netted drying racks on raised concrete platform, would produce better quality and safer dried fish than open-air sun-drying method, but comparable to those by solar drying method.

Ho: Improved sun drying of fish, using netted drying racks on raised concrete platform, would produce fish of the same quality and safety as that of the open-air sun-drying method and will not be comparable to those from solar-drying.

Significance of the Study

Sun- drying processing of fish aids in reducing postharvest losses of fish and serves as a means of livelihood for most of the processors. However, the traditional rudimentary processing method involving the use of traditional open sun-drying has not received much improvement over the years. This improvement include reducing the exposure of fish being dried to dust, flies, adverse weather condition and other agents of contamination. Several studies carried out on the use of solar dryers have shown that it is the best method for preventing microbial and other forms of contamination during the drying of

fish. Due to the design of the solar dryer, drying parameters such as temperature (normally 60 ^{o}C), relative humidity and air speed are more controlled resulting in products with lower water activity. This ensures that certain microorganisms do not grow and multiply on the fish. Further, other enzymatic processes do not occur making the fish dried by solar assuredly safer than those by sun-drying (Banda *et al*., 2017). Notwithstanding, construction of a long-lasting solar dryer comes at a cost which may not be affordable for low-income fish processers (Chiwaula, Kawiya, & Kambewa, 2020).

This study is therefore aimed at developing fairly inexpensive and user-friendly raised concrete platforms, with netted drying racks, for sun-drying of fish, which will reduce drudgery associated with traditional sun-drying and also postharvest losses. In addition, microbial and physical contamination as a result of processing will be reduced since fish is protected because of less human contact during processing. This will go a long way to produce safer and better quality sun dried fish comparable to those of the solar dried fish. Also, the growing consumer demand for convenience foods including snacks can be exploited by developing nutritious and healthy snack fortified with fish powder produced from underutilized small fishes. Increasing the protein content of snack foods may further improve their consumer appeal and acceptance. The development of ready-to-eat snack such as waffles and biscuits with small pelagic fishes will diversify the usage and also maximize their utilization. This could lead to the provision of ready market for sun dried fish and lead to the strengthening of food security and sustainable livelihoods among fish processors and consumers in Ghana.

Delimitation

Although there are various methods of fish processing, this research was focused on using an improved sun-drying method that incorporated netted drying racks on raised concrete platform to improve the open-air sun drying of fish.

Limitations

The outcome of the drying processing is highly dependent on the use of two small fishes, anchovies and Atlantic bumper for the research and may require several varieties of fish species to be used before results are generalized. Also, consumer acceptability outcome of products is subject to the discretion of the panellist, therefore the need to replicate in larger sample size to increase the generalization of the results.

Organisation of the Study

The study is presented in six chapters. Chapter one provides information on the background of the study, statement of problem, hypothesis, justification of research, including objectives of the study, delimitations and limitations of the study, and the organization of the study. An in-depth review of relevant literature to the subject area is presented in chapter two. The third chapter gives details of the methods used in achieving the study objectives. The results of the study and the discussion of the results are provided in chapters four and five, respectively. The last chapter, chapter six, summarizes the entire study, draws conclusions from the results and gives recommendations based on the findings of the study.

CHAPTER TWO

LITERATURE REVIEW

In this chapter, relevant literature pertaining to the thesis was reviewed. Topics that were reviewed in relation to the thesis include: fish production in Ghana and its importance, drying methods for harvested fish and the principles behind them. In addition, the effect of the drying methods on the nutritional, microbial and the drying rate of fish were also presented. Finally, information on the use of fish in food fortification to meet the nutritional needs of consumers was also presented.

Fish Production in Ghana

The most preferred source of animal protein in Ghana is fish, accounting for about 60 % of animal protein intake. Ghana has a high per capita consumption of fish estimated at 25 kg compared to world average of 16 kg per capita per annum for the period 2009- 2011. About 75 % of the total domestic production of fish is consumed locally (Vi*sciano,* Schirone, Tofalo, & Suzzi, *2*012). The marine fisheries sector in Ghana is composed of four main fishing subsectors: artisanal fisheries, inshore fisheries, industrial trawl fisheries and tuna or large pelagic fisheries. The artisanal fisheries subsector is the most important with respect to landed weight of fish, contributing about 60- 70 % of total annual marine fish output. Small pelagic fish species such as round sardinella, flat sardinella, mackerel (horse mackerel, chub mackerel), and anchovies, represent over 80 % of the total small pelagic fish stocks in Ghana. The fisheries sector plays an important role in its contribution to the nation's gross domestic product (GDP), accounting for about 5 % of the

agricultural GDP, with total earnings of approximately 62 million US Dollars in 2010 from fish and fishery products (Antwi-Asare & Abbey, 2011; Dovlo, Amador, & Nkrumah, 2016).

The sector's performance is critical for economic growth, food security, poverty reduction and sustainability of the coastal communities since it employs about 107,518 fishermen and 4,241 fish processors which are mostly women. The returns accruing to artisanal fisheries are affected by several factors including limited value addition and consequent post-harvest losses, weak backward-forward market linkages, poor infrastructure, low bargaining power, as well as low and lack of variety of catch (Quagrainie, 2019).

Traditionally, about 60 % of fish in Ghana is smoked, 10 % is sundried or salted using traditional methods and the rest fried, grilled or steamed or sold as fresh fish in the open market. Other than for human consumption, some fish such as anchovy and tuna officially are used for fish meal (Visciano *et al*., 2012). The artisanal sector employs 80 % of Ghanaian fishers. Although, it is typically men, women play an important role in artisanal fisheries, being almost solely responsible for selling the fish in markets (Akrofi, 2002). They control the marketing, dominate the processing and distribution of fresh fish and even contribute to the acquisition of new fishing nets and canoes (Nunoo, Asiedu, & Kombat, 2015). An informal but strong institutional framework governs artisanal fisheries at the village level (Bennett, 2000; Bailey *et al*., 2010).

Importance of Small Fish and their Products

The marine fish resources of Ghana are usually grouped as small pelagics; large pelagics; demersal; mollusc and crustaceans. The small pelagics cover a wide range of species and are the most abundant marine resources in Ghanaian waters. Four species that are of economic importance are the round sardinella (*Sardinella aurita*), flat sardinella (*S. maderensis*), chub mackerel (*Scomber japonicus*) and anchovy (*Engraulis encrasicolus*) also known as '*abobi* or *amoni*' (Ewe) or '*keta school boys'* (Ga). The large pelagics are mainly tunas. However, small fish have been categorized as having been overfished and there have been declining stocks over the past 28 years (Sarpong, Quartey, & Harvey, 2005; Environmental Justice Foundation [EJF], 2020). Household surveys suggest that small fish, some aquatic animals and processed fish of low market value play a very important role in the diet of the poor. Other advantages small fish offer include the following:

1. They can be processed and stored for a long period of time.
2. They are more affordable for the poor and vulnerable groups particularly in rural and urban areas where limited economic resources prevent dietary diversity.
3. They can also be purchased in small quantities; and can be more evenly divided among household members (Kawarazuka & Bene, 2011).

Consuming small- sized fish species whole (with the bones inclusive), head and viscera contributes significantly to reducing the level of micronutrient and protein malnutrition, as these parts are where most micronutrients are

concentrated. (Thilsted, Roos, & Hassan, 1997; Chamnan *et al*., 2009; Roos, 2001; Abbey *et al*., 2017)

Fish in general are a good source of protein containing almost all the required essential amino acids including the likes of methionine, and cysteine. Small pelagic fish have a known protein content of about 14 to 22 % of the live body weight and as such provide very high-quality animal protein proportional to their muscle biomass. They are particularly high in essential amino acids. Their lysine content is recorded to be more than 10 % of their total protein content and this varies depending on the fish species. This makes fish suitable for complementing the high carbohydrate diets prevailing among the poorer population in both the developed and developing countries. The incorporation of even little quantities of this small fishes can significantly improve the biological value of the diet of young children and lactating women whose protein requirements are much higher.

Small fishes are more nutritious than big ones because they supply relatively higher amounts of minerals per unit weight given that they are often consumed whole with bones and everything, providing exceptional quantities of calcium and other minerals (Thilsted & Roos, 1990). Vitamins A, B_1, B_2 and B_3, D and E are also present in substantial quantities in small fish. Generally, vitamin A from fish sources are much higher and more readily accessible to the body compared to that from plant sources. Again, it has been discovered that the vitamin A content of some small fish is twice as high as the content of carrot or spinach. Thus, the frequent consumption of small fish in the absence of vegetables especially among poor rural families, can help meet their daily requirements (Roos, 2001; Chamnan *et al*., 2009). In a study

by Roos, Chamnan, and Loeung (2007), it was discovered that daily intake of small fish contributed to about 40 % of one's daily vitamin A requirement as well as 31 % of that of calcium at household levels.

Small and fatty pelagic fish like small tuna, mackerel and sardines contain incomparable components for the diets of pregnant and lactating women, since they are the richest source of the fat necessary for the correct development of the brain in unborn babies and infants (Lymer, Funge-Smith, Clausen, & Miao, 2008).

Locally available fish have often been utilised as an ingredient in complementary feeding for infants in some developing countries where under nutrition is a public health concern. A study in Ghana on the nutritional role of local fish in complementary food established that, fish powder from smoked anchovies mixed with local fermented maize porridge supported growth of infants to the same extent as a cereal-legume blend with a vitamin- and mineral-fortified supplement. This indicates the potential role of local fish in improving infant growth (Lartey, Manu, Brown, Peerson, & Dewey, 1999). Sardinella and other small pelagics are also widely used in the traditional hot pepper sauce (*shito*) popular with students, homes and eating joints in Ghana (Kawarazuka, 2010). A research in Uganda also reported that dried small fish used to supplement porridge for undernourished children gave a better outcome in weight growth and mortality as compared to the diets of imported skimmed milk used for undernourished children in hospitals. Fish can therefore be used as an alternative for complementary food for children where milk is not available or affordable (Greco, Balungi, Amono, & Iriso, 2006). Small pelagic fish including anchovies also provide significant amount of fatty

acids especially the polyunsaturated fatty acids, which includes omega-3 fatty acids. This lowers blood pressure, reduces the risk of heart disease (Wang *et al*., 2006), and possibly improves infant growth and cognitive development (Koletzko, Cetin, & Brenna, 2007; Tacon & Metian, 2009).

Additionally, fish contains large amounts of haem iron which is characterized by high bioavailability as opposed to non-haem iron found in plants. A study conducted in Cambodia found that the serving of sour soup made with small fish species, supplied an average of 45 % of the daily requirement of iron in women of childbearing age and 42 % of that in children (Roos *et al*., 2007). Small fish are also rich in zinc compared with other animal-source foods and large fish species. Another survey showed that fish contribute between 33 to 39 % of the total daily requirement of zinc in children and women, respectively (Chamnan *et al*., 2009). Small fish in a plant-based diet is therefore expected to increase zinc intake considerably and to compensate for the low bioavailability induced by the phytate of the staple foods. Overall, all small fish consumed with bones have high calcium content with a bioavailability comparable to that of milk (Hansen *et al*., 1998). Some species however have higher calcium content up to eight times higher than in milk and can provide for the calcium requirement in populations with low intakes of milk and milk products (Larsen, Thilsted, & Kongsbak, 2000). According to a study conducted in Bangladesh, an average daily small fish consumption of 65 g/person can meet 31 % of the average daily requirement of calcium in adults (Roos *et al*., 2007), and 53 % in children (Gibson, Yeudall, & Drost, 2003; Kawarazuka & Bene, 2011). The fact remains that small pelagic fish are nutrient dense and can provide an affordable and much

needed source of high-quality animal protein and essential amino acids, omega-3 fatty acids, vitamins, minerals, and trace elements at affordable prices. This is mostly because the fish is eaten wholly with the head and bones. It is no doubt that the production and consumption of small fishes can help contribute significantly to nutritional as well as livelihood of individuals, particularly people living in the rural areas. It is therefore imperative that more resources are channelled towards ensuring a more balanced approach for the sustainable production of small fish.

Fish Microbial Activities/Fish Spoilage Mechanism

Fresh fish after harvest is highly susceptible to spoilage due to high moisture and nutrients content, making it a good substrate for pathogenic and spoilage microorganism if not handled appropriately. Due to the high mesophilic bacteria load on fish harvested in the tropics, it turns to decay faster if chilling is delayed since temperatures between 35-37 ^{o}C are favourable for their proliferation (Smulders & Collins, 2002). Spoilage of harvested fish is mainly caused by microbial, metabolic, chemical oxidation of lipids and biochemical changes (involving enzymatic and oxidative reactions) (Pal, 2012). The time required for spoilage to commence in a fish may be due to a number of factors; high moisture content, ambient temperature, the fish species, unhygienic handling and time, high fat content, high protein content, the method of capture and weak muscle tissue of the fish. These factors, if not controlled result in the formation of aldehydes, alcohols, ketones etc., which are associated with unpleasant odours, texture and off-flavours (Gram & Dalgaard, 2002). In high temperature zones, spoilage usually starts after 15-20

h of capture. At the fish death, there is first a loss of freshness due to autolytic enzyme activity. This is followed by the movement and spreading of microbes present in the fish through the muscle fibres leading to spoilage. Spoilage occurs both in fresh and lightly preserved fish and fish products. The action of bacteria during the spoilage process degrades available proteins and leads to a decrease in the nutritional value. Bacterial spoilage in fresh fish can also produce toxins (eg. histamine) which cause food poisoning.

It is estimated that one-fourth of global food supply and 30 % of the world's fish landed is lost through microbial contamination alone (Ghaly, Dave, Budge, & Brooks, 2010). A prime source of microbial exposure to any fish is its habitat. Fish microbes can be found both on the outside on the skin/slime and inside in the gills and the gut. Huss (1995) estimated the total number of microorganisms that could be found in the guts and the surface of fish to be between 103-109 CFU/g and 102-107 CFU/g respectively. Adebayo-Tayo, Onilude, Bukola, Abiodun and Ukpe (2006), reported that the types of microorganisms found in the intestines of fish are psychotrophs, and could possibly give an indication of the general contamination in the aquatic environment. *Pseudomonas angulluseptica* and *Streptococcus spp* are among the identified potentially pathogenic bacterial species likely to be observed in any fish (Emikpe, Adebisi, & Adedeji, 2011). Other bacteria include *Enterococcus, Shewanella, Escherichia coli, Aeromonas, Listeria, Alcaligenes, and Enterobacter*. Fungi such as the *Candida, Rhodotorula Aspergillus, and Cryptococcus spp*. were also identified (Pal, 2012).

According to Gram and Huss (1996), the high composition of non–protein nitrogen compounds and low acidity (pH> 6) of the flesh of seafoods

are the major cause of their spoilage, as these conditions favor the growth of spoilage microorganisms. These microbes in turn produce metabolites that affect the organoleptic properties of the products and render them undesirable attributes. Similarly, autolytic activities by endogenous enzymes of seafoods also result in products that initially cause lose of the characteristic fresh odour and taste of fish and then softens the flesh. These changes start short after the death of fish and progress to produce a number of volatile compounds which give the products their spoilage characteristics (Mahmud, Abraha, Mohammedidris, & Mahmud, 2018).

The spoilage of the local anchovies is increased due to poor handling, since the fish, because of its small size, is not gutted during processing, and not stored on ice in spite of the high ambient temperature. These conditions accelerate the viscera releasing bacteria and enzymes which invade the flesh (Abbey, 1998). Therefore, in preserving fish, temperature must be well considered as this can greatly influence microbial activity especially between the range of zero (0) to 25 °C. At zero (0) °C however, the growth rate of microbes is less than one-tenth of the rate at the optimum growth temperature. The number and diversity of microbes associated with fish depend on the geographical location, season and the method of harvest.

Direct transfers through surface contact and factors such as personnel, pests, air movements through activities such as the handling, stowing, cutting, cleaning, and packaging of fish also lead to enhanced microbial activities in fish (Pal, 2012). Bremner (2002), found that fish handling, washing, salting, drying and storage are the critical control points in fish processing since potential hazards are bound to occur at these processing points. Even though

the spoilage patterns of fish progress simultaneously, speeding up the overall spoilage of the products, the preservation methods intended to stop the various spoilage patterns are directed to target these causes in different approaches to extended the shelf life of processed fish (Mahmud *et al.*, 2018).

Traditional Fish Processing Methods

The perishable nature of fresh fish demands it to be preserved shortly after capture to maintain its quality. This can be carried out either on board the fishing vessel or on land depending on the method being used. In Ghana, there are several available methods for preserving fish including both traditional and modern techniques. The choice of preservation method is very key as this can influence flavour and texture, thus, resulting in a range of different products. Besides the benefit of increasing shelf life, preserving fish helps to reduce food waste in times of abundant harvest and also makes packaging easy for transportation. Preserving fish can be done by applying either the concept of moisture content reduction by salting, smoking and drying; cooking via boiling or frying; pH reduction by fermentation or temperature control with the use of ice or refrigerators. Salting, fermenting and drying/smoking are three commonly practiced methods of preservation in Ghana.

The post-harvest management of fish is mostly carried out by the informal sector of the Ghanaian economy. It is a form of livelihood to many traditional processors living in near-shore towns in Ghana (Ames, Gorham, & Abrams, 1999; Mustapha, Ajibola, Salako, & Ademola, 2014). Wazed, Islam, and Uddin (2009) estimated that about 30 % (about 307,500 MT) of the freshly harvested fish is spoiled every year due to lack of proper preservation

facility. About 40 % (71,750 MT, dry weight) of the remaining harvested fish is dried. Among the dry fishes, about 60% (43,050 MT) is contaminated by both insects and insecticides and therefore are not fit for human consumption.

Generally, fish processing methods could be high or low temperature treatments. These include chilling, freezing, canning, smoking, drying, salting, frying and fermenting, sun-drying, solar drying and grilling. Various combinations of these do give the fish product a form which is attractive, fresh to the consumers with prolonged storage life. These processing methods have different applications, techniques and significant influence and effect on the chemical, physical and nutritional composition of processed fish. This is because heating, freezing and exposure to high concentration of salt lead to chemical and physical changes. Ultimately different quality could be obtained through these methods, hence subsequent effect on processed fish's shelf life also varies (Lourdes, Fernaldo, & Carrenol, 2007; Abraha, Xia, & Fang, 2018).

Fermentation

The process of fermentation is known to be indigenous with African culture. In Ghana, just as in many other African countries., it remains one of the commonest methods of preserving fish. Fermentation of fish is the controlled action of the desirable or beneficial microorganisms in order to alter the flavour or texture of the fish and extend the shelf life. These bacteria increase the acidity of the fish and therefore prevent the growth of spoilage and food-poisoning bacteria. The fermentation and degradation of the fish-protein are controlled by the addition of salt. The concentration must be high

enough to inhibit the growth of pathogenic and spoilage bacteria, but still at a level where fermentative microorganisms and enzymes can be active to soften (break down) the flesh (Wazed *et al*., 2009).

Enzymatic ripening and maturation are important processes constantly taking place in every semi-preserved cold stored fish product which has not been heat treated. This means that both textural and organoleptic properties change during storage. Enzymes in the cell such as cathepsins although present in low concentrations partly digest muscle proteins and even connective tissues during long storage, giving the products a softer texture and a more rich flavour. Application of such methods normally concerns major fish products like fillets or whole fish, but salting is also applied for semi-preservation of by-products like tongue, cheeks and even cod swim bladder which is an attractive consumption product in Southern Europe (Bremner, 2002). The fermentation period takes several months. In Africa, mainly partially fermented products are consumed. The processing often involves salting and drying, and the fermentation period lasts only a few days. Due to the breakdown of protein these products have in general a quite strong odour (Sampels, 2015). In Ghana, fermented fish is locally known as *Koobi, Ewule, Kako* or *Momone* and they differ not just in terms of the type of fish species used but also by the duration of fermentation. The basic processes involved includethoroughly washing and dressing fish, salting, and leaving the fish to ferment for a couple of days.

Smoking

Smoking is one of the oldest methods of processing and preserving fish as well as creating new products with certain organoleptic characteristics and texture (Arvanitoyannis & Kotsanopoulos, 2012). During the smoking process, pre-salted, whole or filleted fish are treated with smoke from incomplete wood burning or combustion. Traditionally, hardwoods such as maple, oak, alder, hickory, birch and fruitwoods are normally used (Moody, Silva, Prinyawiwatkul, & Day 2002). The various techniques and the types of wood used lead to the typical taste of the final product (Jonsdottir, Olafsdottir, Chanie, & Haugen, 2008). Various compounds such as organic acids, alcohols, carbonyls, hydrocarbons, phenols etc., arise during the pyrolysis of the wood. These are responsible for the preserving, antimicrobial and antioxidant effect of the smoke (Hall, 2011). Smoking have a drying effect and therefore decreases the water activity and also increases the inhibition of bacterial growth thereby minimizing spoilage, increasing storage shelf life and the availability of fish to consumers. In addition, the dried surface of the smoked fish or products is a barrier against microbes (Hall).

Smoke density, concentration of active components of smoke in combination with salt content, and time and temperature of smoking, affect the spoilage and pathogenic microflora of smoked products (Adeyeye & Oyewole, 2016). Therefore if the time, temperature and type of wood is not controlled and selected as per the standards, chemical, physical and nutritional contents of smoked fish products will be affected. There is a production of polycyclic aromatic hydrocarbons (PAHs) which contaminate smoked fish especially if the process is not controlled adequately (Guillen, Sopelana, & Partearroyo,

1997). This poses certain diseases on consumers from carcinogenic effect of woods. The changes resulting from smoking of fish are hard texture, colour change ranging from golden brown to black and loss of heat sensitive nutrients (Horner, 1997).

Smoking of fish can be categorized into hot and cold smoking, depending on the amount of temperature and preference of consumers. The temperature of cold smoking does not exceed 30 or 33 °C, whiles hot smoking temperature can reach up to 80 or even 100 °C resulting in fully cooked products (Moody *et al.*, 2002; Hall, 2011; Arvanitoyannis & Kotsanopoulos, 2012). The intensity of heat generated during smoking can lead to the denaturation of protein and amino acid of fish and this leads to alteration in the physical and chemical properties of protein. This causes a reduction in the biological availability of protein. Belitz, Gorsch and Schieberle (2009) showed that overheating might occur in most traditional smoking methods of fish processing. This significantly reduces the availability of essential amino acids (methionine, tryptophan and lysine) (Abraha *et al*., 2018).

Solar drying

Solar dryers have been developed worldwide as a means of concentrating solar energy for drying, cooking and other purposes (Eyo, 2001). It differs from open sun-drying in that a structure, often very simple in construction is used to enhance the effect of the sun's radiation since solar dryers are enclosed structure (Ojutiku, Kolo, & Mohammed, 2009). Most designs have a glass or plastic cover that increases the temperature of the air around the fish, and hence accelerates the drying. The solar dryer depends on

concentration of radiation through plastic or the glass surfaces; combined with the greenhouse effect for trapping heat within a small enclosure where fish is placed. The trapped solar energy increases drying efficiency by reducing relative humidity in the enclosure which helps to evaporate moisture from the fish. This method has found wide application in the drying of fish (Olokor & Ngwu, 2001). Solar drying as an improved method of sun-drying, minimizes or eliminates some of the limitations of open sun-drying. Solar-drying protects food from dust, insects, pests and minimizes case hardening which may occur from direct exposure to sunlight (Sacilik, Keskin, & Elicin, 2006; Jon & Kiang, 2008).

A research on different forms of drying of fish showed that solar tent dryer required less time; 58 h, to complete the drying process. This is due to the circulation of hot air within the solar tent dryer, which increased internal dryer temperature and reduced drying time. Raised bamboo platform placed in the open place required 82 h for drying fish. The fish dried on black polythene required the longest drying time of 130 h. This was due to the accumulation of water on the black polythene sheet, which was absorbed by the fish again. Abraha, Samuel, Mohammud, Admassu and Al-hajj **(**2017**)** and Relekar *et al*. (2014) observed that 3 days were required for fish drying in solar tent dryer. Also they reported that fish dried on sloping rack-required 4 days for reducing moisture up to 20 percent. A research on solar tunnel dryer designed by the Asian Institute of Technology (AIT) showed that the dryer was efficient for the processing of products, with better biochemical, microbiological, as well as good textural qualities and pleasant odour (Chavan, Yakupitiyage, &

Kumar, 2011). The dryer had an efficiency of 19.87 percent when used in drying of mackerel which was stored up to 120 days.

Solar dryers can be categorized into two classes based on the mode of air flow through the dryer- natural convection and forced convection. Dryers that employ forced convection require a source of motive power, usually electricity, to drive the fan that provides the air flow. In many areas of tropical developing countries, motive power from any source is either unavailable or, at best, unreliable and expensive, and forced-convection dryers would not be a practical proposition for the majority of artisanal fishermen in these areas. Some examples of innovative solar dryers include; Solar Tent Dryer (STD), Plastic Dryers, Mosquito Net Dryers, Aluminium Dryers and Glass Dryers (which contain black stones) (Akintola & Fakoya, 2017).

Improved dryers capable of rapid drying under dust-proof conditions have the following characteristics:

1. Greenhouse effect by fitting transparent air-tight coverings over the products exposed to the sun
2. Increased thermic absorption by blackened surfaces
3. Air circulation by convection (air inlet low-air outlet high)
4. Possibility of increasing thermal absorption by arranging black surfaces in rows alternating with rows of exposed products in upwards order

Possibility of certain adjustments: regulation of air circulation by partial closure (total closure during night) of air inlets and outlets, shade drying by covering or semi-covering of exposed products (Akintola & Fakoya, 2017). The solar energy received by the drying chamber of solar dryers is dependent

on the sunshine hours, climate, weather, atmospheric clearness, and location (Dhumne, Vipin Bipte, & Jibhkate., 2016). According to Ekechukwu and Norton (1997), solar dryers may further be sub-grouped into three categories: integral type (direct mode), distributed type (indirect type) and mixed mode. In a direct type, solar drying material is placed in a drying chamber with a transparent cover through which solar radiation enters and heats the food materials to be dried. In an indirect type, solar energy is captured by a solar collector, which in turn heats the air. This heated air is then passed to the drying cabinet/chamber. In mixed mode, solar energy is collected in separate solar collector and heated air is then passed over the drying material. The drying materials absorb the solar energy directly through the transparent cover (Dhumne *et al*.).

Sun drying

Traditionally, sun drying of fish carried out under the open sun is the simplest and cheapest preservation technique used from days immemorial to preserve the fish (Jain & Pathare, 2007). Effective open sun drying is mainly dependent on the environmental temperature, relative humidity and wind speed. Drying temperature and time are the main factors which affect nutritional composition of fish. Taking this into consideration, drying would be appropriate at 60 °C for 15 h or 70 °C for 10 h (Idah, 2013; Abraha *et al*., 2018a).

Drying as a method of preservation improves the stability or shelf life of fish by reducing the water and microbial activity as well as physical and chemical changes during storage. This maintains the quality of the fish in

terms of its nutrient, flavour, texture, and appearance, (Darvishi, Farhang, Hazbavi., 2012; Abraha *et al*., 2018) and brings a substantial reduction in weight and volume, minimizing packaging, storage and transportation costs (Vega-Galvez *et al.*, 2009). It also reduces post-catch losses especially in the period of glut, thereby ensuring continuous availability of cheap animal protein to people all year round.

Traditionally, whole small fish or split large fish are spread in the sun on the sandy -ground, or on mats, nets, roofs or on raised racks, on rocks, grasses along the beach for a period of one to three days to dry (Wazed *et al*., 2009; Olokor & Ngwu, 2001). This method is preferred only for very small fish species (e.g. anchovies) which can be dried within hours. Salting the fish by dipping in brine have been found to reduce the incidence of fly larvae infestation, as does raising the fish off the ground onto racks. With the fish placed on the ground the fly larvae can move easily into the fish and return to the ground when the fish are either too hot or too dry.

Some major disadvantages with traditional open sun drying include; inability to control weather conditions or uncertainties, long processing time and poor hygiene of product. Contamination of fish with dust and other foreign particles as well as high labour cost and requirement of large drying area are additional disadvantages (Jain & Pathare, 2007; Mahmud *et al*., 2018). These go a long way to affect the quality of dried fish by causing yellowing discolorations, off-odours, high sand contents and belly bursting. These lower the prices of products (Karim, Sufi, & Hasan, 2017). Also, exposure of fish for long period of time to sunlight can oxidize the lipids, which can reduce nutritional quality and increase health risks of consumers. According to

Smida, Bolje and Ouerhani (2014), drying has a great negative effect on protein content at a lower drying speed (Abraha *et al*., 2018b). In addition, an uncontrolled growth of microbes due to prolonged processing time may lead to serious public health implications. Therefore keeping of quality and safety of the product is of utmost importance (Relekar *et al*., 2014; Ochieng, Oduor, & Nyale, 2015). Reza, Bapary, Azimuddin, Nurullah, and Kamal (2005) and Alam (2007) reported that anchovies which are spread on bamboo mat that lay on the ground are as disadvantaged as those spread on the bare ground. Having the fish on racks during sun drying have been found to allow air circulation below the fish. It is also more convenient to gather up the fish for storage under cover overnight, or when it rains (Plahar, Nerquaye-Tetteh, & Annan , 1999; Bremner, 2002).

In Ghana, Small pelagics or small fish, especially anchovies (*Engraulis encrasicolus*), atlantic bumper (*Chloroscombrus chrysurus*) and african moonfish (*Selene dorsalis*) are mainly dried under the sun directly by spreading the fish on the bare ground or beach sand for 2 to 5 days depending on the intensity of the sun. The processors mostly wash the fish once with sea water and strain, sprinkle some of the sea water on the ground and follow it with the sprinkling of the fish. Some processors also dry on concrete pavements by the roadside, stones, footbridges and open racks. Others sprinkle immediately after purchasing without any form of washing. When dried, the fish is swept into a heap with a standing broom, collected into huge baskets and covered with thick polyethylene for keeping (7 to 12 months) either in the open, under shed or store rooms until ready to be sold. Examples of these processes are found in Figure 1 and Figure 2.

(a)

(b)

(c)

(d)

Figure 1: Drying of fish in open sun (a). washing (b). sprinkling of fish (c) and (d). drying on bare ground.

Source: Field data (2020)

(a)

(b)

(c)

(d)

Figure 2: Packaging and storage of fish (a) and (b) gathering of fish (c) and (d). storage of sun dried fish.

Source: Field data (2020)

Improved Sun-Drying Methods

Traditionally, many fish processors spread fish on the ground, on rocks or on beaches to dry in the sun. Others dry on mats or reeds laid on the ground in order to minimize contamination of the fish by dirt, mud and sand. Due to the numerous disadvantages associated with open sun-drying, the use of raised sloping drying racks has been introduced as a simple, but often effective improvement in recent years (Davies & Davies, 2009). A cleaner product is obtained from rack drying since the fish do not come into contact with the ground. They are also less accessible to domestic animals and pests, such as mice, rats and crawling insects, which contaminate or consume them. Protection from rain is simply accomplished by covering the rack with a sheet of waterproof material (e.g. plastic); if fish on the ground are covered, they are protected from falling rain but not from water on the ground itself. Drying rates are also higher because air currents are stronger above the ground and air can pass under the fish as well as over them. The use of a sloping rack allows any exudate to drain away.

Nunoo *et al.* (2015) reported that, sardine processors in United Republic of Tanzania who use raised platform in the drying of fish acknowledge that they dry faster and free from sand. The buyers also find the quality to be good and are prepared to pay a higher price. In Uganda however, due to limited awareness among consumers of the quality and safety advantages of rack dried over ground-dried fish the same product does not attract a better price (Nunoo *et al*.).

A survey conducted in Nigeria showed the need for improved methods for drying of fish. It showed that fish when lifted from the ground on a net

(instead of being dried on the ground) increases the quality of the dried fish so much that drying in a solar dryer would not add further value to the fish (Jensen Frank, & Kristensen, 1999; Akintola & Fakoya, 2017)**.** Sun-drying can be improved considerably by raising the fish off the ground on wooden frames. This allows air to circulate beneath the fish, thus facilitating drying from both sides. It also breaks the cycle of insect reproduction. Research has shown that, drying fish on racks with mosquito netting reduces contamination and insect infestation considerably (Sankat & Mujiaffar, 2004; Relekar *et al*., 2014). The quality of sardine dried with fish rack, solar dryer and traditional sun drying was evaluated. It was observated that, fish rack assisted sundried and solar dried sardines tend to have better quality than traditionally sun dried sardines (Immaculate, Sinduja, & Jamila, 2012; Praveen *et al*., 2017)

A research into raised open racks for sardine drying showed that there was a significant moisture reduction of the samples and takes lesser days of drying than the traditional method. This was attributed to the efficient air circulation beneath the racks which blew away the humid water vapour collecting below the racks. The availability of mesh pores raised above the ground allowed water dripping from the samples and provided a wider flatter surface allowing single spreading of samples (Ochieng *et al*., 2015). Drying racks offer air circulation below the fish, reduces the incidence of fly larvae infestation and offer more convenience to gather up the fish for storage. A simple and hygienic wooden frame rack with tunnel structure roofs have been proposed for fish drying (Karim *et al*., 2017).

Process hygiene is greatly improved if, instead of spreading produce on open ground, a clean firm, smooth surface is employed - such as plastic

sheets, cement, concrete, wood or metal. Where land is available for the purpose, specially constructed drying floors are used, or platforms raised above ground level. The improvement in hygiene may be accompanied by a minor improvement in drying efficiency arising from the fact that the materials used to make the floor or platform absorb solar radiation more efficiently than soil, and thus becomes hotter and transfer more energy to the produce. This effect is most evident when metal sheeting such as the flat roof of a building is used. Some improved methods also involve the use of blackened surfaces. Black surfaces absorb solar radiation more efficiently than others, and so platforms for drying can be improved in this way. Jon and Kiang (2008) demonstrated that the time required to dry cassava chips on a concrete floor is reduced by about 15 % if the floor is painted black.

The use of woven matting for sun drying has also been found to speed up drying to some extent by facilitating air movement around the produce (Alam, 2007). It also makes it convenient handling the fish. Drying on mesh trays made of plastic netting stretched on wooden frames and supported by chicken wire is essentially a wind assisted drying method. The trays are mounted on bamboo supports at an angle, facing the direction of the prevailing wind. Where wind conditions are favorable, appreciable drying also occurs overnight for products which are spread in late afternoon. This effect does not occur to any significant extent for chips spread overnight on blackened concrete surfaces. This practice is adopted in Australia for sun-air drying of fruits mainly grapes and in Colombia for coffee and cassava drying. Drying on these mesh trays do not require intermittent turning of the product. Notwithstanding, it is important to maintain the required hygiene during the

different phases of fish drying in order to obtain products free of contamination (Relekar *et al*., 2014).

Effect of Drying on Physical, Chemical and Sensory Qualities of Sun-dried and Solar-dried Fish

Despite the numerous advantages of processing by drying, the chemical composition and nutrients of the food product can be significantly altered. Changes in nutritional value of dried foods may be due to the type of food, drying method, intensity of treatment (pre-treatments), and operating conditions (particularly temperature). Some measures that can be taken to reduce nutrient losses include: minimizing drying time, use of lower temperatures, and maintaining low levels of moisture and oxygen concentration during storage. One effect frequently observed when drying foods is shrinkage, which considerably affects their structure and texture (Guine, 2015; Adak, Heybeli, & Ertekin, 2017; Guine, 2018).

A study by Dewi (2002) on the effect of salting, drying and cooking protein pattern changes by electrophoresis, reported that fish proteins undergo undesirable changes in functionality and nutritional quality when processed by these methods. Fish drying tends to increase the solubility of proteins, thus degrading myosin to smaller units with lower molecular weight. Salting and drying also results in lipid oxidation by concentrating unsaturated fatty acids. This results in physical and chemical changes such as amino acid destruction, decrease in protein solubility due to polymerization, formation of amino acid derivatives and reactive carbonyl as well as changes in protein digestibility (Abraha *et al*., 2018a).

Generally**,** high moisture content of dried products favours microbial growth and infestation of the product by flies resulting in serious consumer food borne illnesses (Huang *et al*., 2010). Research has also revealed that when moisture content is reduced to 25 %, contaminating agents cannot survive and autotypic activity is greatly reduced. However, to prevent mould growth during storage, moisture content must be further reduced to 15 %. Typical microbial species of fish can generally withstand at temperature range of 45-50 ^{o}C before proteins are denatured or cooking starts (Wazed *et al*., 2009). Dried-salted fish with salt content of 10-15 %, can effectively inhibit fish spoilage, but may be a limiting factor to consumer acceptance. Some vitamins are sensitive to heat and sunlight. According to Roos, Mohammed and Thilsted (2003), almost all vitamin A in small sized fish is destroyed after sun-drying. During drying, food loses its moisture content, which results in increasing the concentration of nutrients in the remaining mass. Some vitamins are however sensitive to heat, sunlight and water, while other nutrients such as protein, fat, iron and calcium are stable, even after processing and cooking. A study in Thailand revealed that, boiling and sun drying of small fish destroys 90 % of vitamin A whiles an alternative steamed and oven-dried method resulted in only 50 % loss (Chittchang, Jittinandana, Sungpuag, Chavasit, & Wasantwisut, 1999).

Ochieng *et al*. (2015) also reported that reduced moisture content increased protein contents in dried sardines. Chukwu and Shaba (2009) investigated protein content increase in cat fish (*Clarias gariepinus*) and reported that since protein nitrogen was not lost during drying, an observed increase of proteins in dried fish samples can be attributed to the dehydration

of water molecules present between the proteins and which causes concentration of proteins in the dried fish products. Also lipid contents decreases in dried than fresh samples and the variation could have resulted from the evaporation of moisture content with lipids. Drying methods that depend on high temperature treatment have also been found to trigger lipid oxidation and result in off flavoured fish products (Mahmud *et al*., 2018). Tunison *et al*. (1990), Ojutiku *et al*. (2009) and Ochieng *et al.* (2015) all reported a slightly lower ash content, protein and fat in raised open rack dried samples than samples dried on the bare ground. However, the product quality values were slightly lower in terms of protein, fat and ash contents. This probably resulted from the nutrient concentrated waters dripping away from the samples through the rack pores during processing.

A research by Kituu, Shitanda and Kanali (2007) suggested that brining can be used to minimize the effect of drying on chemical composition of fish when used as pre-treatment. Brining reduced moisture content and played a significant role in reducing drying rate and preserving fish nutrient. Other studies have also shown that application of drying to dehydrate fish does not only remove water, but excess of such heat can affect the valuable nutritional content of the dried fish and its products. Oparaku and Nwaka (2013) studied the effect of processing on the nutritional qualities of three fish species (*Synodontis clarias*, *Trachurus trecae* and *Clarias gariepinus*). The findings showed that the fat loss phenomenon was intensive in the boiling and solar dried fish than in smoked samples. Fat may exude with the moisture evaporation through extended heat treatments (Mahmud *et al*., 2018).

Mean microbial load in raised open rack dried samples was less 1.48×10^2 CFU/ g for yeast and moulds and 1.56×10^2 CFU/ g for bacteria than those dried using the traditional drying method. This was attributed to the hygienic and safe practices during processing. This microbial load reduction in the raised open rack dried sardines suggests a safer product similar to that reported by Rahman, Guizani, Al-Ruzeiki and Al Khalasi (2000) in the case of convection air-drying where they observed significant differences in total bacterial counts (Ochieng *et al*., 2015).

Principles of Fish Drying

Drying is a process of simultaneous heat and mass transfer operation for which energy must be supplied (Yilbas, Hussain, & Dincer, 2003). The main objectives of drying are to preserve foods and increase their shelf life by reducing the water activity; reducing the need of expensive cooling systems; reducing space requirements for storage and transport; and diversifying the supply of foods with different flavours and textures, thus offering the consumers a great choice when buying foods (Guine, 2018). The principle of drying process is the removal or lowering free water available in the matrix of foods that support the growth of microorganisms, termed as water activity (a_w). This method has been proven to be effective in extending the shelf life of fishery products since fish and fishery products are known for their high moisture content in their fresh state which makes them conducive for microbial growth. However, if the drying is too rapid, it might result in layer/ case hardening (hard texture) and thus affects the palatability feature of the product undesirably. In addition, if the drying process is slow, undesirable

microbes might survive and grow (Mahmud *et al*., 2018; Cassens, 1994). The water activity levels of microorganisms are different (Mahmud *et al*., 2018).

The drying process begins with fish drying by the process of convection mass transfer immediately it is exposed to air. That is, heat is transferred to the product from the heating medium (air) resulting in mass transfer of moisture from the interior of the product to its surface and from the surface to the surrounding air. The water is moved to surface of the food by diffusion. Air speed rate and humidity are the main factors that affect the evaporation of water from fish surfaces when it is exposed. The evaporation of water from the surface continues at a constant rate until the surface begins to dry creating a moisture concentration gradient between the surface and the interior. This gradient increases water movement from the interior unto the surface. Over a period of time, the moisture loss slows down, when the moisture concentration gradient decreases, thereby decreasing the drying rate, this is referred to as the falling rate period. Moisture content of the fish will continue to decrease progressively until equilibrium is reached such that there is no further change in the moisture content of the fish. This process induces chemical and physical changes in the material undergoing dehydration. (Bremner, 2002).

Drying which involves the use of heat to vaporize water present in the food combines both heat and mass transfer for which energy must be supplied. To use hot air flowing over the food is the most common way of transferring heat to a drying material. This process is carried out mainly by convection (Cruz, Guine & Gonçalves, 2015; Guine, 2018).

Drying rate of small fishes (drying rate curve)

There are two stages in a typical drying process: the first stage is the removal of surface moisture; the second stage is the removal of internal moisture from within the solid material. Perry and Sumaila (2007) reported that drying rate periods could be categorized as: Constant rate period, First falling rate period and Second falling rate period. During the constant rate-drying period, the surface of the material is still wet and the rate of drying is governed by evaporation of free moisture from the products surface or near surface areas.

The falling-rate period of drying is controlled largely by the product and is dependent upon the movement of moisture within the material from the centre to the surface by liquid diffusion (Minkah, 2007). The water that migrates to the surface carries solutes from the food, originating tensions in the structure, variable according to the type of food, its composition and the processing parameters. The drying may cause some changes in mechanical properties, structure, volume, porosity and density of the foods (Guine, 2018). The drying process of agricultural material takes place in the falling rate period (Saeed, Sopian, & Zainol, 2006; Falade & Abbo, 2007; Nguyen & Price, 2007; Singh Shrivastava, & Kumar, 2018). This means that diffusion is the dominant physical mechanism governing moisture movement in the material (Akpinar, Bicer, & Midilli, 2003; Doymaz, 2007).

The influence of drying rate parameters on moisture ratio and drying rate of tilapia fillets was studied and it was observed that drying took place only in falling rate period. Moisture ratio decreased and drying rate increased with increase in drying temperature, drying velocity and decrease of fillet

thickness (Guan, Wang, Li, & Jiang, 2013; Praveen *et al*., 2017). The rate of drying is dependent on the vapour pressure difference between the surface of the product and the air. Drying air temperature, air velocity, shape and size of the drying particles can significantly affect the drying rate (Muliterno, Rodrigues, de Lima, Ida, & Kurozawa, 2017).

The dehydration temperature has great influence on the texture of the food and, in general, faster processes and higher temperatures cause greater changes. The high temperature causes profound physical and chemical alterations on the surface of the foods, thus leading to the formation of a hard surface layer, which keeps the foods dried at the surface but moist inside. The structural changes during drying influence the texture of the final product, according to the rate of water elimination. According to Idah (2013), drying temperature and time are the main factors which affect nutritional composition of fish. Taken this into consideration, drying would be appropriate at 60 °C for 15 hours or 70 °C for 10 hours.

If shrinkage occurs, as found in the air-dried foods, a very dense structure is formed and the dried product is harder. On the contrary, if no shrinkage occurs, like in the case of lyophilized foods, a highly porous structure is formed and the product has a smoother texture (Guine, 2018). The rate of drying was observed to be greater in sun-dried fish during the first two days of a research than that of those inside a solar dryer due to the greater flow of air around the sample. However, the drying rate during the later stage was greater inside the solar dryer. It was also reported that the quality of fish dried in the solar dryer was extremely good in terms of odour, rancidity and microbial or insect attack (Sablani, Rahman, Mahgoub, & Al-Marzouki ,

2002). Also, the air temperature when drying on the bare sand were found to be similar to that of the ambient air and the drying rates observed were higher due to the conductive heat transfer from the sand to the fish samples by direct contact. However, the potential of contaminations when drying on the bare sand was much higher (Sablani *et al*.).

Drying curve

Drying kinetics is generally monitored experimentally by measuring the weight of a drying sample as a function of time (Sopian, Saeed, & Abidin, 2008). Drying curves may be represented in different ways; averaged moisture content versus time, drying rate versus time, or drying rate versus averaged moisture content (Coumans, 2000; Sopian *et al.*). Kane, Ahmed and Kauhila (2009) reported that drying time decreased as drying temperature was increased from 40 to 70 °C and drying air flow rate was increased from 0.028 - 0.056 m^2/s. The drying air conditions have an important influence on the rate of these curves. It is apparent that drying rate decreases continuously with the moisture content. Rate of drying also increases with the increase of air-drying temperature.

Drying curves are used to show the influence of the factors, which affect the rate of drying, example: temperature, air velocity, particle size and thickness. Typically, the moisture content falls from the initial value with drying time. As drying progresses, the drying rate falls further and tends to zero as the moisture content approaches the equilibrium value.

Safety of Traditionally Processed Fish

Microbialogical safety

Fish is a highly perishable food product due to its high moisture and nutrient content. This makes it a good substrate for the growth of a wide range of spoilage and pathogenic microorganism. Improper handling and processing of seafoods, including fish, can also lead to its contamination and subsequent growth of pathogenic microorganisms. In addition, the natural occurrence of aquatic bio-toxins and natural pathogenic flora of the aquatic environment also contribute to seafood borne diseases (Mahmud *et al*., 2018). Good hygiene and manufacturing practices as well as temperature control are therefore important requirements for the prevention and inhibition of microbial growth (Sofos & Georgnaras, 2010).

Plahar *et al*. (1999) observed that quality assurance systems which help to produce high quality fish products are not in place in the whole raw material procurement, processing, storage and distribution chain of fish in Ghana. Foodborne pathogens such as *Salmonella spp*, *Escherichia coli, Shigella spp, Vibrio spp*., *Clostridium botulinum*, *Staphylococcus aureus* and *Clostridium perfringens* in tropical fish (Feldhusen, 2000) may survive, grow and eventually reach infectious levels or produce toxins (Medvedova, Valík, & Studenicova, 2009) under poor storage and handling conditions. Nketsia-Tabiri (2004) reported Total Viable Count (TVC) between 4.11 - 6.78 log CFU/g, counts of *S. aureus* between 2.85 - 4.15 log CFU/g and mould and yeast count of between 1.38-3.38 log CFU/g in market samples of salted and dried tilapia (*koobi*) in Ghana. The total viable count in this product increased to 7.5 ± 2.5 log CFU/g after 4 weeks storage under ambient conditions.

Anihouvi, Sakyi-Dawson, Ayernor and Hounhouigan (2007) also reported *S. aureus* in 17.7 % of salted and fermented traditional fish products as well as histamine, moulds and *Clostridium spp*., however, the presence of *Salmonella* was not reported.

One practice which reduces the product quality of anchovies and has the tendency of causing food poisoning is washing anchovies with turbid/dirty seawater which is normally the practice of traditional processors as the anchovies are taken from boats and taken to drying space. This reduces the cleanliness and appearance of the dried anchovies (Setiabudi, Herawati, Purnomo, & Sehabudin, 2018). Blowfly infestation of traditionally processed fish in some developing countries is a serious problem that results in significant physical and economic losses. Insects such as blowflies and beetle have been identified as vectors of bacteria in fish, as well as agents of physical damage to fish. Fish spoilage is normally characterized by softening of the muscle tissue, offensive odour with the subsequent rotting of the fish mainly caused by microbial activity.

Throughout processing, the wet fish are attacked by blowflies which lay their eggs on them and later form intensive infestation by maggots (larval stages) that penetrate the fish bodies causing significant postharvest losses Flies try to protect their eggs by laying them in depressions such as incisions in the flesh of fish or in orifices such as gills and mouth; hence by products such as heads and skeletons are ideal breeding ground for flies. The smell, especially from off-flavours resulting from microbial processes, attracts flies to the fish products. The practice of not covering fish during transportation

after catch also exposes fish to flies. Fish dried on the ground also easily gets infected with fly larvae that stay in the soil (Getu & Misganaw, 2015).

Chemical safety

Histamine level in fish is another quality index for spoilage in fish. These monoamines, according to Onal (2007), are biogenic amines formed when products such as fish in storage or under process is going bad under the action of the bacteria with histidine decarboxylase enzymes. Typical examples are the *Enterobacteriaceae* and Enterococcus family, which are mostly found in the gills, gut cavity, or added accidentally through poor handling. Histamine contamination is prevalent among pelagic fish such as mackerel and sardine. Therefore, icing of fish was suggested by Abbey (1998) to minimize histamine formation. Histamine levels above 40-100 mg and higher has been reported to cause severe food poisoning which can lead to ill health and death. Onal suggested the maximum level of histamine between 50-100 mg/kg. Codex (2007) set limits of 10 mg/ kg as indicator of decomposition and 20mg/kg as indicator of poor handling..

Generally, processing mainly controls microbiological hazards, but leaves chemical hazards or biotoxins virtually unaffected. Effective control of chemical hazards and biotoxins has to be applied mostly during primary production and the pre–harvest stages (Mahmud *et al*., 2018).

Fortification of Ready-to-eat-food Using Fish Powder

Food fortification is the addition of one or more nutrients to foods with the objective of increasing the level of consumption of the added nutrients to

improve nutritional status of a given population. Micronutrient fortification of foods commonly consumed by a given population can be a powerful strategy to combat micronutrient deficiencies in a sustainable manner. By selecting the right food ingredient to act as a 'food vehicle' of specific micronutrient(s), the need for encouraging individual compliance or changes in the customary diet will be minimized (Lotfi, Mannar, & Merx, 1996; Pee & Bloem, 2009). Even though fish constitutes 50- 80 % of consumed animal protein in Ghana (Sumberg, Jatoe, Kleih, & Flynn, 2016; FAO, 2018b), the burdens of malnutrition are a persistent and on-going challenge in Ghana. Several studies in Ghana have shown high prevalence of undernutrition, stunting, anaemia and vitamin A deficiency among children<5 years of age co-occurring with increasing obesity rates in the adult population (GSS *et al.*, 2015; Hasselberg *et al.*, 2020b).

To improve the nutritional status of moderately undernourished children, it is estimated that approximately one-third of protein should be provided by animal-source foods in the diet. By doing so, lysine from animal source foods can be fully utilised to compensate the shortage of lysine in staple foods subsequently having a significant impact on their growth (Michaelsen *et al.*, 2009). In this respect, fish is more affordable and accessible animal-source foods, and therefore fish, frequently consumed by the poor is very important, especially for women in the reproductive age and children. The incorporation of low cost but highly nutritious species of fish into our diet such as snacks for school children will help to meet partly their dietary requirement of proteins for the day and enhance micronutrient intakes.

Small pelagic forage fish such as anchovy and sardine are rich in polyunsaturated fatty acids. They are cheaper and preferably consumed by low-income households and thus have a high potential to address micronutrient deficiencies when used for fortification (Tacon & Metian, 2009). Fish bones are very rich in calcium which is about eight times higher than that of milk, and has the same bioavailability as milk (Hansen *et al.*, 1998; Larsen *et al*., 2000). Therefore, small fish consumed with bones or in a form of powder are important as a source of calcium, especially in populations with low intakes of milk and milk products.

Inclusion of small fish as a complementary food during the first 1,000 days of life have been found to significantly contribute to both macro- and micronutrient intakes in infants and young children and represents a promising food-based strategy towards improving nutrition (Bogard, Thilsted, & Marks, 2015). In a study by Egbi *et al*. (2015), the effect of adding small amounts (3 %) of fish powder made of anchovy or sardine and vitamin C to school meals proved beneficial, resulting in the prevalence of anaemia being reduced among study participants (Hasselberg *et al.*, 2020a). Gibson *et al*. (2003) also introduced fermented porridge mixed with whole- dried fish with bones and fruit as a complementary food (Kawarazula & Bene, 2011).

In recent times, demand for ready-to-eat foods that are quick and easy to prepare and consume is an increasing trend cutting across the population especially income groups. Due to lack of time, consumers are willing to pay for processors and street-food vendors to carry out some or all of the food processing and preparation for them This has led to the growing demand for post-harvest activities in the food system. At the same time, there are

increasing concerns about food safety, quality and healthfulness (Staatz & Hollinger, 2016). Ready-to-eat foods can be readily consumed without further preparation or processing and thus are extremely convenient for present-day, busy consumers (Farber, Ross, & Harwig, 1996). Market for children's food is growing and children have an increasing influence on future convenience foods and purchasing behaviour (Dodds, 2008).

Consumption of starchy snack products which are low in protein and high in fat and carbohydrates is on the increase (Ranhotra & Vetter, 1991; Rhee, Kim, Jung, & Rhee, 2004). Incorporation of functional ingredients such as fish protein powder into these starchy snack products can increase their nutritional value (Riaz 2001; Veronica, Olusola, & Adebowable, 2006).

Demands for fish protein ingredients including dried fish protein to develop functional food or ready-to-eat products are gradually growing in the world to help increase the nutrient content in diets and to expand the utilization of fishery resources (Thorkelsson, Slizyte, Gildberg, & Kristinsson, 2009; Vakily, Seto, & Pauly, 2012). Underutilized/ low value fish species and the by- products of fish processing are sources for developing fish protein ingredients (Arason *et al*., 2009a; Thorkelsson *et al*., 2009). According to several studies, sensory attributes of fish protein powder (FPP) are similar to dry fish and can therefore be successfully marketed in the areas where fish powder from dried fish is used in tasty, spicy dishes consumed with the staple dish. (Venugopal, 2006; Shaviklo, Thorkelsson, Kristinsson, Arason, & Sveinsdottir, 2010). Venugopal showed that, nutritive value of cereal proteins could be increased when combined with a fish protein powder (FPP). That is, the addition of 3 % of FPP to wheat flour (protein content, 10.4 %) increased

its protein content to 12.4 % with an increase of net protein utilisation (NPU) from 50 to 67. Successful fortification of products such as puffed corn snack, ice cream, bread, biscuits, mayonnaise, crackers with FPP have been reported. Extruded puffed corn snacks seasoned with 18 % FPP were liked by Iranian children aged 7–12 years old. This gives a further option for the utilization of fish powder (Shaviklo, Kargari, & Zanganeh, 2013). The physicochemical and sensory properties of a high-protein noodle produced by the incorporation of FPP were also evaluated. Results showed no significant difference in the colour, hardness and elasticity between the control and noodles incorporated with 5 % FPP. (Shaviklo, 2016).

Notwithstanding, fish-derived ingredients may have a negative impact on sensory characteristics despite improving nutritional and functional quality of the products (Shaviklo *et al*., 2013). Studies on sensory quality of fish-enriched foods ingredients gave negative reports both on flavour and odour, if the enrichments are done at inappropriate levels. Therefore, the level of enrichment should not affect acceptance and sensory properties of the product (Shaviklo, 2011).

CHAPTER THREE

MATERIALS AND METHODS

This chapter describes the materials and the methods used for the study. It covers the acquisition of the raw material; (fresh anchovy and atlantic bumper fish) through to processing, using four drying processing facilities to obtain the dried fish. The dried fish was then milled into fish powder, which was then utilized in the production of two food products; instant cereal mix and biscuit. In addition, fresh and traditionally dried fish samples were obtained from four artisanal processing sites and used for comparative study. Microbiological and chemical analyses were carried out on both the fresh and dried samples from the experiment and that from the processors.

Research Design

This research was mainly a quantitative type of research since experiments were done to explain phenomena by collecting numerical data that can be analysed using statistical approaches (Aliaga & Gunderson, 2000; Creswell, 2003). The experimental design was basically a 2 x 4 factorial design; thus factor 1 (2 fish species): factor 2 (4 drying methods). The design chosen helped to investigate the comparative potential of solar drying and traditional sun-drying as well as two improved sun-drying methods for production of shelf-stable and quality dried anchovies and Atlantic bumper fishes. The improved sun-drying methods consisted of a raised concrete platform (RCP) only and also a raised concrete platform with netted drying racks.

Sources of Fish Samples

Source of fish for experiment

About 20 kg each of freshly landed anchovies and Atlantic bumper fish (Figure 3) were purchased from purposively selected fish mongers at the Tema Canoe beach in Tema Newtown, Greater Accra Region. The fish samples were then transported in an ice chest the same day to the CSIR-Food Research Institute, Accra for drying using four different methods;

1. Sun drying on the bare ground (open air drying)
2. Sun drying directly on the raised concrete platform dryer (RCP)
3. Sun drying on the raised concrete platform dryer with netted drying racks (RCP+NDR)
4. Solar drying using the Hohenheim Solar Tunnel Dryer.

Fresh fish samples, after receiving were first washed in clean potable water to get rid of sand and debris. They were further rinsed in already prepared clean brine solution of about 5 g/100 ml. Straining was done using a clean perforated basket or rubber strainer to remove as much excess water as possible before the drying process was started.

(a) (b)

Figure 3: Fish samples (a). fresh Atlantic Bumper fish (b) fresh Anchovies.

Source: Field data (2020)

Source of fish from traditional processors for comparative study

Fresh and traditionally sun-dried anchovies and Atlantic bumper fish used in this study were obtained from randomly selected artisanal fish processors from fish processing sites in 3 regions: Greater Accra, Central and Volta regions. The fish samples were obtained from the Greater Accra Region at Tema New Town and Jamestown landing beach; located between Latitude 5º 38’ N and Longitude 0º 1’E; and Latitude 5º 32’ N and Longitude 0º 12’W, respectively. Fish samples were also obtained from Moree, near Cape Coast in the Central Region with geographical coordinates between Latitude 5º 7’ N and Longitude 1º 12’W; and Adina in Volta Region located between Latitude 5º 50’ N and Longitude 0º 29’E.

These purchased samples served as reference for the comparative studies to that of the experimental samples. The fresh samples were washed

with sea water at the processing sites, as normally done by fishmongers, and stored on ice flakes in a cold chest with small perforations on the bottom sides which allowed for a controlled draining of fish blood during transportation. The dried samples were also transported in labelled polyethylene packages and sent the same day to the laboratory at the Council for Scientific and Industrial Research-Food Research Institute (CSIR-FRI), Accra, for analysis.

Facilities used in Experiment for Drying Fish

Four drying facilities were used for the study:

1. A Hohenheim-type Solar Tunnel Dryer
2. A specially constructed dryer on a raised concrete cement platform
3. A specially constructed dryer on a raised concrete cement platform with netted drying.
4. Drying on the bare ground, mimicking traditional sun drying method.

All these facilities were assessed at the CSIR-FRI.

The raised concrete platform. An improved fish drying platform was constructed on the premises of CSIR-Food Research Institute under the Institute's donor funded project "*Small fish and food security: Towards innovative integration of fish in African food systems to improve nutrition (Small Fish Food*)" sponsored by European Union and Federal Ministry of Food and Agriculture (BMEL) of the Federal Republic of Germany.

Figure 4 is an isometric drawing of the dryer purposely designed and constructed for this study. It consists of a rectangular concrete platform built from 4 inches blocks and filled with sand. The front elevation of the platform

is 950 mm high, whilst back elevation is 800 mm, giving the platform a gentle slope of 9 ^{o}. The dryer has a set of tubes of diameter 101.6 mm inserted in the middle of the platform both lengthwise and breadthwise to serve as heat vents on all the four sides of the platform. The purpose of the heat vents is to prevent heat build-up within the platform, which could cause cracks on the surface of the platform. The slope of 9 ^{o} of the surface of the platform ensures that oils and other fluids from fish being dried do not accumulate on the platform to serve as hotspots for bacteria growth. The slope also ensures that these fluids are drained off the fish and makes it easier to clean the platform after drying. The concrete construction of the platform is strengthened with iron rod reinforcements and 3-inch thick plastering. On top of this rectangular block is a drying rack made from reinforced iron rods, which holds the drying fish. The height of the platform is at the waist level and this helps reduce drudgery associated frequent bending as with the traditional fish drying floors used by processors. The dryer with regular use is expected to last for about 3 years.

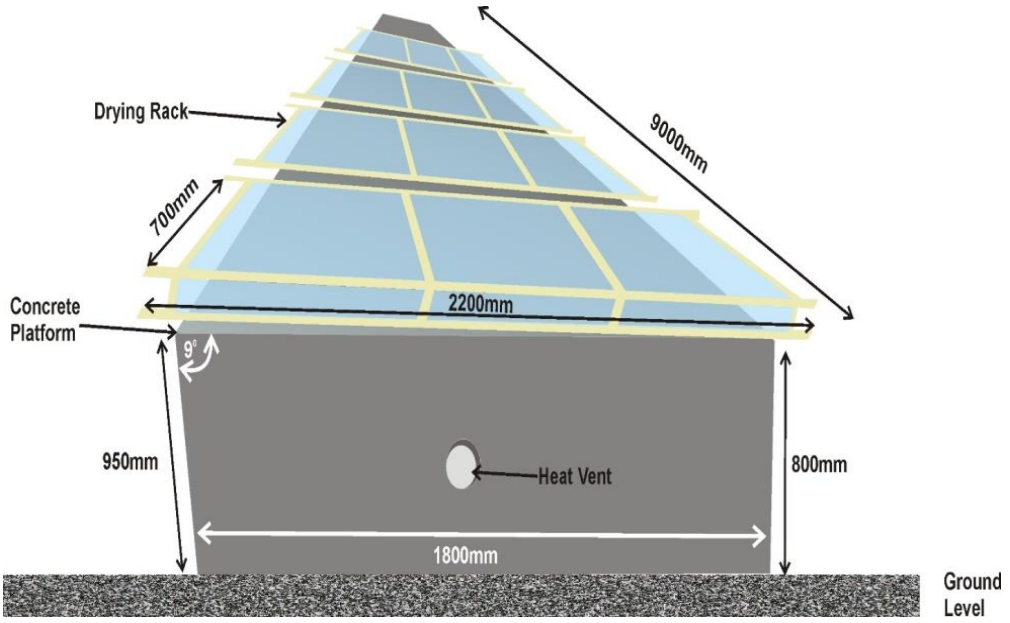

Figure 4: Isometric drawing of the raised concrete platform with netted drying racks.

Source: Field data (2020)

Description and operation of the hohenheim solar tunnel dryer

The second drying facility used for the study was a Hohenheim-type solar tunnel dryer (Figure 5). This dryer is one of the direct- type family of solar dryers and can be conveniently described as a long low transparent tunnel (Dhumne *et al.*, 2016). In its standard form, the solar dryer is 18 metres long and 2 metres wide. It consists of two sections or zones. The first 8 metres of the unit act as the solar collector and the second 10 metres are used for the drying bed. Each zone has the same cross-section and is covered with a transparent film glazing and therefore both the solar collector surface and the item being dried simultaneously absorb any solar radiation incident on the unit (Banda *et al.,* 2017; Dhumne *et al*.).

The Hohenheim solar dryer has been designed in such way that natural air from outside enters the dryer at the southern end and is drawn over the

heating chamber of the dryer, which constitutes the black body section of the solar dryer. The air becomes heated and assisted by two extractor fans, powered by photovoltaic cells mounted over the top of the solar, flows over the drying fish and then out of the dryer at the northern end. The drying tunnel is connected in a series to supply hot air directly into the drying tunnel using two DC fans operated by a solar module (Dhumne *et al*., 2016).

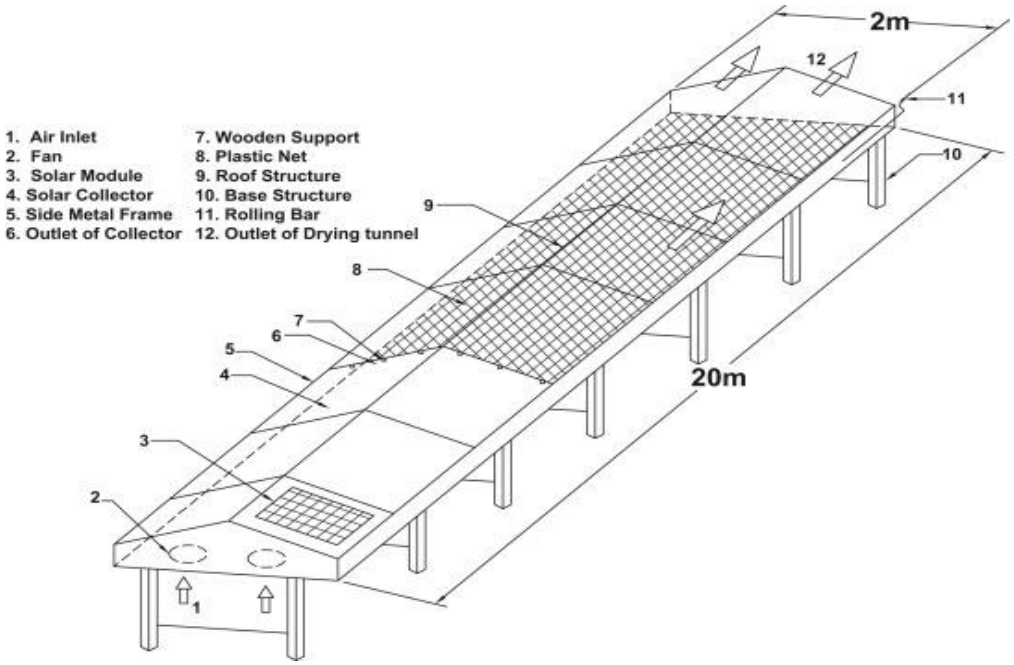

Figure 5: Isometric Drawing of the Hohenheim Solar Tunnel Dryer used for the study.

Source: Patil and Gawande (2016)

Description of the netted drying racks. Fish drying racks were purposely constructed for the study. Each pair of drying racks consists of a rectangular wooden frame on which is mounted an iron mesh with two wooden handles at each end (Figure 6). The two racks are joined together on one of the lengthwise sides of the rectangular racks with hinges to form one unit, making it possible to open and close the joined racks. With this design,

one is able to load the drying rack with fish and close it with a lock. The rack therefore facilitates easy handling of the fish. Two persons holding the handles at the opposite ends of the rack can turn the fish over by flipping the racks over during sun drying The use of the rack also minimized contact of processors with the fish, since one would otherwise turn the fish over periodically by hand or by using a broom. There is also a fine nylon net inserted between the iron mesh and the wooden frame which prevents flies from settling on the fish directly during drying.

Figure 6: The raised concrete platform with netted drying rack.

Source: Field data (2020)

Description of Procedures used for the Drying of Fish

Description of sun drying on the bare ground (traditional method)

The traditional open sun drying as described by Saka (2015) with modification (which involved the washing of the fish samples with 5 % brine solution instead of using sea water which may be contaminated with

pathogenic halophiles) was used to dry anchovies and the Atlantic bumper fish on the bare ground. Fresh fish was washed with the 5 % brine solution and then spread over the moist bare ground, which had been dampened with some water to reduce the dust in the air. After drying continuously for about 14 h, the fish was turned to the other side with sticks or long brooms. The fish was left on the ground to dry thoroughly before collection (Figure 7). To reduce the moisture content further, the fish sample was returned to the ground or to a mat for drying in order to extend the shelf life during storage. Moisture content of the fish samples after the drying periods was recorded as 13-14 %. Drying on the bare ground took approximately 20 h. Figure 8 is a flow diagram of the traditional sun drying of fish.

Figure 7: Drying of fish on the bare *ground*.

Source: Field data (2020)

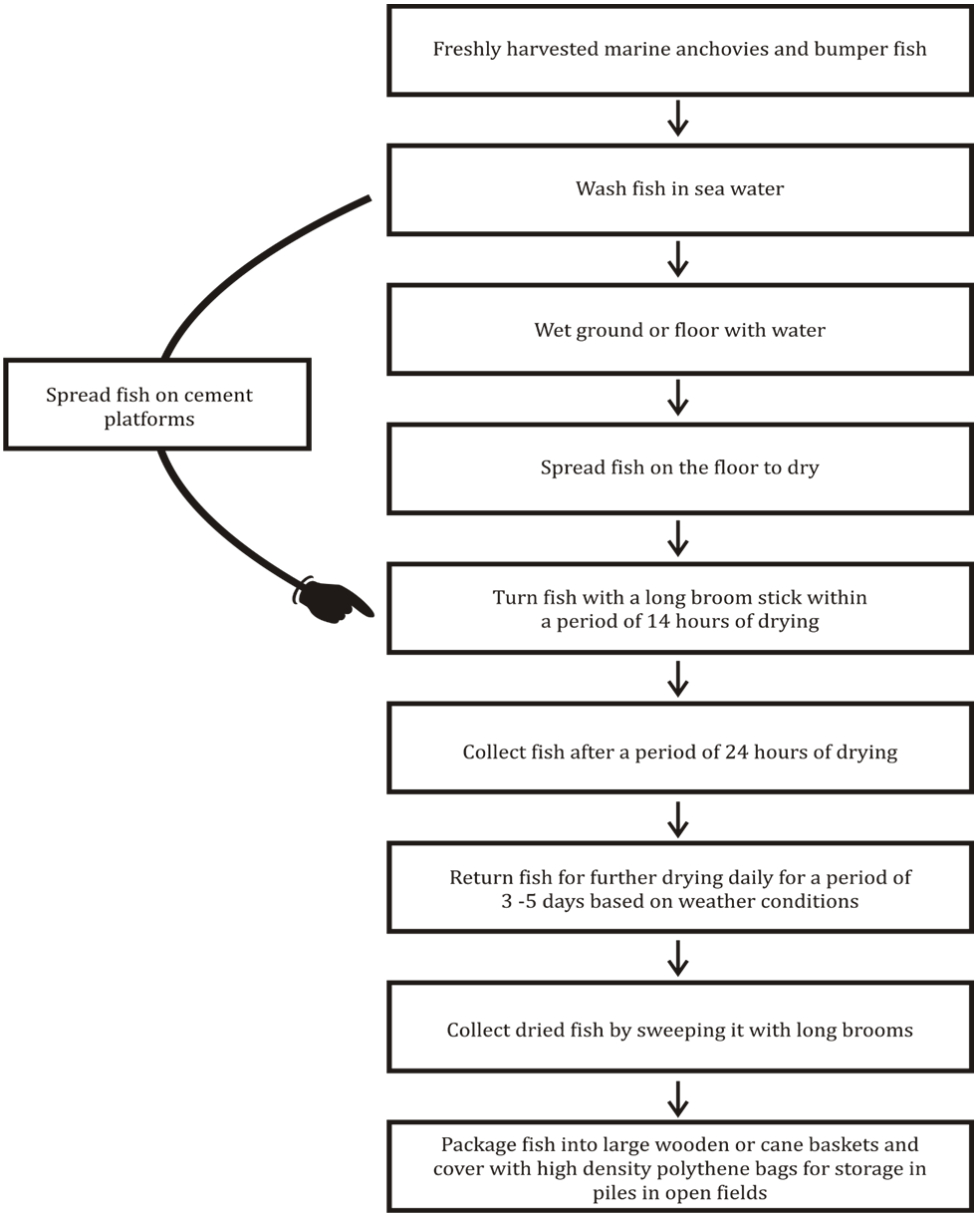

Figure 8: Flow diagram showing the process of traditional sun-drying of fish.

Source: Field data (2020)

Sun drying on the raised concrete platform only

Approximately 3 kg samples each of Anchovies and Atlantic bumper fish were spread thinly on the drying surface of the raised concrete platform (Figure 9) and allowed to dry. The fish was gathered, collected and carried to the fish laboratory after the days drying period (for fear of rain) and brought back the next day to continue drying. Drying progressed till the fish samples reached a moisture content of 10-11 % (w.b).

(a) (b)

Figure 9: Drying fish on raised concrete platforms (a) and (b)

Source: Field data (2020)

Drying on the raised concrete platform with netted Drying Racks

Approximately 2.5 kg of anchovies and Atlantic bumper fish, after washing, were spread thinly and evenly on the drying racks (Figure 8) and placed on the drying platform (Figure 6) to facilitate air movement around the fish hence aid drying. The racks were flipped over to dry the lower side of the fish during the days drying. The fish racks were removed and carried to the

fish laboratory at sunset (for fear of rain) and returned the next day to continue the drying process till all the fish were thoroughly dried to a moisture content of 12-13 % (w.b) as depicted in Figure 10. This took approximately 20 h of drying.

(a) (b)

Figure 10: Drying on the raised concrete platform with netted drying racks (a) and (b).

Source: Field data (2020)

Solar drying using the Hohenheim solar tunnel dryer

Approximately one (1) kg sample each of anchovies and Atlantic bumper fish were dried in the Hohenheim Solar Tunnel dryer (Figure 11). Samples were spread thinly on plastic meshes placed over mesh type metallic drying trays. The trays were then arranged inside the Hohenheim Solar Tunnel Dryer. Drying was carried out from 8:30 am to 4:30 pm daily. However, the drying process was discontinued on the second day due to interruption of rain,

which was unavoidable since drying was done during the rainy season. During such periods the fish was collected, covered with aluminium foil in a tray and kept in the fish laboratory. Drying continued this way till all the fish were thoroughly dried to a moisture content of 7- 8 %.

Figure 11: Drying fish in the Hohenheim Solar Tunnel Dryer.

Source: Field data (2020)

Processing of Dried Fish Samples into Flour

The dried anchovies and Atlantic bumper fish samples from all the drying methods were de-headed, de-gutted and milled into fish powder with a particle size of 500 μm. About 1 kg lots of powdered fish were then packaged and sealed into polyethylene bags and stored in the refrigerator at 4 ^{o}C for subsequent use for food formulations (Figure 12).

Figure 12: Fish flour samples in sealed in polythene bags.

Source: Field data (2020)

Laboratory Analyses on the Fresh and Dried Fish Samples

Determination of moisture content of samples

The moisture contents were determined using the air-oven method (AOAC 32.1.03 (2016)). A cleaned coded glass petri dish was placed in an oven at 103 °C for 20 min and then transferred into a desiccator and weighed immediately when cold. Approximately 3 g of the sample replicate was transferred in the cooled dish and dried in the oven at 103 °C for 4 h. Dishes containing samples were transferred into a desiccator for them to cool after the drying time was up. Dishes were then weighed soon after reaching room temperature (25 ^{o}C). The loss in weight after dehydration was calculated as a ratio of the original sample before dehydration. The moisture content, in wet basis, was converted into moisture in dry basis, before used to calculate the drying rate, using the equation 1:

$$\%\ moisture\ (wet\ basis) = \frac{Loss\ in\ weight\ of\ sample\ after\ drying}{initial\ weight\ of\ wet\ sample} x100 \ldots\ldots \quad (1)$$

$$\%\ moisture\ (dry\ basis) = \frac{Loss\ in\ weight\ of\ sample\ after\ drying}{final\ weight\ of\ dry\ sample} x100$$

Determination of drying curve

The drying curves of the drying samples were determined by sampling from the bulk fish being dried every two hours for all the treatments. The moisture content of the samples was determined as described in 3.6.1. The drying curve was then plotted using the moisture content obtained per every sampling time (2 h).

Chemical analysis

Proximate analysis (moisture, protein, fat and ash) as well as mineral analysis were carried out. In addition, the level of histamine and contamination with heavy metals (lead, cadmium and arsenic) were also determined on the dried fishes (anchovies and Atlantic bumper) samples obtained from the four different drying facilities employed in the study.

Preparation of samples for chemical analyses

About 1 kg of dried fish samples from the different drying methods as well as the fresh fish samples were homogenized using a laboratory blender (Panasonic Mx-Ac 300 Mixer Grinder). Samples from the homogenates were used for the various analyses, which were carried out in duplicates.

Proximate and mineral analysis on fish

Proximate and mineral analysis (moisture, protein, fat, ash, calcium, iron, phosphorus) were determined using standard procedures of the Association of Official Analytical Chemists (AOAC) international.

Determination of ash content of samples.

Ash content was determined by using the muffle furnace method (AOAC 32.1.05 (2016)). Approximately 3 g of sample was placed in a previously weighed silica crucibles and then placed into furnace and ashed for 8 h at 550°C (±10 °C). The weight of the ash was expressed as a ration of the initial weight of the original sample. After 8 h of ignition of samples, the temperature of the furnace was left to drop to at least 250 °C and then crucibles were transferred into desiccator. They were weighed soon after reaching room temperature. The ash content of the samples was calculated using equation 2:

$$\%Ash = \frac{Weight\ of\ ash}{inital\ weight\ of\ sample} x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Crude fat content

The fat content was determined by AOAC 920.39 (2000) using the continuous soxhlet extraction method. About 2 g of previously dried sample was placed in an extraction thimble and stopped with grease- free cotton. The flask was dried, cooled and weighed prior to the extraction process. The thimble was placed in the extraction chamber and 240 mL of petroleum ether (analytical reagent) was added to extract the fat. The extraction was done for 5 h at a condensate rate of 5- 6 drops per second. The extracted fat in the flask

was then dried in an oven at 103 ± 2 °C for 1 h. The dried fat was then cooled, and weight recorded. A blank was run in the same procedure but without the sample. The percentage fat was calculated using equation 3:

$$\% Fat = \frac{\text{weight of fat in sample after extraction}}{\textit{weight of original sample taken before extraction}} x\ 100 \quad \ldots.. 3$$

Crude protein content

The crude protein content was determined using the Kjeldahl method AOAC 991.20 (2000). About 0.2 g of the samples were weighed on a filter paper and transferred into the Kjedahl flask. About 15 mL of concentrated sulphuric acid and the catalyst (kjeltab) were added to the sample and digested at a temperature of 400 °C for 2 h. The digestion process was stopped when there was a colour change. The digested sample was steam distilled with 80mL of water and 80 mL of 40 % sodium hydroxide. Ammonia produced during distillation was received into a conical flask containing 25 mL of boric acid (4.0 %) using screened methyl red as indicator. The solution was then titrated against 0.01 N of the HCl solution to the end point (T). A blank (B) was run in the same condition as that of the sample. The crude protein is determined by multiplying the percentage nitrogen by a constant factor of 6.25, (AOAC, 2000). The crude protein of the samples was calculated using equation 4:

$$\% protein = \frac{(T-B)\ x\ 14.01\ x\ N\ x\ 100}{weight\ of\ sample} x\ Factor \ldots\ldots\ldots\ldots\ldots 4$$

Calcium content

The calcium content was determined according to the method AOAC 11.2.01G (2016). Approximately 3 g of fish sample was ashed at a temperature of 550 ± 10 °C. Exactly 10 mL of 50 % HCl was added to the ashed sample and transferred into a 50 mL volumetric flask and made to the mark with distilled water. An aliquot (5 mL) of the solution was transferred into a 250 mL conical flask and 100 mL of distilled water was added, followed by 10 mL of 50 % HCL as well as two drops of methyl red indicator. The solution was then placed on a hot plate. Exactly 5 g of urea was added to the solution on the hot plate when it started to boil. It was then followed by the addition of 15 mL ammonium oxalate. After a period of 10 min, 50 % NH_4OH was added for a change in colour. The solution was left to precipitate over a period of 4 h, filtered using a number 1 Whatman filter paper. The filter paper was then washed with 300 – 350 mL distilled water. The filter paper was then crushed in a beaker with 50 mL of 2 N H_2SO_4. This was allowed to boil on a hot plate. Titration was then carried on against 0.02 N KMn_2O_4 until a light pink colour was observed. The titre value was obtained and calcium content was calculated using the equation 5:

Calcium content (mg/100 g) is expressed as

$$Ca\left(\frac{mg}{100g}\right) = \frac{(titre - blank) \times 0.4 \times 100}{weight\ of\ sample \times \left(\frac{20}{50}\right)} \quad \text{.....5}$$

Phosphorus content

The phosphorus content of the samples was determined according to the AOAC 3.4.11 (2016) procedure, Ammonium molybdate blue method. Approximately 3 g of fish sample was ashed at a temperature of 550 ± 10 °C. Exactly 10 mL of 50 % HCl was added to the ashed sample and transferred into a 50 mL volumetric flask and made to the mark with distilled water. An aliquot (0.1 mL) of solution was transferred into another 50 mL volumetric flask. A pinch of ascorbic acid was added to the solution. The walls of the volumetric flask were washed with some amount of distilled water after which the solution was made to stand for about 10 min. 5 mL of ammonium molybdate (25 g/L sodium molybdate in 50 % sulphuric acid) was added to the solution. This was then placed into a water bath at a temperature of 100 °C until a blue colour developed. The volumetric flask was then topped up with distilled water to the mark. Phosphorus content was then determined by the use of spectrophotometer (Cecil CE 74000, 7000 series) at a wavelength of 655 nm. The absorbance was read and the phosphorus content determined by calculation. A blank determination was used to zero the system. The concentration is read by tracing the absorbance to a standard phosphorus curve, using equation 6:

$$\text{Phosphorus content (mg/100 g)} = \frac{concentration\ of\ P \times 250}{weight\ of sample \times volume} \quad \ldots\ldots\ldots\ldots 6$$

where *P* is concentration of standard phosphorus

Iron content

Iron content of the samples was determined based on the 2, 2-Bipyridine method (AOAC, 2016). Approximately 3 g of fish sample was ashed at a temperature of 550 ± 10 °C. 10 mL of 50 % HCl was added to the ashed sample and filtered into another 50 ml volumetric flack and made to the mark with distilled water. An aliquot (5 ml) of the solution was pipetted into a 50 mL volumetric flask. A pinch of ascorbic acid was added to the solution. The walls of the volumetric flask were washed with some amount of distilled water after which the solution was made to stand for about 10 min. 10 mL of 20 % ammonium acetate was added to the solution. A 2 mL of 0.2 % 2, 2-Bipyridine was immediately added to develop a light pink colour. It was then kept in the dark for 1 h. The volumetric flask was then topped up with distilled water to the mark. Iron content was then determined using spectrophotometer (Cecil CE 74000, 7000 series) at a wavelength of 520 nm. The absorbance and iron content were calculated using equations 7 and 8, respectively:

$$Concentration = \frac{Absorbance}{0.1367} \quad \text{.....7}$$

$$Iron\left(\frac{mg}{100g}\right) = \frac{concentration\ of\ Fe \times 250}{weight\ of\ sample \times volume} \quad \text{.....}$$

Determination of heavy metals concentrations in fish

The heavy metal concentrations in the samples were determined using methods AOAC 9.1.09 and AOAC 9.2.03 (AOAC, 2000). Approximately 0.2 g of sample was weighed into a beaker, using an analytical balance, and digested with 5 mL concentrated nitric acid (65 % purity) and was then placed on a hot plate for 1 h. A 1 mL of sulphuric acid was then added and repeated

at an interval of 30 min until a total digestion period in 3 h. After digestion 5 mL of distilled water added and stirred thoroughly. A 1 % nitric acid was added to the digest and then filtered into a 50 mL volumetric flask to the mark. The heavy metals in the sample were then determined using the GTA 120 Graphite Tube Atomizer, 200 Series AA. The heavy metals determined in mg/ 100g included lead, cadmium and arsenic with detection wavelengths of 283.31 nm, 228.80 nm and 193.7 nm respectively; using equation 9:

$$[metal] = \frac{Reading \times dilution\ factor \times nominal\ volume}{weight\ of\ sample} \quad \text{.....9}$$

Determination of histamine in fish

The histamine levels in the samples were determined using spectrophotometric method described by Hardin and Smith (1976). About 10 g of the fresh and dried fish devoid of scales, skin, guts and other undesirable parts were minced and used for the analysis. About 100 mL of freshly prepared 2.5 % trichloroacetic acid (TCA) was added, homogenized and filtered. The volume of the TCA sample was noted and neutralized to pH 7 with 1N KOH and 0.2N HCl, the new volume was then recorded.

Narrow chromatography column was packed with 1 g Amberlite CG-50 resin and washed with 150 mL acetate buffer to make the surface of the liquid align to the surface of the resin. About 75 mL of the neutralized TCA sample solution was then added to the column and drained onto the surface of the Amberlite CG-50. The column was then washed with 100 mL acetate buffer to remove interfering substances. Histamine was eluted with exactly 25 mL of 0.2 N HCl and collected in a 50 mL beaker. A blank determination was

done using similar volume of 2.5 % TCA. About 1 mL of the HCl eluate was added to 15 mL 5 % Na_2CO_3 in a stoppered test tube previously chilled in an ice water bath. A volume of 2 mL of chilled diazo reagent was then added to the mixture and allowed to stand at 0 ^oC for 10 min prior to absorbance measurement. Absorbance of mixture was measured at 495 nm using distilled water as a reference.

A standard curve was also prepared by using 1 mL aliquot of a standard histamine solution (0-80 µg histamine/ml 0.2 N HC). 80 µg/mL (2mg/25ml) in the acid eluent. Histamine is calculated using equation 10.

$$H = \frac{3.3F}{E} \text{ X CONC.(µg/g) read off from standard curve} \quad \ldots\ldots\ldots 10$$

Where H =Histamine (ppm/ µg/g)

F= Volume of sample after neutralization

E= Volume of extract after filtration through Amberlite CG-50 resin column.

Microbiological Analysis of Fish Samples.

The safety of fresh and processed fish (both experimental and reference samples) was determined by microbial analysis. Enumeration and detection of enteric and indicator pathogens such as *Bacillus cereus, Enterobacteriaceae, Enterococcus, yeast* and *moulds, Staphylococcus aureus, E.coli, Aerobic mesophiles* and *Total coliforms* were carried out.

Homogenization and serial dilution

For all samples, ten grams (10 g) were added to 90.0 mL sterile Salt Peptone Solution (SPS) containing 0.1 % peptone and 0.8 % NaCl, with pH adjusted to 7.2 and homogenized in a stomacher (Lad Blender, Model 4001, Seward Medical, England), for 30 s at normal speed to obtain 1:10 dilution. Further dilutions were done to obtain ten-fold dilutions after which 1 mL aliquots of each dilution was directly inoculated into sterile Petri dish and the appropriate media added for enumeration of microorganisms. All analyses were done in duplicate.

Enumeration of aerobic mesophiles

Aerobic mesophiles were enumerated by the pour plate method on Plate Count Agar medium (Oxiod CM325; Oxoid Ltd., Basingstoke, Hampshire, UK). About 1 ml of each dilution was inoculated into sterile Petri dishes and sterile molten Plate count agar was poured on it. The plates were left to set at room temperature. The plates were then incubated at 30 °C for 72 h in accordance with NMKL. No. 86, 2013. Plates containing colonies between 25- 250 were selected and counted.

Enterobacteriaceae determination

Enterobacteriaceae was determined by the pour plate method according to NMKL No. 114 (2004). Exactly, 1 ml of the serial dilution was inoculated into sterile Petri dishes. Molten TSA was poured on the Petri dishes and swirled to evenly mix the inoculum and the agar. The media in plates were then allowed to set and pre-incubated at room temperature for 1-2 h. After the

incubation the TSA was overlaid with Violet Red Bile Glucose Agar (VRBGA) (Oxoid CM107) with pH 7.4 and allowed to set again at room temperature and then incubated at 37 ^{o}C for 24 h.

Enumeration of yeast and moulds

Yeast and moulds were enumerated by spread plate method on Dichoran Rose Bengal Chloramphenicol (DRBC) Agar (OXIOD CM0727), Ph 5.6, containing Chloramphenicol supplement to prevent bacteria growth and incubated at 25 ^{o}C for 3-5 days in an upright position inn accordance with (ISO 21527-1:2008).

Enumeration and isolation of total coliform

Coliform bacteria were counted by the pour plate method using tryptone soya Agar medium (OXOID CM131) adjusted to pH 7.3 and overlaid with Violet Red Bile agar (OXOID CM 107) with pH adjusted to 7.4 and incubated at 37 °C for 24 h. Colonies were confirmed using Brilliant Green Bile Broth (OXOID CM 31) at pH of 7.4 and incubated at 37 °C for 24 h in accordance with NMKL no.44, (2004). Positive reaction was indicated by the production of gas at the entire bent portion of the Durham tube.

Enumeration of *Escherichia coli*

E. coli were enumerated by the pour plate method using Tryptone Soya Agar medium (OXOID CM131) adjusted to the pH 7.3 and overlaid with Violet Red Bile agar (OXOID CM 107) with pH adjusted to 7.4 and incubated at 44 °C for 24 h. Suspected colonies were confirmed using E.C. broth

(OXOID CM 853) with pH adjusted to 6.9. Colonies that produced gas that has filled the entire concave part of the Durham tube were taken as thermos-tolerant coliform bacteria. To determine *E. coli* thermo-tolerant bacteria were confirmed for Indole production. This was done by sub-culturing into positive tubes into tryptone broth and incubate at 44 °C for 24 hours. Indole test was carried out by adding 0.3-0.5 ml of Kovac‘s reagent into the culture. Red ring colouration at the surface of tryptone broth indicated Indole positive in accordance with NMLK no.125, 2013.

Enumeration of *Staphylococcus aureus*

Staphylococcus aureus was determined using the spread plate method on Baird Parker Agar (BP, CM 275 Oxiod Ltd, Hampshire, England) containg Egg Yolk Tellurite Emulsion (SR54). Suspected colonies were confirmed for coagulase positive on rabbit coagulase plasma (C14389) according to NMKL Method No. 66 (2009). About 0.1 mL of each serial dilution was inocultaed onto the surface of the already prepared Baird Parker in a petri dish. With th use of sterile spreaders, the inoculum was uniformly spread on the surface of the agar. The inoculum was left to dry at room temperature and incubated at 37 ^{o}C for 48 h. Suspected colonies wre confirmed on blood agar base and for coagulase test. Colonies showing haemolysis on the blood agar and coagulates on the rabbit coagulase plasma indicate positive *Staphylococcus aureus.*

Enumeration of *Bacillus cereus*

Bacillus cereus was enumerated by spread plate technique on Bacillus Cereus Agar Base (CM0617) to which Polymyxin B. supplement (SR0099E)

was added. Suspected colonies were confirmed on Blood Agar Base (OXIOD CM0055), for the presence of haemolysis as described by NMKL No. 67,2010.

Enumeration of *Salmonella*

Salmonella spp in the samples were determined according to NMKL No. 71, (1999). A weight of 25 g of the sample was measured into a sterile bag and 225 mL of Buffered Peptone Water (CM0509) was added and used as pre –enrichment broth and incubated at 37 ^{o}C for 21 h. Exactly 1ml of the suspension was sub-cultured into Rapapport Valisialdis Soya Peptone Broth (CM0866) broth and incubated at 37 ^{o}C for 24 h. After incubation, the suspension was subsequently streaked on XLD Agar (CM0469 Oxoid Ltd, Hampshire, England) and incubated at 37 ^{o}C for 24 h. Suspected *Salmonella* species was confirmed by biochemical test on Tripple Sugar Iron Agar (Vm381715 214, Merck KGaA Darmstadt,Germany) and serological test using *Salmonella* Polyvalent Agglutinating Sera (30858501ZD01, UK).

Enumeration of *Listeria monocytogenes*

Listeria monocytogenes in the samples were determined according to ISO 11290-1 (1996). A weight of 25 g of the sample was measured into a sterile bag and 225 mL of primary enrichment medium (half- Fraser broth; B1) was added and incubated at 30 ^{o}C for 24 h, after which 0.1 mL of the suspension was sub-cultured into 10 ml of secondary enrichment medium (Frase broth; B2) and incubated at 37 ^{o}C for 24 h. After incubation, the

suspension was plated on oxford agar for 24 h at 30 ^{o}C aerobically and PALCAM agar for 24 h at 30 ^{o}C.

Food Products Preparation

The fish powder obtained from dried anchovies and Atlantic bumper fish were used in the production of two food products:

1. Biscuits to serve as a healthy snack for both adults and children
2. Instant Cereal Mix to serve as complementary food for children and can however serve as breakfast cereal for adults as well

Incorporating the dried fish powder into biscuit

The percentages of the flour proportions of wheat flour and fish powder used for the biscuit preparation, as shown in Table 1, took into considerations the work of Elbandy (2015), and Abraha *et al*. (2018). Elbandy produced fortified biscuit, using 3, 6 and 9 % of crayfish protein concentrate powder, whilst Abraha *et al.* incorporated sturgeon fillet protein concentrate at 5, 7 and 10 %. These research works made use of fish protein concentrates from various fish species and not the fish powder. Also, the researchers did not fortify the wheat flour with fish protein concentrate beyond 10 %. This therefore explains the need to make use of under- utilized fish powder, which is accessible and can easily be processed. Fish protein concentrate (FPC) are specially concentrated high-quality protein (between 75 and 95 %) than the original fish flesh, therefore increasing fish powder further to 15 % will compensate for the protein content of fish powder fortified biscuit.

Table 1 - *Flour Proportions for Biscuit Preparation*

Product	Flour proportions (g/ 300g)	
	Wheat flour	Fish powder
5% Anchovies	285	15
10% Anchovies	270	30
15% Anchovies	255	45
5% Bumper	285	15
10% Bumper	270	30
15% Bumper	255	45
Control	300	0

Source: Field data (2020)

Biscuits were prepared according to the method described by Aroyeun (2009), with modifications in the weight of the ingredients used. All ingredients for the biscuit preparation were pre-weighed into bowls. The proportions of wheat flour and fish powder were poured into a mixing bowl and 200 g of margarine was rubbed by hand. The rest of the dry ingredients; 150 g of sugar, 2.5 g of nutmeg, 2.3 g of ginger and 7.5 g of baking powder were then added. Two (2) eggs were beaten into the mixture in addition to 2.5 ml of flavour and 100 ml of diluted milk. The mixture was then kneaded by hand to form dough. The dough was rolled on a flat surface into sheets and cut into even sizes with the biscuit cutter. A baking sheet was then greased with oil and the cut dough arranged on it. Baking was done at a temperature of about 200 ^{o}C for 20 min to obtain a very crispy biscuit. The baked biscuits were left to cool on a wire rack. They were then packed and sealed in airtight container to prevent flattening.

Incorporating the dried fish powder into instant cereal mix

The mixture formulations for instant cereal mix are shown in Table 2. It is made up of fish powder, rice flour, milk powder and sugar at various weights (grams).

Table 2 - *Mixture Formulations for Instant Cereal Mix*

Product	Flour composition (g/100g)		Other ingredients (g/100g)	
	Rice Flour	Fish Powder	Milk Powder	Sugar
F1 Anchovies	54	6	30	10
F2 Anchovies	63	3	24	10
F3 Anchovies	60	9	21	10
F1 Bumper	54	6	30	10
F2 Bumper	63	3	24	10
F3 Bumper	60	9	21	10
Control	60	0	30	10

Source: Field data (2020)

The formulation of flour used for the instant cereal mix was based on previous trials of proportions, which were done to select the best formulations. The main ingredients (rice flour, fish powder) were weighed and a measured amount of water twice the weight of the dry ingredient was added and stirred manually to obtain a uniform suspension. The suspension was drum-dried (Andritz Gouda drum dryer - Model E5/5, Holland). The pressure of steam used was 10 bar and temperature, 130 ºC while revolution of drums was at 15 rev/min. Thin dry films produced from the drum drying were then milled into flour of desired particle size. The flour was then mixed with sugar and

powdered milk and packaged for consumer acceptability test. Exactly 300 mL of water at about 85 ºC was added to 100 g of the instant cereal mix and stirred consistently to form a smooth paste before it was served to the sensory panellist for assessment.

Consumer Acceptability Test

Consumer acceptability test was carried out on fish fortified biscuit and instant cereal mix prepared from the fish powder obtained from the sun drying using drying racks on raised concrete platform. This selection was due to the microbial quality of the processed fish as compared to the other processing methods of sun drying used in the research. Sixty (60) untrained (but familiar with the product) panellists were recruited randomly from CSIR-FRI, Shiahie-Accra where the sensory analysis was performed. Due to the Covid-19 pandemic, panellists were made to wash and sanitize their hands before the evaluation. The booths of the sensory laboratory were also thoroughly sanitized each time after use by panellists. Food products prepared from the fish powder were served on coded disposable plates and presented to consumers in a randomized order of presentation (Stone & Sidel, 2004). Water and slices of cucumber were also provided for consumers to use during the test to minimize any residual effect between samples. Consumer preference test was carried out using a questionnaire (Appendices 1 and 2) for a 9-point hedonic scale with 1 - dislike extremely, 5 – neither like nor dislike and 9 - like extremely (Peryam *et al*., 1957). Sensory attributes determined included aroma, colour, mouth feel, aftertaste and overall acceptability.

Statistical Analysis

All data collected in the study were subjected to analysis of variance using Minitab Release 17 statistical software (Minitab Inc. Brandon Court, United Kingdom). Means were separated at 95 % confidence interval to determine statistically significant differences between them. Graphs were generated using Microsoft Office, Excel 2017.

CHAPTER FOUR

RESULTS

This chapter presents all the results of the experiments carried out as explained in Chapter 3; the Materials and Methods. There are two main sets of results; the first set is drying data of the fish samples using the four different drying methods, data on the chemical and microbiological analyses of dried anchovies (*Engraulis Encrasicolus*) and Atlantic bumper fish (C*hloroscombrus Chrysurus*). The second is for results on consumer acceptability tests of instant cereal mix and biscuits formulated with the dried fish powders.

Drying Curves of Anchovy Fish using Three Sun Drying and Solar Drying Methods

Figure 13 shows the drying curves of anchovies using three sun-drying methods with temperature (bare ground drying, raised concrete platform (RCP) and raised concrete platform with netted drying racks (RCP+NDR)). Generally, it was observed that there was a decrease in moisture with drying time (Figure 13 and 14). The rate of drying of the anchovies were faster in the solar dryer than that with the sun dryers. Moisture losses due to the drying methods were dependent on time and temperature. The initial moisture of the anchovy samples was 78.71 %.

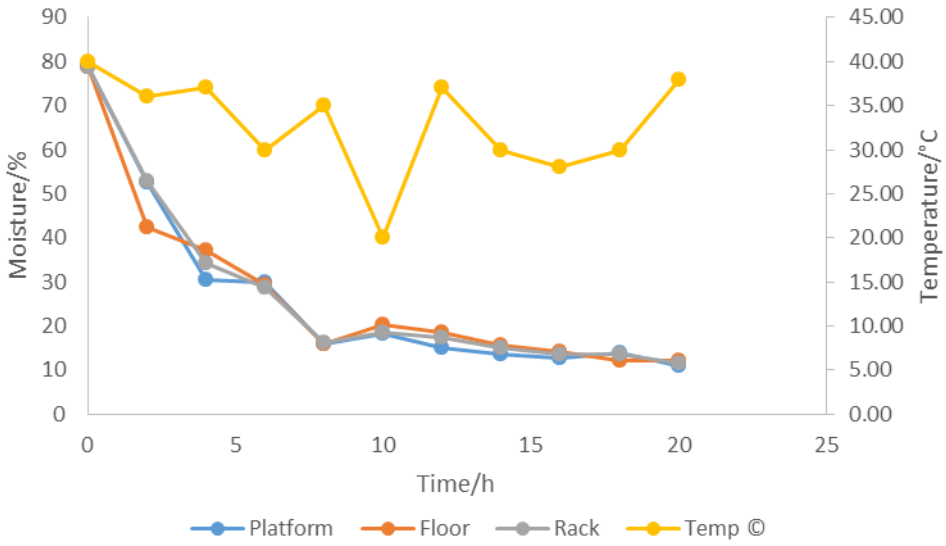

Figure 13: Drying curves of anchovies using the three sun-drying methods: Bare Ground, RCP and RCP+NDR as well as the recorded ambient temperature during the drying process.

Source: Field data (2020)

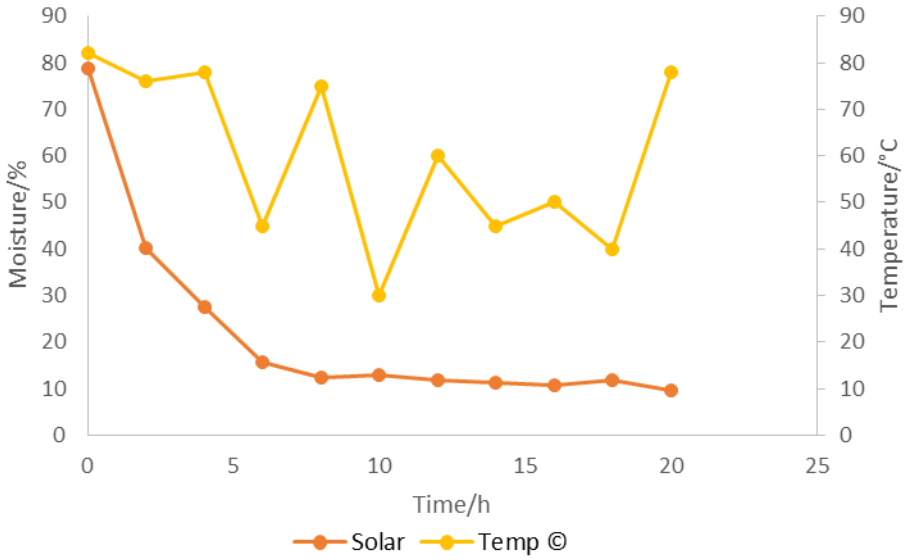

Figure 14: Drying curve of Anchovies in the Solar-dryer and ambient Temperature

Source: Field data (2020)

Though there was a general decrease in moisture content over the drying period, moisture content of the samples dried using sundrying momentarily increased initially at10 h and then again at18 h of drying. This can be attributed to drops in ambient temperature to 20 ^{o}C (at 10 h) and 30 ^{o} C (at 18 h) respectively (Figure. 13 and 14). The three sun-drying methods (bare ground drying, raised concrete platform (RCP) and raised concrete platform with netted drying racks (RCP+NDR)) used depicted comparable patterns of drying with fluctuations in the moisture content as temperatures reduced. Steeper drying curves were obtained with samples that were solar dried than those from the two improved sun-drying methods, even though there were minimal fluctuations in moisture loss.

During the early mornings of the study, the temperature was low and this must have caused moisture absorption by the samples. Percentage moisture loss was higher at the beginning of the drying processing but decreased with decreasing moisture content. Drying temperatures in the solar dryer were higher as compared with the sun-drying method. The maximum temperature of 82 ^{o}C was recorded in the solar dryer whiles 40 ^{o}C was recorded during the Sun- drying processing. The critical moisture content of 15.79 % was recorded on the 6th hour in the solar dryer whiles 29.85 %, 29.39 % and 28.63 % were recorded respectively for RCP, bare ground and RCP+NDR on the sun dried sample at the same time. Solar dried anchovies recorded the lowest moisture content after the drying period whiles the moisture content of the sun dried anchovies were comparable. The falling phase was the longest phase of drying as found in Figure 13 and 14. It was between the 8 h to 20 h of drying.

Drying Curve of Atlantic Bumper Fish using Solar Drying and Sun Drying Methods

The changes in moisture content of Atlantic bumper fish against drying time as well as drying temperature is as shown in Figures 15 and 16. As shown in both Figures 15 and 16, there was a general reduction in moisture content of the fish samples with time in all four drying facilities. The moisture loss was highest during the first 4 hours, as shown by the steep nature of the drying curves. Beyond this time, there was a slight reduction in the rate of moisture loss till the 8^{th} hour leading to an equilibrium moisture content though there was a slight short term increase in the moisture content of the fish at 10 h. This point coincided at the stage when the ambient temperatures were lowest resulting in high atmospheric humidity. Therefore samples turn to absorb moisture from the atmosphere.

The ambient temperature used for open sun drying was between 25- 40 ^{o}C compared with the temperature of the solar tunnel dryer, which ranged between 30 and 82 ^{o}C during the day. The higher temperatures in the solar dryer accounts for the faster drying and thereby lower moisture content in the solar tunnel dryer compared with the open sun drying method (bare ground, dried, RCP, RCP+NDR). The falling phase was the longest phase during the drying process since it ranged between the 8 and 20 h of drying.

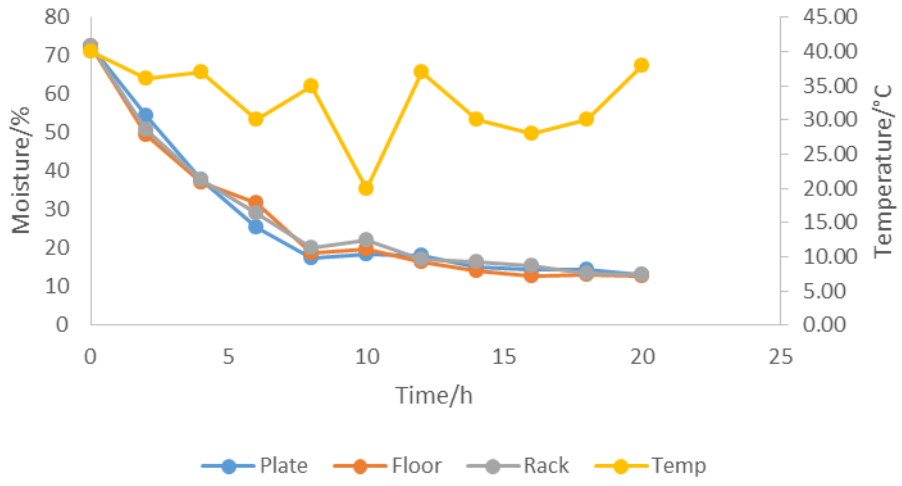

Figure 15: Drying curves of Atlantic bumper fish using the three sun-drying methods: Bare Ground, RCP and RCP+NDR as well as recorded ambient temperature during the drying process.

Source: Field data, (2020)

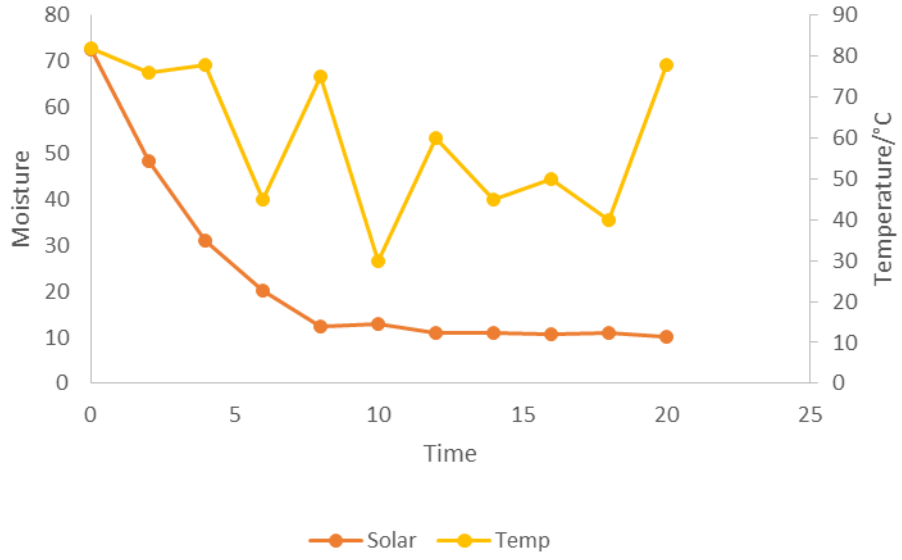

Figure 16: Drying curve of Atlantic bumper fish in the Solar-dryer and ambient temperature inside the dryer.

Source: Field data (2020)

Proximate Composition of Fresh and Dried Anchovies from the Different Drying Methods

Table 3 shows the results for the proximate composition of different samples of anchovy fish, dried using the four different drying methods as compared to the fresh sample. Moisture contents of the anchovies decreased in the following order after 20 hours of drying, from 71.30 % (Fresh) > 13.14 % (Bare Ground drying) > 11.91 % (Raised Concrete Platform + Netted Racks drying) > 10.74 % (Raised Concrete Platform drying) > 7.50 % (Solar drying) There were significant differences ($p < 0.05$) in the moisture contents of all samples from the different drying methods (Table 3). The minimum moisture content for all the dried samples were recorded in the solar dried samples whiles the maximum moisture contents were obtained for samples on the bare ground.

The fat content of the samples ranged from 6.58 ± 0.08 to 8.03±0.10% (dwb); with the highest in the fresh samples. The least fat content was obtained from the solar dried samples. The protein content of the samples was from 11.98 to 74.28 % (dwb). Table 3 shows that the highest protein content was obtained using solar and then RCP+NDR drying methods, followed by RCP sample and then the bare ground sample, with comparable values at ($P > 0.05$).

Table 3 also shows that the ash content in the anchovies increased from 8.25 % in the fresh samples to a range of 8.27 % to 12.78 % (dwb); with the highest recorded from the samples dried on the bare ground dried.

Table 3 - *Proximate Composition on Dry Weight basis of Fresh and Dried Anchovies after Drying for 20 h*

Anchovy Sample According to Drying Method	Proximate Composition (g/ 100g) in dry basis			
	Moisture	Fat	Protein	Ash
Fresh	71.30±0.08[a]	8.03±0.10a	11.98±0.10[e]	8.25±0.05[d]
Bare ground	13.14±0.10[b]	6.95±0.10b	66.43±0.09[d]	12.78±0.10[a]
RCP	10.74±0.10[d]	7.19 ±0.10b	67.17±0.09[d]	9.60±0.10[b]
RCP+NDR	11.91±0.07[c]	6.96±0.11b	70.04±0.05[b]	9.11±0.10[c]
Solar	7.50±0.10[e]	6.58±0.10c	74.28±0.08[a]	8.27±0.10[d]

Sample means with the same superscript among the different drying methods used for drying Anchovy fish are not significantly different ($p > 0.05$) from each other. Key: RCP- Raised Concrete Platform; RCP+NDR- Raised Concrete Platform+ Netted Drying Rack.

Source: Field data (2020)

Mineral and Histamine Contents of Fresh and Dried Anchovies from the Different Drying Methods

The mineral contents of Iron, phosphorus and Calcium of the anchovies are displayed in Table 4. The maximum mineral contents (65.13 ± 2.22, 5309.5 ± 5.92 and 5155.00 ± 2.61 mg/100 g of Fe, P and Ca respectively) were recorded in the fresh anchovy samples. Minimum values for all the mineral components of the samples were recorded in the samples that were dried using the raised concrete platform. Iron content decreased from 65.13 mg/100g in the fresh anchovies to a range of 31.12 to 35.31 mg/100g in the dried anchovies. Solar dried anchovies had the highest mineral contents (Fe, P and Ca) amongst all the drying methods. Notwithstanding, the phosphorus and iron contents were comparable amongst the drying methods.

The heavy metal components analysed during the study were Cadmium (Cd), Lead (Pb) and Arsenic (As). Cd and Pb were below detection limits. As content were in the range of 0.03±0.00 and 0.68±0.08. Maximum and minimum values were recorded in the fresh and solar dried samples respectively. As contents of all the dried samples were not significantly different ($p>0.05$) from each other, but significantly different ($p<0.05$) from the fresh samples

Histamine content of the anchovies was 0.0489 ppm in the fresh samples, but decreased significantly ($p<0.05$) to a range of 0.0130 and 0.0098 ppm after drying. Solar dried anchovies had the least histamine content of 0.0098 ppm, whilst those dried using the RCP, RCP+NDR and Bare ground were 0.0118, 0.123 and 0.0098 ppm, respectively (Table 4).

Table 4 - *Mineral and Histamine Contents of Fresh and Dried Anchovies after Drying for 20 h*

Anchovy Sample According to Drying Method	Mineral Content (mg/100 g)			Heavy Metal Content (mg/100g)			Histamine
	Fe	P	Ca	Pb	Cd	As	(PPM)
Fresh	65.13±2.22[a]	5309.5±5.92[a]	5155.00±2.61[a]	ND	ND	0.68±0.08[a]	0.0489±0.0016[a]
Bare ground	33.98±0.71[bc]	1842.23±0.43[b]	2974.46±0.51[cd]	ND	ND	0.04±0.00[b]	0.0130±0.0003[b]
RCP	31.19±0.43[c]	1790.33±8.08[b]	2955.35±0.95[d]	ND	ND	0.04±0.00[b]	0.0118±0.0003[bc]
RCP+NDR	31.12±0.22[c]	1804.56±0.33[b]	3002.26±0.53[c]	ND	ND	0.04±0.00[b]	0.0123±0.0003[b]
Solar	35.31±0.80[b]	1839.41±0.09[b]	3101.77±4.58[b]	ND	ND	0.03±0.00[b]	0.0098±0.0000[c]

Sample means with the same superscript among the different drying methods used for drying Anchovy fish are not significantly different ($p > 0.05$) from each other. Key: RCP- Raised Concrete Platform; RCP+NDR- Raised Concrete Platform+ Netted Drying Racks

Source: Field data (2020)

Proximate Composition of Fresh and Dried Atlantic bumper Fish from the Different Drying Methods

The proximate composition of Atlantic bumper fish, dried using the four different drying methods are as provided in Table 5. The initial moisture content of the fresh Atlantic bumper fish at 67.59 % decreased during the drying process. Comparing the drying methods, the minimum and maximum moisture contents were recorded in the samples that were solar and bare ground dried, respectively. There were significant differences ($p<0.05$) in all the samples analysed (Appendix 3). The moisture content of the samples was reduced in the following order during drying, from 67.59 (Fresh) > 15.34 (Bare Ground drying) > 13.98 (Raised Concrete Platform + Netted Racks drying) > 12.96 (Raised Concrete Platform drying) > 10.53 % (Solar drying).

The fat content of the fresh Atlantic bumper fish was 9.99 %, which decreased significantly ($p<0.05$) to a range of 6.88 to 8.34 % after drying. The least fat content (6.88%) was recorded in the solar dried samples.

Values recorded for the protein content of the samples were from 13.40±0.99 in the fresh samples to 71.69±0.85 % (dwb) in the solar dried samples (Table 5). Protein contents of all dried samples were significantly different from the fresh samples. The ash content of the samples ranged from 6.33±1.03 % in the solar dried samples and 11.31±1.00 % in the samples that were dried on the bare ground. There was no significant difference ($p<0.05$) between the solar and Raised Concrete Platform + Netted Drying Racks dried samples with reference to the ash content.

Table 5 - *Proximate Compositions of Fresh and Dried Atlantic Bumper Fish after Drying for 20 h*

Atlantic Bumper Fish Sample According to Drying Method	Proximate Composition (g/ 100g) on dry weight basis			
	Moisture	Fat	Protein	Ash
Fresh	67.59±0.85^{a}	9.99±1.01^{a}	13.40±0.99^{d}	4.27±1.04^{c}
Bare ground	15.34±1.07^{b}	8.34±0.32^{ab}	61.79±0.86^{c}	11.31±1.00^{a}
RCP	12.96±1.00^{bc}	7.920±1.02^{ab}	67.43±0.86^{b}	7.63±1.02^{b}
RCP+NDR	13.98±0.99^{b}	8.32±1.01^{ab}	67.46±0.86^{b}	6.49±1.03^{bc}
Solar	10.53±1.00^{c}	6.88±1.03^{b}	71.69±0.85^{a}	6.33±1.03^{bc}

Sample means with the same superscript among the different drying methods used for drying Atlantic bumper fish are not significantly different ($p > 0.05$) from each other. Key: RCP- Raised Concrete Platform; RCP+NDR- Raised Concrete Platform+ Netted Drying Racks

Source: Field data (2020)

Mineral and Histamine Contents of Fresh and Dried Atlantic Bumper Fish from the Four Different Drying Methods

The mineral and histamine contents of the fish samples are given in Table 6. Generally, the mineral (Fe, P and Ca) contents of the fish reduced from the fresh samples to the dried samples. Samples that were dried by the solar method recorded the highest mineral contents compared to those by the other methods. Arsenic was the only heavy metal that was detected in the fish samples. Pb and Cd were below the detection limit. Arsenic was only detected in the fresh and bare ground samples. The recorded values for both samples were significantly different from each other.

Histamine content of the Atlantic bumper fish ranged from 0.0104 ± 0.0000 (in the samples that were solar dried) to 0.0294 ± 0.0027 ppm (in the fresh samples) (Table 6). A general reduction was observed from the fresh to the dried samples. The fresh samples were significantly different from all the dried samples. However, there was no significant difference in all the samples from the various drying methods. The sun-dried anchovies and Atlantic bumper fish samples obtained from Tema New Town, James Town, Moree and Adina processing sites were used as reference samples in comparison to the fish samples dried using the Raised Concrete Platform+ Netted Drying Racks (method of interest). The fresh fish samples (Anchovies and bumper) used in the drying experiment were compared with the fresh fish obtained from the processing sites. Also, the raised concrete platform with netted drying racks (RCP+NDR) samples were compared with the dried fishes obtained from the processing sites.

Table 6 - *Mineral and Histamine Contents of Atlantic Bumper Fish after Drying for 20 h*

Atlantic Bumper Fish Sample According to Drying Method	Mineral Content (mg/100 g)			Heavy Metal Content (mg/100g)			Histamine
	Fe	P	Ca	Pb	Cd	As	(ppm)
Fresh	37.48±0.28[b]	4273.59±6.41[a]	4354.80±2.00[a]	ND	ND	0.0010±0.0000[a]	0.0294±0.0027[a]
Bare ground	30.85±0.52[c]	1489.96±2.92[d]	4030.02±0.58[d]	ND	ND	0.0003±0.0000[b]	0.0129±0.0000[b]
RCP	27.17±0.64[d]	1497.79±1.41[d]	3939.30±16.3[e]	ND	ND	ND	0.0116±0.0001[b]
RCP+NDR	28.63±1.13[d]	1533.72±5.67[c]	4094.10±2.07[c]	ND	ND	ND	0.0122±0.0001[b]
Solar	41.58±0.50[a]	1564.23±0.06[b]	4209.91±13.19[b]	ND	ND	ND	0.0104±0.0000[b]

Sample means with the same superscript among the different drying methods used for drying Atlantic bumper fish are not significantly different ($p > 0.05$) from each other. Key: RCP- Raised Concrete Platform; RCP+NDR- Raised Concrete Platform+ Netted Drying Racks

Source: Field data (2020)

Proximate Composition of Fresh and Dried Anchovies from the Four Different Processing Sites

The proximate compositions of both fresh and dried anchovy are depicted in Table 7. The moisture content of the fresh fishes ranged from 70.30 to 72.44 %. The highest moisture content was recorded in samples from Tema and James Town. For the dried samples, the RCP+NDR dried samples had the least moisture content. Dried samples from Tema had the highest moisture content as compared with the other samples from the other towns and RCP+NDR. The moisture content of the samples that were from James Town and Adina were not significantly different ($p > 0.05$).

Generally, the fat contents of the experimental fresh samples were significantly different ($p > 0.05$) from the fresh samples from the various towns except samples from James Town (Table 7). The samples from Tema had the least fat content, but not significantly different from samples from Adina. The fat content of the dried samples from the various towns were virtually the same statistically (not significantly different ($p > 0.05$) from each other), however, samples from Adina were not significantly different from the experimental samples.

The protein content of the fresh anchovy from the experiment and that of all the processing sites increased (concentrated) after moisture loss through drying (Table 7). Dried anchovy from RCP+NDR however recorded the highest protein content of 70.05 g/100g.

The ash content was not significantly different amongst the fresh anchovy samples except fresh anchovy from James Town which recorded the lowest ash content of 11.75 %. After the drying process, the ash content

ranged from 9.11 to 13.05 g/100g showing significant increase in the ash content especially from the processing sites as found in Table 7. Raised concrete platform with netted drying racks dried anchovy recorded the lowest significant ash content of 9.11 g/100g.

Table 7 - *Proximate Composition of Fresh and Dried Anchovies from the Four Different Processing Sites*

State of Sample	Source of Sample	Proximate Composition (g/ 100g)			
		Moisture	Fat	Protein	Ash
Fresh	Experimental	71.30±0.08^{b}	8.03±0.10^{a}	11.10±0.10^{b}	8.22±0.10^{a}
	Adina	71.44±0.08^{b}	7.16±0.10^{c}	12.10±0.10^{a}	7.95±0.10^{b}
	Tema	72.35±0.08^{a}	7.05±0.10^{c}	12.19±0.10^{b}	7.13±0.10^{c}
	Moree	70.30±0.09^{c}	7.49±0.11^{b}	12.94±0.10^{a}	7.25±0.11^{c}
	James Town	72.44±0.08^{a}	8.16±0.10^{a}	13.07±0.10^{a}	5.18±0.10^{d}
Dried	RCP+NDR	12.71±0.11^{c}	6.96±0.10^{a}	70.05± 0.08^{a}	9.11±0.10^{d}
	Adina	13.95±0.10^{b}	6.98±0.10^{a}	64.44±0.09^{c}	12.75±0.10^{b}
	Tema	16.09±0.10^{a}	6.10±0.10^{b}	63.12±0.09^{e}	13.01±0.10^{a}
	Moree	15.94±0.10^{a}	6.00±0.07^{b}	64.06±0.60^{d}	13.05±0.10^{a}
	James Town	14.01±0.10^{b}	7.07±0.10^{a}	65.17±0.09^{b}	12.04±0.10^{c}

Sample means with the same superscript among the different drying methods used for drying anchovies are not significantly different ($p > 0.05$) from each other. Key: RCP+NDR- Raised Concrete Platform+ Netted Drying Rack; Experimental: fresh fish samples used in the drying experiment.

Source: Field data (2020)

Minerals and Histamine Contents of Fresh and Dried Anchovies from the Four Different Processing Sites

Table 8 shows that the contents of all the three minerals (Fe, P and Ca) in the anchovy fish decreased as a result of the different methods of drying used in this study. The three minerals (Fe, P and Ca) analysed in the Atlantic bumper fish also decreased in all the fresh samples after the drying processing. Heavy metals such as lead and cadmium were not detected in both the fresh and the dried samples. Arsenic was however detected in all the fresh anchovy samples ranging from 0.68 to 1.34 mg/100g. The experimental fresh sample recorded the lowest value. There was a significant reduction to 0.03 mg/ 100g of the arsenic content in all the dried samples with no significant differences amongst them.

Generally, there was a reduction in the histamine content after drying the fresh samples. The histamine contents of all the anchovy samples from the processing sites were comparable, with an average value of 0.020 ppm. The Raised Concrete Platform+ Netted Drying Racks dried anchovy recorded the lowest histamine value of 0.012 ppm.

Table 8 - *Minerals and Histamine Contents of Fresh and Dried Anchovies from the Four Different Processing Sites*.

State of Sample	Source of Sample	Mineral Composition (mg/100 g)			Heavy Metal Composition (mg/100g)			Histamine
		Fe	P	Ca	Pb	Cd	As	(ppm)
Fresh	Experimental	65.13±2.22^{a}	5309.50±5.95^{a}	5155.00±2.61^{a}	ND	ND	0.68±0.08^{b}	0.049±0.001^{b}
	Adina	49.96±1.67^{b}	4880.66±9.50^{b}	4211.73±3.17^{e}	ND	ND	1.28±0.04^{a}	0.054±0.001^{ab}
	Tema	51.54±0.23^{b}	4495.80±6.90^{e}	4323.00±2.29^{d}	ND	ND	1.22±0.23^{a}	0.049±0.001^{b}
	Moree	49.15±0.90^{b}	4801.08±3.66^{c}	4974.06±6.42^{b}	ND	ND	1.16±0.21^{ab}	0.059±0.002^{a}
	James Town	51.82±0.04^{b}	4584.84±6.90^{d}	4379.56±2.29^{c}	ND	ND	1.34±0.34^{a}	0.060±0.004^{a}
Dry	RCP+NDR	31.12±0.22^{bc}	1804.56±0.33^{b}	3002.26±0.53^{b}	ND	ND	0.03±0.00^{a}	0.012±0.000^{b}
	Adina	33.79±0.26^{a}	1571.46±6.50^{e}	3031.80±15.6^{b}	ND	ND	0.30±0.02^{a}	0.021±0.000^{a}
	Tema	31.68±0.67^{b}	1877.00±1.15^{a}	3273.63±10.85^{a}	ND	ND	0.30±0.02^{a}	0.020±0.000^{a}
	Moree	33.75±0.08^{a}	1620.33±11.88^{d}	2509.78±13.8^{c}	ND	ND	0.30±0.01^{a}	0.019±0.000^{a}
	James Town	30.03±0.88^{c}	1772.02±13.19^{c}	2526.80±2.77^{c}	ND	ND	0.30±0.01^{a}	0.022±0.003^{a}

Sample means with the same superscript among the different drying methods used for drying anchovies are not significantly different ($p > 0.05$) from each other. Key: RCP+NDR- Raised Concrete Platform+ Netted Drying Rack; Experimental: fresh fish samples used in the drying experiment

Source: Field data (2020)

Proximate Compositions of Fresh and Dried Atlantic Bumper fish from the Four Different Processing Sites

The proximate compositions of fresh and dried Atlantic bumper fish from the four different processing sites are shown in Table 9. With reference to the Atlantic bumper fishes, moisture content for the fresh fishes used in the study ranged from 67.59 to 70.09 % (d.s). The least value of moisture content was found in the experimental fish samples, whilst the highest moisture content was in those from James Town. The moisture content of the fresh samples were different significantly ($p<0.05$) except those from Tema and James Town. RCP+NDR dried samples recorded the lowest moisture content of 13.96 %.

As shown in Table 9, the fat content decreased slightly, from a range of 7.69 – 9.99 to 6.07 – 8.31 %, after the drying process. Also, the protein content of the samples increased significantly ($p> 0.05$) after drying. Protein contents of fresh Atlantic bumper obtained from the processing sites were comparable to those of the fresh samples used in the drying experiment. The ash content was also comparable amongst the fresh Atlantic bumper fish samples. After the drying processing however, the ash content ranged between 6.49 to 12.18 % indicating significant ($p> 0.05$) increase in the ash content especially from the processing sites as found in Table 9. Raised Concrete Platform with Netted Drying Racks (RCP+NDR) dried samples recorded the lowest significant ($p> 0.05$) ash content of 6.49 %.

Table 9 -*Proximate Compositions of Fresh and Dried Atlantic Bumper Fish from the Four Different Processing Sites*

State of Sample	Source of sample	Proximate Composition (g/ 100g) in dry weight basis			
		Moisture	Fat	Protein	Ash
Fresh	Experimental	67.59±0.85^{b}	9.99±1.00^{a}	13.40±1.00^{a}	4.27±1.04^{c}
	Adina	68.65±0.85^{ab}	8.97±010^{a}	12.23±1.00^{a}	5.52±.03^{a}
	Tema	70.02±0.84^{a}	7.69±1.02^{b}	12.73±0.62^{a}	6.29±0.03^{a}
	Moree	68.78±0.85^{ab}	7.83±1.02^{b}	14.15±0.99^{a}	5.65±1.03^{a}
	James Town	70.09±0.84^{a}	8.80±0.01^{a}	12.39±1.00^{a}	5.42±1.02^{a}
Dried	RCP+NDR	13.98±1.00^{b}	8.31±1.01^{a}	67.46±0.85^{a}	6.49±1.03^{b}
	Adina	15.46±0.98^{ab}	5.35±1.03^{b}	63.89±0.86^{bc}	11.00±1.01^{a}
	Tema	15.81±0.98^{ab}	6.45±1.03^{ab}	62.79±0.86^{bc}	11.29±1.00^{a}
	Moree	16.38±1.00^{a}	7.15±1.03^{ab}	62.22±0.09^{c}	11.11±0.10^{a}
	J. Town	15.95±1.00^{ab}	6.07±0.10^{ab}	64.20±0.09^{b}	12.18±0.99^{c}

Sample means with the same superscript among the different drying methods used for drying Atlantic bumper fish are not significantly different (p> 0.05) from each other. Key: RCP+NDR- Raised Concrete Platform+ Netted Drying Rack; Experimental: fresh fish samples used in the drying experiment

Source: Field data (2020)

Mineral and Histamine Contents of Fresh and Dried Atlantic Bumper Fish from the Four Different Processing Sites

Table 10 gives the results of the mineral (Fe, P and Ca) and histamine contents of the fresh and dried Atlantic bumper fish from the experiment and fish processing sites. The three minerals decreased significantly ($p > 0.05$) after the drying processing. Raised Concrete Platform with Netted Drying Rack dried samples had higher iron and calcium content compared to those from processing sites. Lead and cadmium contents were below the detection limits in all the samples. Arsenic contents recorded during the study were 0.06 mg/100g, 0.10 mg/100g, 0.06 mg/100g and 0.25 mg/100g in fresh fish samples from Adina, Tema, Moree and James Town respectively, which decreased to a range of 0.02 to 0.08 mg/100g. However, arsenic content was below the detection limits in fresh and dried samples from the Raised Concrete Platform+Netted Drying Rack method.

Histamine levels in fresh Atlantic bumper fish which were initially between 0.029 and 0.053 ppm reduced significantly to a range of 0.010 to 0.020 ppm after the drying on the Raised Concrete Platform with Netted Drying Racks (RCP+NDR) (Table 10).

Table 10 - *Mineral and Histamine Contents of Atlantic bumper Fish from the Four Different Processing Sites*

State of Sample	Source of Sample	Mineral content (mg/100 g)			Heavy Metal Content (mg/100g)			Histamine (PPM)
		Fe	P	Ca	Pb	Cd	As	
Fresh	Experimental	37.48±0.28^{a}	4273.59±6.41^{d}	4354.80±2.00^{a}	ND	ND	0.00±0.00^{c}	0.029±0.003^{d}
	Adina	34.76±3.15^{ab}	3994.59±6.80^{e}	3969.98±3.02^{c}	ND	ND	0.06±0.00^{a}	0.045±0.001^{b}
	Tema	39.18±1.00^{a}	4432.25±4.06^{b}	4065.60±7.61^{b}	ND	ND	0.10±0.00^{b}	0.040±0.000^{c}
	Moree	39.12±3.25^{a}	4488.35±1.74^{a}	3948.21±5.94^{c}	ND	ND	0.06±0.02^{b}	0.050±0.003^{ab}
	J. Town	29.96±2.08^{b}	4318.98±0.98^{c}	4070.20±6.00^{b}	ND	ND	0.25±0.04^{a}	0.053±0.000^{a}
Dried	RCP+NDR	28.63±1.13^{a}	1533.72±5.67^{a}	4104.06±6.51^{a}	ND	ND	ND	0.010±0.001^{e}
	Adina	24.18±0.70^{b}	1687.7±15.60^{b}	3868.10±3.20^{d}	ND	ND	0.03±0.00^{b}	0.016±0.001^{b}
	Tema	28.72±0.58^{a}	1532.20±15.5^{b}	3984.86±6.91^{b}	ND	ND	0.03±0.00^{b}	0.012±0.000^{d}
	Moree	21.96±1.14^{c}	1520.50±12.84^{b}	3890.31±4.30^{c}	ND	ND	0.02±0.00^{c}	0.014±0.000^{c}
	J. Town	22.67±0.20^{bc}	1363.06±6.50^{c}	3823.04±3.12^{e}	ND	ND	0.08±0.00^{a}	0.020±0.000^{a}

Sample means with the same superscript among the different drying methods used for drying Atlantic bumper fish are not significantly different ($p > 0.05$) from each other. Key: ND=Not detected; RCP+NDR- Raised Concrete Platform+ Netted Drying Racks; Experimental: fresh fish samples used in the drying experiment

Source: Field data (2020)

Microbial Counts of Fresh and Dried Fish (Anchovy and Atlantic bumper fish) from the Four Different Drying Methods

The effects of using the four different drying methods on the microbiological quality of anchovies are presented in Table 11. The highest microbial counts for aerobic mesophiles, coliforms, moulds, *Staphylococcus aureus, B. cereus* and *Enterobacteriaceae* were 5.89 $\log_{10}$ CFU, 2.50 $\log_{10}$ CFU, 4.31 $\log_{10}$CFU, 3.61 $\log_{10}$CFU, 2.07 $\log_{10}$CFU and 4.83 $\log_{10}$CFU respectively. These values were recorded in the samples that were dried on the bare ground. The aerobic mesophiles were the only organisms present in the solar dried samples.

Coliform bacteria, moulds and *Bacillus cereus* were not detected in the fresh anchovy as well as dried and RCP+NDR dried anchovies (Table 11). In contrast, anchovy dried on the bare ground recorded the highest counts of 2.50, 4.31 and 2.07 $\log_{10}$ CFU/g respectively for coliforms, moulds and *Bacillus cereus* whiles RCP recorded lowest counts of 1.83, 2.00, 1.69 $\log_{10}$ CFU/g respectively. *Staphylococcus aureus* was not detected in either the fresh or dried anchovies except in anchovies dried on the bare ground which had a microbial count of 3.61 $\log_{10}$ CFU/g.

Table 11 - *Microbial Quality (log_{10} CFU/g) of Fresh and Dried Anchovies from the Four Different Drying Methods*

Anchovy Sample According to Drying Method	Aerobic mesophiles	Coliforms	Moulds	*Staphylococcus*	*B. cereus*	Enterobacteriaceae
Fresh	3.15±0.04[c]	ND	ND	ND	ND	2.20±0.03[c]
Bare ground	5.89±0.02[a]	2.50±0.05[a]	4.31±0.05[a]	3.61±0.04	2.07±0.10[a]	4.83±0.02[a]
RCP+NDR	3.02±0.02[d]	ND	ND	ND	ND	1.81±0.08[d]
RCP	4.69±0.03[b]	1.83±0.18[b]	2.00±0.06[c]	ND	1.69±0.13[b]	3.23±0.07[b]
Solar	2.92±0.01[e]	ND	ND	ND	ND	ND

Sample means with the same superscript among the different drying methods used for drying Anchovy fish are not significantly different ($p > 0.05$) from each other. Key: ND=Not detected; RCP- Raised Concrete Platform; RCP+NDR- Raised Concrete Platform+ Netted Drying Racks

Source: Field data (2020)

Table 12 shows the microbiological quality of Atlantic bumper fish during the various drying processes. Aerobic mesophiles were present in all the dried samples with significant difference ($p > 0.05$) among all the samples. Aerobic mesophiles ranged between 2.61 and 5.70 $\log_{10}$ CFU/g. The solar dried samples recorded the lowest counts whiles fish dried on the bare ground recorded the highest counts. Generally, there was an increase in the aerobic mesophilic count for bare ground dried and RCP dried fish but a reduction in counts for solar dried and RCP+NDR dried fish.

Microbial counts for coliforms and Enterobacteriaceae followed a similar pattern. There was an increase in counts for bare ground dried Atlantic bumper fish as a result of the drying, but a decrease in counts for RCP dried fish. After the drying, no counts for coliforms and Enterobacteriaceae were however recorded for solar and RCP+NDR dried Atlantic bumper fish as Table 12 shows.

Moulds and *Bacillus cereus* count for the fresh and dried Atlantic bumper fish also followed the same pattern. No counts were detected for the microbes in the fresh fish and remained non detectable in the solar dried and RCP+NDR dried fishes. There were however moulds and *Bacillus cereus* count in Atlantic bumper fish samples dried on the bare ground and RCP; the latter recording the highest significant ($p > 0.05$) count.

Staphylococcus aureus was not detected in either the fresh or dried Atlantic bumper fish, but, in anchovies dried on the bare ground, a microbial count of 3.20 log 10 CFU/g was recorded.

Table 12 - *Microbial Quality (log_{10} CFU/g) of Fresh and Dried Atlantic Bumper Fish from the Four Different Drying Methods*

Bumper Sample According to Drying Method	Aerobic mesophiles	Coliforms	Moulds	*Staphylococcus*	*B. cereus*	Enterobacteriaceae
Fresh	3.67±0.03[c]	2.64±0.04[b]	ND	ND	ND	3.2±0.03[b]
Bare ground	5.70±0.02[a]	3.19±0.05[a]	3.23±0.07[a]	3.20±0.04	2.34±0.06[a]	4.46±0.04[a]
RCP+NDR	3.55±0.07[c]	ND	ND	ND	ND	ND
RCP	4.94±0.14[b]	1.45±0.02[c]	2.08±0.05[b]	ND	1.78±0.00[b]	2.1±0.03[c]
Solar	2.61±0.08[d]	ND	ND	ND	ND	ND

Sample means with the same superscript among the different drying methods used for drying Atlantic bumper fish are not significantly different ($p > 0.05$) from each other. Key: RCP- Raised Concrete Platform; RCP+NDR- Raised Concrete Platform+ Netted Drying Racks

Source: Field data (2020)

Microbial Quality of Fresh and Dried Anchovy from the Four Different Processing Sites

The microbiological analysis of anchovy samples (fresh and dried) from the four different processing sites are presented in Table 13. For fresh anchovy from the four study sites, Enterobacteriaceae, yeast and moulds were not detected in any of the samples. Coliform bacteria were not detected in the experimental and Adina samples of fresh anchovy. Fresh anchovy samples from James Town recorded the highest aerobic mesophilic count while samples from Tema recorded the highest Enterobacteriaceae. For the dry anchovy samples, Enterobacteria and yeast were not detected from all the four study sites (Table 13). Coliform bacteria were not detected in anchovy samples dried on the RCP + NDR. Moulds were detected in dried samples from James Town and Tema. Dried samples from James Town recorded the highest aerobic mesophiles, Enterobacteriaceae and Coliforms.

Table 13 - *Microbial Quality (log_{10} CFU/g) of Fresh and Dried Anchovies from the Four Different Processing Sites*

Sample	Source of sample	Aerobic mesophiles	Enterobacteriaceae	Coliforms	Enterococcus	Yeast	Mould
Fresh	Experimental	3.15±0.04^{c}	2.20±0.02^{c}	ND	ND	ND	ND
	Adina	5.96±0.03^{ab}	2.74±0.08^{b}	ND	ND	ND	ND
	James Town	6.01±0.10^{a}	3.71±0.04^{a}	2.25±0.06^{a}	ND	ND	ND
	Moree	5.99±0.02^{a}	2.87±0.31^{b}	1.69±0.02^{c}	ND	ND	ND
	Tema	5.85±0.02^{b}	3.89±0.04^{a}	1.84±0.04^{b}	ND	ND	ND
Dried	RCP+NDR	3.02±0.02^{c}	1.90±0.08^{e}	ND	ND	ND	ND
	Adina	4.39±0.00^{d}	3.38±0.05^{c}	2.18±0.03^{b}	ND	ND	ND
	James town	6.96±0.22^{a}	4.49±0.15^{a}	3.33±0.04^{a}	ND	ND	1.89±0.90^{a}
	Moree	4.84±0.02^{c}	2.62±0.05^{d}	1.66±0.19^{c}	ND	ND	ND
	Tema	5.77±0.03^{b}	3.91±0.02^{b}	3.08±0.05^{a}	ND	ND	2.21±0.62^{a}

Sample means with the same superscript among the different processing sites are not significantly different ($p > 0.05$) from each other. Key: ND=Not detected; RCP+NDR- Raised Concrete Platform+ Netted Drying Racks; Experimental: fresh fish samples used in the drying experiment.

Source: Field data (2020)

Table 14 provides specific microorganisms of health importance detected and analysed. None of the organisms were detected in the experimental fresh sample. *Staphylococcus aureus* was detected in all the samples from the various sites except the experimental sample. Samples from Moree recorded the highest *Staphylococcus aureus* count. For the dried samples, none of the organisms were detected in the RCP + NDR sample. *B. cereus* and *S. aureus* were detected in all the samples except the RCP + NDR samples. Dried samples from Tema recorded the highest *B. cereus* and *S. aureus* counts.

Table 14 - *Microbial Quality (log_{10} CFU/g) of Fresh and Dried Anchovies from the Four Different Processing Sites*

Sample	Source of sample	*E. Coli*	*B. Cereus*	*Staphylococcus aureus*	*Listeria monocytogenes*	*Salmonella*
Fresh	Experimental	ND	ND	ND	ND	ND
	Adina	ND	ND	3.32 ± 0.10^{a}	ND	ND
	James Town	ND	ND	2.64 ± 0.01^{b}	ND	ND
	Moree	ND	ND	3.45 ± 0.07^{a}	ND	ND
	Tema	ND	ND	2.28 ± 0.00^{c}	ND	ND
Dried	RCP+NDR	ND	ND	ND	ND	ND
	Adina	ND	1.19 ± 0.02^{b}	1.11 ± 0.10^{d}	ND	ND
	James Town	ND	2.75 ± 0.07^{a}	1.88 ± 0.56^{c}	ND	ND
	Moree	ND	1.343 ± 0.37^{b}	2.49 ± 0.08^{b}	ND	ND
	Tema	ND	2.92 ± 0.03^{a}	2.81 ± 0.14^{a}	ND	ND

Sample means with the same superscript among the different processing sites are not significantly different ($p > 0.05$) from each other. Key: ND=Not detected; RCP+NDR- Raised Concrete Platform+ Netted Drying Racks

Source: Field data (2020)

Microbial Quality of Fresh and Dried Atlantic Bumper Fish from the Four Different Processing Sites

Table 15 shows the microbiological quality of fresh and dried Atlantic bumper fish from the four different processing sites that were visited. Enterococcus, yeast and moulds were not detected in any of the fresh samples from the various sites. Samples from James Town recorded the highest aerobic mesophiles, Enterobacteriaceae and coliform counts while the experimental sample recorded the least counts of these microorganisms. For the dried samples, only aerobic mesophilic count was recorded when RCP + NDR drying method was used. Enterococcus and yeast were not detected in any of the dried samples. Moulds were detected in dried samples from Moree.

Table 15 - *Microbial Quality (log_{10} CFU/g) of Fresh and Dried Atlantic Bumper Fish from the Four Different Processing Sites*

Atlantic bumper	Source of sample	Aerobic mesophiles	Enterobacteriaceae	Coliforms	Enterococcus	Yeast	Mould
Fresh	Experimental	3.67 ± 0.03^{c}	3.26 ± 0.03^{c}	2.64 ± 0.04^{d}	ND	ND	ND
	Adina	4.15 ± 0.25^{b}	3.71 ± 0.02^{b}	2.96 ± 0.02^{bc}	ND	ND	ND
	James Town	4.86 ± 0.13^{a}	4.10 ± 0.14^{a}	3.29 ± 0.06^{a}	ND	ND	ND
	Moree	3.82 ± 0.01^{c}	3.67 ± 0.03^{b}	2.93 ± 0.01^{c}	ND	ND	ND
	Tema	4.69 ± 0.01^{a}	3.92 ± 0.04^{a}	3.13 ± 0.15^{a}	ND	ND	ND
Dried	RCP+NDR	3.55 ± 0.07^{e}	ND	ND	ND	ND	ND
	Adina	4.75 ± 0.03^{c}	3.68 ± 0.04^{b}	1.36 ± 0.00^{c}	ND	ND	1.11 ± 0.00^{c}
	James Town	5.80 ± 0.25^{b}	4.93 ± 0.03^{a}	2.70 ± 0.09^{a}	ND	ND	2.80 ± 0.00^{a}
	Moree	4.06 ± 0.19^{d}	3.24 ± 0.56^{b}	1.99 ± 0.04^{b}	ND	ND	ND
	Tema	6.30 ± 0.03^{a}	4.79 ± 0.01^{a}	2.67 ± 0.03^{a}	ND	ND	1.70 ± 0.00^{b}

Sample means with the same superscript among the different processing sites are not significantly different ($p > 0.05$) from each other. Key: ND=Not detected; RCP+NDR- Raised Concrete Platform+ Netted Drying Racks; Experimental: fresh fish samples used in the drying experiment.

Source: Field data (2020)

Table 16 shows the microorganisms of health importance. *E. coli*, *Listeria monocytogenes* and *Salmonella* were not detected in any of the samples. *Bacillus cereus* was detected in fresh samples from Moree and Tema, but *S. aureus* was detected in samples from James Town, Moree and Tema. For the dried samples, *E. coli*, *Listeria monocytogenes* and *Salmonella* were not detected in any of the dried samples. *B. cereus* was detected in samples from Moree and Tema and *S. aureus* from James Town, Moree and Tema.

Table 16 - *Microbial Quality (log_{10} CFU/g) of Fresh and Dried Atlantic Bumper Fish from the four Different Processing Sites*

Atlantic bumper	Source of sample	*E. coli*	*B. cereus*	*Staphylococcus aureus*	*Listeria monocytogenes*	*Salmonella*
Fresh	Experimental	ND	ND	ND	ND	ND
	Adina	ND	ND	ND	ND	ND
	James Town	ND	ND	1.14 ± 0.00^{b}	ND	ND
	Moree	ND	1.77 ± 0.05^{b}	1.11 ± 0.00^{b}	ND	ND
	Tema	ND	3.88 ± 0.02^{a}	1.81 ± 0.05^{a}	ND	ND
Dried	RCP+NDR	ND	ND	ND	ND	ND
	Adina	ND	ND	ND	ND	ND
	James Town	ND	ND	3.81 ± 0.02^{a}	ND	ND
	Moree	ND	1.74 ± 0.02^{b}	3.66 ± 0.02^{a}	ND	ND
	Tema	ND	3.90 ± 0.01^{a}	2.06 ± 0.35^{b}	ND	ND

Sample means with the same superscript among the different processing sites are not significantly different ($p > 0.05$) from each other. Key: ND=Not detected; RCP+NDR- Raised Concrete Platform+ Netted Drying Racks; Experimental: fresh fish samples used in the drying experiment.

Source: Field data (2020)

Consumer Acceptability of Biscuit Prepared from Fish Powder

Fortified biscuits products prepared from fish powder are shown in Figure 17. Scores of the various sensory parameters recorded for biscuit prepared from fish powder ranged from 4.68 to 8.17 as presented in Table 17. Least scores for the sensory attributes were recorded for biscuit samples that contained 15% bumper fish powder, whiles higher scores were recorded for samples with 5% bumper fish powder, comparable to the control product (samples without fish powder). There was no significant difference ($p>0.05$) between 5% bumper fish powder fortified biscuit and the control biscuit product. All other biscuit samples prepared from anchovy fish powder were significantly different ($p<0.05$) from the control.

Figure 17: Fortified biscuits products prepared from fish powder.

NB: A – Anchovy, B – Bumper

Source: Field data (2020)

Table 17 - *Consumer Acceptability Results of Biscuit Prepared from Fish Powder*

Fish Powder	Percentage of fish powder Incorporated	Aroma	Crispiness	Taste	After-taste	Overall Acceptability
Control	0	7.93±1.18[a]	7.83±1.15[a]	7.98±0.83[a]	7.87±0.95[a]	8.17±0.81[a]
Anchovy	5	7.09±1.22[b]	7.61±1.22[a]	6.81±1.32[bc]	6.56±1.23[bc]	6.95±1.23[bc]
	10	6.66±1.44[bc]	6.47±1.25[c]	6.22±1.23[c]	5.80±1.33[c]	6.11±1.32[d]
	15	5.20±1.90[d]	6.65±1.37[bc]	5.11±1.74[d]	4.72±1.69[d]	4.98±1.71[e]
Bumper	5	7.25±1.37[ab]	7.53±1.23[a]	7.35±1.19[ab]	7.30±1.36[ab]	7.43±1.29[ab±]
	10	6.24±1.54[c]	7.25±1.24[ab]	6.55±1.33[c]	6.31±1.48[c]	6.41±1.52[cd]
	15	4.68±1.84[d]	6.15±1.44[c]	5.21±1.68[d]	4.85±1.65[d]	4.90±1.63[e]

Sample means with the same superscript among the biscuit products are not significantly different (p> 0.05) from each other.

Source: Field data, (2020)

Consumer Acceptability of Instant Cereal Mix Prepared from Fish Powder

Fortified instant cereal mix and biscuit prepared are shown in Figure 18. The sensory scores obtained for the cereal mix (rice and fish powder at different percentages) during the sensory analysis are presented in Table 18. Scores for the various sensory parameters ranged from 4.85 to 7.43. Least scores for the various sensory attributes were recorded for samples that contained 9 % bumper fish powder while appreciable scores were recorded for samples that contained 3 % anchovies and 3 % bumper fish powder, compared to the control (samples without fish powder).

Figure 18: Anchovy fortified instant cereal mix (A) and Bumper fish fortified biscuit (B) prepared from fish powder.
C- Control (instant cereal mix without fish powder)

Source: Field data (2020)

Table 18 - *Consumer Acceptability Results of Instant Cereal Mix Prepared from Fish Powder*

Control	Percentage (%) of fish powder incorporated	Aroma	Consistency	Taste	After taste	Overall Acceptability
Control	0	7.32±1.48^{a}	7.41±1.04^{a}	7.43±1.20^{a}	7.25±1.31^{a}	7.37±1.33^{a}
Anchovy	3	6.87±1.48^{ab}	6.55±1.74^{bc}	6.48±1.54^{b}	6.60±1.36^{ab}	6.49±1.55^{ab}
	6	6.25±1.76^{bcd}	6.55±1.48^{bc}	6.20±1.66^{bc}	5.85±1.84^{bc}	6.17±1.86^{bc}
	9	5.62±1.89^{de}	6.36±1.76^{bc}	5.41±1.97^{cd}	5.34±1.99^{c}	5.25±1.94^{cd}
Bumper	3	6.66±1.33^{abc}	6.58±1.49^{abc}	6.71±1.49^{ab}	6.45±1.63^{ab}	6.75±1.53^{ab}
	6	5.83±1.82^{cde}	6.68±1.40^{ab}	5.95±1.83^{bc}	5.86±1.83^{bc}	6.07±1.86^{bc}
	9	5.13±1.99^{e}	5.82±1.84^{c}	4.88±1.87^{d}	5.14±2.01^{c}	4.85±1.81^{d}

Sample means with the same superscript among the instant cereal mix products are not significantly different ($p > 0.05$) from each other

Source: Field data (2020)

CHAPTER FIVE

DISCUSSION

The chapter presents discussion on the results as presented in chapter four in relation to the objectives of the study. The main objective was to undertake a comparative investigation of the effect of four drying methods on the proximate, chemical and histamine as well as the microbiological contents of dried anchovies and Atlantic bumper. The four drying methods were traditional sun-drying on the bare ground, improved sun-drying on concrete platform, improved sun-drying concrete platform with netted drying racks and solar-drying. The study also investigated the use of the fish powders from these four drying methods in two new food formulations.

Drying Curves of Anchovy and Atlantic Bumper Fish During the Drying Process

Drying air temperature has been found to be a major factor that influences the drying kinetics of products (Saeed *et al*., 2006; Sopian *et al.*, 2008). The higher the temperature, the bigger the saturated and partial pressure difference of water vapour in the drying-air, which is the main driving force for drying; since there is a maximum amount of water (saturation) that air can hold at a given temperature. Abraha *et al*. (2017) reported that, circulation of hot air in solar dryers result in high internal dryer temperature reducing the drying time of fish, whiles in open sun-drying, fish require a longer drying time because of erratic changes of temperature, with relatively low temperature as well as an accompanying humidity of the

ambient air. This accounts for the fluctuations in the moisture content especially for the open sun drying method.

The solar dried samples were left in the solar dryer overnight whiles that of the open sun drying had to be collected each night, covered and returned for drying the next day. It was observed that the sun-drying samples had some moisture/ tiny quantities of water collected around them when collected early in the morning. Compared to open sun-drying, solar-drying can generate higher air temperature which provides larger driving force for heat transfer and thereby increasing the evaporation rate of water significantly, resulting in lower final moisture content of dried samples (Olabinjo, Olajide, & Olalusi, 2014). Similar behaviour has been reported by several authors (Akendo, Gumbe, & Gitau, 2008; Belghit, Kouhila, & Boutaleb, 2000; Falade & Abbo, 2007; Madamba, Driscoll, & Buckle, 1996). Research by Bellagha, Amani, Farhat and Kechaou (2002) and Mwithiga and Mwangi (2005) on lightly salted sardines (*sadinella aurita)* and fish fillet respectively reported that higher air temperature produced a higher drying rate and reduced drying period (Omodara & Olaniyan, 2012). These observations were similar to the results of the current study.

The time of the day as well as the weather condition highly affected the moisture removal of samples being dried. According to Guan *et al*. (2013), the higher the drying temperature, the faster the drying rate and shorter the drying time. The relatively faster rate of drying in the improved sun-drying methods with concrete platform compared to the traditional, bare ground sun-drying can be explained by the fact that the slopping rack significantly improves the drying process through easier loss of water from the fish as

explained by Abraha *et al.* (2017). The higher moisture removal at the beginning of the drying process can be attributed to the readily available water (unbound) at the surface of the fish (Owureku-Asare, 2018). The amount of free water present at the start is very important, since the rate of water removal is higher during this phase (Faustino, Barroca, & Guine, 2007). As the drying proceeds, the free water present decreases quite rapidly, so that at the final stages, water was hardly available and the drying became very slow (Sopian *et al*., 2008). The efficiency of the drying process gradually decreases till it reaches an equilibrium stage phase where there is no further net loss of moisture (mass transfer) or change in weight of the food material. This is because unbound water is no longer available for removal in the drying process. A falling-rate phase begins when the surface of the food materials heats up as water leaves the interior of the food at the same rate as it evaporates from the surface (moisture concentration gradient). This means that diffusion is the dominant physical mechanism governing moisture movement in the material (Akpinar *et al*., 2003; Shanmugama & Natarajan, 2006), which is dependent on the moisture content of the samples (Prachayawarakorn, Tia, Plyto, & Soponronnarit, 2008; Sopian *et al*., 2008).

Kilic (2009) noted that an increased drying temperature decreased the fish quality because it accelerated the biochemical and microbiological decomposition of fish, especially salted fish. Lower ambient temperatures during drying provides a better fish texture and sometimes colour since it gives a more springy and not dry and brittle as found in solar dried fish (Saka, 2015).

Nutrient Composition of Fresh and Dried (Anchovy and Atlantic Bumper Fish) from the Four Different Drying Methods

Generally, visual physical observations of the dried fish samples pointed to the fact that the sun drying methods, especially using the raised concrete platform with netted drying racks, had a brighter and whitish appearance as well as a more acceptable texture than those from the solar-dryer. The latter dryer gave dark-baked appearance, hard and brittle dried fish, which had poor texture and were very susceptible to breaking. Fish dried on the bare ground and the platform were contaminated with sand particles and showed signs of contamination by blow flies, but those inside the solar tent dryer were free of these contaminations. This is confirmed by previous studies by Olokor and Ngwu (2001) and Braguy *et al*. (2005).

Moisture content is an important determinant of shelf stability of food products. This is because products with higher moisture content have high water activity, which enhances microbial activity leading to spoilage (Ashworth & Draper, 1992). The relatively high temperature and low relative humidity created in the solar dryer ensured more moisture evaporating from the sample. This makes the solar dried samples more shelf stable (Chukwu & Shaba, 2009; Sultana, Islam, & Kamal, 2009) compared to the samples from the other drying methods that had higher moisture content. The moisture contents for the fresh fish samples (FFS) recorded in this study were similar to the results of that obtained by Simat and Bogdanovic (2012).

Ojutiku *et al*. (2009) have explained that though dried fish at 25 % moisture content can be stable, they are easily prone to mould growth. However at 15 % moisture content, mould growth is minimal thereby

extending the shelf life of the fish. From the current study, the dried anchovy samples, with the moisture contents of between 7.50 -13.14 % will have a longer shelf life than the fresh fish samples (Sugathapala, Suntharabarathy, & Edirisinghe, 2012). A study by Rasul, Majumdar, Afrin, Bapary and Azad (2018) showed that traditionally dried fish samples tend to have higher moisture contents than fish samples dried by the improved and solar drying methods. These findings agree with the results of the present study.

Samples from the bare ground had higher ash content ($p<0.05$) compared to the other samples. The observed phenomenon may be attributed to contamination of fish samples by sand and dirt during the drying process (Rasul *et al*., 2018). The low values recorded in the solar dried samples may be due to the complete protection of the fish from dust, wind-blown particles and other foreign matter in the solar tent dryer as reported by Bala and Mondols (2001) and Chavan, Basu and Kovale (2008).

The increase in protein content recorded in the present studies was due to concentration of proteins after the removal of water molecules present between proteins during drying as reported by Ninawe and Ratnakumar (2008). Immaculate *et al. (*2012) also recorded an increase in protein content of sardine during rack drying, solar drying and traditional drying. There was no protein nitrogen loss observed in the solar tent dryer since the activity of enzymes and microorganisms were halted by the high temperatures in the dryer and low water content of dried samples. In view of these the protein content increased with the reduced moisture content when compared with the fish dried in open sun rack dryer as reported by Ninawe and Rathnakumar, and Chukwu and Shaba (2009). Begum, Uddin, and Akter (2013) found that

drying time as well as moisture loss causes a denaturation of the proteins in some fish samples.

Generally, an inverse relationship existed between the moisture and fat, protein and ash content of the samples analysed during the study. The observed pattern is similar to the studies conducted by Nurullah *et al*. (2006) on small fish species which were dried by solar tunnel and traditional sun drying methods. Chukwu and Shaba (2009) and Ninawe and Rathnakumar (2008) also reported that a reduction in moisture content causes an aggregation of protein, minerals, fat in dried fish samples.

The decrease in fat contents in the dried samples compared to the fresh samples (anchovy and atlantic bumper fish) could be attributed to the evaporation of moisture with lipids from the samples during drying. Solar dried samples recorded the least fat content amongst the dried samples. The decrease in fat content may also be attributed to the high temperature treatment (82 ^{o}C) from the drying methods which have also been found to trigger lipid oxidation (Mahmud *et al*., 2018).

Generally, a reduction in the nutrients may be attributed to the nutrient concentrated waters dripping away from the samples through the rack pores during processing similar to findings by Ochieng *et al*. (2015).

Histamine contamination is prevalent among pelagic fish such as mackerel and sardine. In view of this, Abbey (1998) and Kose and Erdem (2003) suggested that icing of fish after harvesting could minimize histamine formation. Codex (2007) has set limits of 10 mg/ kg for histamine as indicator of decomposition and 20 mg/kg as indicator of poor handling of fish. According to Onal (2007), histamine levels above 40-100 mg/kg and higher

causes severe food poisoning that can lead to ill health and death. However, the histamine contents of all the samples (both fresh and dried anchovies) during this study were less than 1 mg/kg which shows that they were safe with respect to histamine content. It also shows proper handling of the fresh anchovies, as well as prompt processing after harvest. Similar to the present study, Plahar *et al*., (1999) also did not detect histamine in either fresh or dried anchovy. Some studies have however reported significant levels of histamine in herrings and other species. (Pan & Orejana, 1985).

Nutrient Composition of Fish (Anchovies and Atlantic Bumper Fish) from Improved Drying Method (RCP+NDR) Compared to the Traditional Sun Drying Method

The results of this study has shown that the crude protein and ash content of the fish increased after drying while moisture and crude fat decreased in dried fish samples from all the processing sites. These results were comparable to the findings of Abraha *et al* (2017). The decrease in moisture content is due to the loss of free water present in muscle when exposed to heat as reported by Collignan, Santchurn, and Zakhia-Rozis (2008).

Several authors have reported that, moisture content has a tremendous effect on the ultimate quality and storage life of dried fish. Higher moisture content make products susceptible to microbial and enzymatic spoilage (Kumar *et al*., 2017). The moisture content of the dried fish samples from the traditional drying methods obtained from the processors had higher moisture content compared with those from the improved drying methods. This

observation is consistent with what has been reported in literature (Relekar *et al*., 2014). Even though the same species of fish was used in processing, variations in the moisture content can be attributed to fluctuations of traditional drying conditions which leads to higher moisture content in traditionally dried fish (Bulushi, Guizani, & Dykes, 2013). Similarly, Id, Chandra, Id and Afrin (2018) also recorded higher moisture content in traditionally produced dried fish than in fish produced by the improved methods (drying on racks). According to Relekar *et al*., dried fish procured from the local market have lower protein content compared to fish dried by improved methods and this may be attributed to the removal of water to a greater extent.

Generally, differences in the nutritional or chemical composition of fish of the same species can be attributed to seasonality, feeding habits, sex, source variation and difference in drying methods used in processing (Oparaku & Nwaka, 2013; Boran, Boran, & KaraCAm, 2008). Several studies have established that open sun drying, on the bare ground, increases the level of sand or grits in dried fish. (Relekar *et al*., 2014; Immaculate *et al*., 2012). The higher ash values recorded for samples from processors are therefore expected. Earlier studies also showed higher ash content in the sand dried sardines compared to the fresh samples due to the sand contamination (Sablani *et al*., 2002). The raised concrete platform with netted drying racks samples recorded significantly ($p<0.05$) lower values for ash content which was in agreement with the findings of Tunison *et al.* (1990) and Ojutiku *et al.* (2009). This can be attributed to the reduction of the extent of contamination from

dust, insects and a host of others due to the raised platform as well as the use of netted racks as covering.

Fat content of fish is more variable than other proximate components and may reflect a natural variance in different or the same fish species. The decrease in fat contents in the dried samples compared to the fresh samples may be due to the evaporation of moisture with lipids from the samples (Mahmud *et al*., 2018).

From Table 8 and 10, heavy metals such as lead and cadmium were not detected in either the anchovies or the Atlantic bumper fish samples. The maximum level of arsenic concentration for fish is 1.0 mg/kg according to the Australian standard (Australia-New Zealand Food Authority, 2010). None of the fish samples examined in this study exceeded the concentrations set by the Australian standards. High concentrations of heavy metals are mostly recorded in large fishes which prey on other fish especially cephalopods like squid (Caurant & Amiard-Triquet, 1995). Durmus *et al*., (2018) detected these heavy metals in red mullet fish at higher concentration contrary to the current study.

Microbial Counts of Fresh and Dried Fish (Anchovy and Atlantic Bumper Fish) from the Four Different Drying Methods

The population of aerobic mesophiles recorded in this study were comparable to those reported by Mansur, Rahman, Khan, Reza and Kamrunnahar- Uga (2013). The high aerobic mesophilic contamination level of the dried anchovies and the Atlantic bumper fishes from the bare ground are clear indications that samples were handled under poor hygienic conditions as suggested by Kung *et al*. (2015). The solar-dried samples recorded the least

aerobic mesophiles indicating good hygienic condition during drying as reported by Id *et al*. (2018). Though aerobic mesophiles is an indication of poor hygienic conditions during the drying process, the values were below the maximum allowable limit of aerobic mesophiles for fish by the Ghana Standards Authority (GSA) and the International Commission on Microbiological Specifications for Foods (ICMSF) standard of 7 log CFU/g (ICMSF, 1988). This can generally be attributed to the pre-washing of fresh fish with 5 % salt solution as well as the wearing of gloves during fish handling.

The microbial contamination of the bare ground and platform dried fish samples is likely to be due to exposure to contamination from the environment with coliforms, moulds and *Bacillus* since these organisms were not detected in the fresh fish samples. Anchovies dried using the solar and RCP+NDR methods were housed in protective drying chambers that ensured reduced chances of microbial contamination.

The dusty environment, poor hygienic conditions, contaminated contact surfaces, or poor handling practices accounted for the high levels of microbial contaminants recorded for the bare ground and Raised Concrete Platform dried fishes. The coliform counts of the two dried fish samples from the bare ground far exceeded the Ghana Standards Authority (GSA) limit of 1.6 log CFU/g (GS 747: 2003). Hasselberg *et al*. (2020a) also recorded high microbial counts in dried fish under similar circumstances. High incidence of mesophiles and total coliforms were also recorded by Selmi, Bouriga, Cherif, Toujani and Trabelsi (2010) in bare ground sun-dried fish compared to that dried under controlled conditions.

Karim *et al.* (2017) also recorded high Enterobacteriaceae counts for anchovies dried in open sun whiles rack dried samples recorded low counts. Ochieng *et al.* (2015) reported that the mean microbial load of dried samples dried on the raised rack was less (1.48×102 CFU/g for yeast and moulds and 1.56× 102 bacteria) than those dried using the traditional bare ground drying method. This was attributed to the clean and safe practices followed during processing using the raised rack method.

In a similar study by Sabo (2018), higher counts of *S. aureus* were recorded for anchovies dried under traditional open sun drying than the count for solar dried samples, which may be attributed to the hygienic drying conditions provided by the drying tent. Plahar *et al.* (1999) also found the presence of *S. aureus* in anchovy fish samples dried on the bare ground. The recorded values from the present study were however below the GSA's and the International Commission on Microbiological Specifications for Foods (ICMSF) standards of 4.0 log CFU/g for *S. aureus* (ICMSF, 1988). The absence of *Staphylococcus aureus* in some of the dried samples can be attributed to the less contact of fish with the processors during drying as well as less contact with contaminated surface.

Salmonella spp, which is a food-borne hazard, was not detectedin any of the dried fish samples. Hasselberg *et al*. (2020a) did not also detect *Salmonella* in dried fish samples. *E.coli* was also not detected in the present study, however Sabo (2018) recorded counts of *E.coli* for both fresh and traditionally sun dried anchovies.

Microbial Quality of Fresh and Dried Fish (Anchovies and Atlantic Bumper Fish) from the Four Different Processing Sites

Sugathapala *et al.* (2012) have explained that the moisture content of a food product is an exact susceptibility indicator for microbial spoilage. Thus, when the dried product moisture is high, it favours microbial growth and infestation of the product by flies resulting in foodborne illnesses when consumed (Huang *et al.,* 2010). It has been reported that a well dried fish of 15 % moisture content or less, will prevent mould growth and thereby increase the products shelf life (Ochieng *et al*. 2015). Low moisture content is an indication of low water activity and vice versa. Most organism especially bacteria species require higher water activity above 0.91 to proliferate (Mahmud *et al*., 2018). Drying therefore reduces the water activity of fish which limits the growth of many microorganisms (Bulushi *et al*., 2013). This explains the low bacteria load recorded in the RCP+NDR dried fishes compared with the bare ground samples which had higher moisture content. In the present study, fish samples dried using raised concrete platform with netted drying racks (RCP+NDR) recorded lower moisture levels than samples dried on the bare ground by the traditional processors. Hence are expected to have longer shelf life, if conditions of low moisture content are maintained.

Also fish samples dried using RCP+NDR had lower microbial load (aerobic mesophiles, Enterobacteriaceae) compared with the other methods. The observed phenomenon might be due to the reduced contamination levels of RCP+NDR. This observation is similar to the studies conducted by Id *et al*. (2018). They observed that fishes dried using improved racks had lower microbial load compared with the ones that were dried using the traditional

bare ground method. Despite the aerobic mesophilic count of all the traditionally dried fishes being higher than those of the RCP+NDR, the microbial loads of all the samples were within the acceptable limit recommended by ICMSF, (1988).

Traditional processors generally, wash fresh fish after catch with sea-water at coastal landing sites. This step can introduce a high level of contamination if the coastal waters are heavily polluted. Sorting to remove foreign materials is also typically done by hand which further contributes to add more microorganisms. A study by Karim *et al*. (2017) reported Enterobacteriaceae were recorded in anchovies dried in open sun drying but not detected on those dried using different types of drying racks. This observation is similar to the findings of the current study.

Coliform bacteria and *Escherichia coli* are faecal bacteria and are classified as indicator bacteria for faecal contamination of food that harbours an increased risk to contain pathogenic bacteria (Akinwumi & Adegbehingbe, 2015). Coliforms were not detected in the fish dried uisng the RCP+NDR.The dried fish samples from the traditional processors however had high coliform counts which indicated faecal contamination. Possibly from the fish habitat, dusty environment, contaminated contact surfaces or poor handling practices. The drying of the fish was not sufficient to reduce the coliform counts. As suggested by Hasselberg et al. (2020a) several points along the value chains are possible critical points where contamination could also take place. The guidelines set by the Ghana Standard Authority (GSA) on the limit for coliform bacteria in hot smoked fish is 1.6 log CFU/g (GS 747 : 2003). All the samples exceeded this limit which is stated for hot smoked fish only.

The presence of *S. aureus* in both the fresh and dried fish from the landing sites is an indication of unhygienic handling conditions. Fresh fish from the processors had higher *S. aureus* counts than the experimentally dried samples in this study. Amegovu, Mawadri, Mandha and Yiga (2017) and Budiati, Rusul, Alkarkhi, Ahmad and Arip (2011) also reported similar findings. This could have been due to high moisture content of fish at the landing sites favouring microbial growth. Plahar *et al.* (1999) observed the presence of *S. aureus* in the bare ground dried anchovy fish samples in Ghana. The observed values in this study were however below the acceptable limit of 4.0 log CFU/g for *S. aureus* set by GSA and ICMSF (1988).

A study by Antwi-Agyei and Maalekuu (2014) detected *Salmonella spp and E. coli* in fish samples in the Kumasi metropolis of the Ashanti Region, Ghana These microorganisms were however not detected in the present study.

To prevent mould growth in fish, the moisture content must be below 15 % (Akinola & Bolaji, 2006). Due to the relatively higher moisture content in the Tema (21.16 %) and James Town (20.58 %) dried anchovies as well as the Atlantic bumper fish, moulds and bacteria were detected. Alam (2007) and Ochieng *et al*. (2015) have reported similar findings.

The pathogenic microorganisms *E. coli*, *Listeria monocytogenes* and *Salmonella spp* were not detected in any of the samples (both fresh and dried) (as found in Tables 15 and 18). Contrary to this, some studies have reported the presence of *E. coli* in some fish samples in Ghana (Antwi-Agyei & Maalekuu, 2014; Hasselberg *et al*., 2020b). Tano-Debrah *et al*. (2011) attributed the occurrence of *Listeria monocytogenes* on sun-dried tilapia from

James Town and in some informal fish markets in Accra mainly to post-process contamination. Aboagye (2016) has suggested that salting and drying methods used by processors cannot adequately control the organism.. *Salmonella spp* has mostly not been detected in studies on dried fish as reported by Lu, Pace, and Plahar (1991), Hasselberg *et al*. (2020a) and Ikutegbe and Sikoki (2014).

According to El Sheikah, Ray, Montet, Panda and Worawattanamateekul (2014), poor hygienic conditions prevailing at most processing sites, in addition to evidence from studies reporting on the poor quality of water used for washing the catch fish and drying temperatures could account for the high incidence of pathogenic and spoilage organisms observed in traditionally dried fish sample. Some of the hygienic issues observed at processing sites in the present study included the presence of livestock, drying of fish directly on the ground near refuse dump sites, and exposure of fish to blow flies, dust and rodents. The RCP+NDR method of drying however protects the fish from these factors as well as reduces the contacts of processors to the fish being dried. This accounts for the reduction in microbial load in the fish samples dried on the RCP+NDR. Rahman *et al.* (2000) and Ochieng *et al.* (2015) have also made similar reports.

Consumer Acceptability of Biscuit Prepared from Fish Powder

Venugopal (2006) has explained that, the nutritive value of cereal proteins can be increased when fortified with fish protein powder. However according to Majumdar and Singh (2014) and Shaviklo (2016), the addition of fish powder to foods like biscuits affects their key sensory characteristics such

as flavour, odour and overall acceptance of the product. Therefore, appropriate incorporation level is recommended at any circumstance to meet the desired objective and satisfy consumers' need. Abraha, Xia and Fang (2018), found that snack containing 9 % fish protein powder had lower scores for odour, texture, flavour, and overall acceptability, whereas snack fortified with 7 % fish protein powder had higher scores and was acceptable. A similar trend was observed in the present study where sensory scores for taste and the other attributes reduced with increasing percentage of the fish powder (Table 18). Biscuit prepared from the 5 % Atlantic bumper fish powder had comparable attributes to that of the control due to less fishy flavour.

Hardness (cripsiness) is the textural property which attracts more attention in evaluation of quality characteristic of baked products, because of its close association with human perception of freshness (Chauhan, Kumar, & Gupta, 2016). Khan and Nowsad (2012) reported that biscuit fortified with 7-10 % fish proteins tends to have a crusty texture and good acceptance by young consumer (Abraha *et al.*, 2018). Panelists in this present study, however, gave low scores (like slightly) for biscuits even with the incorporation of fish powders at 10 and 15 %. Elbandy (2015) and Bharat, Taral and Animal (2020) have reported that incorporation of up to 6 % fish powder into wheat flour blend did not cause any significant deleterious effect on all tested organoleptic attributes of the biscuit produced and had better acceptability. However in this study, 9 % of fish powder caused a significant ($p<0.05$) reduction in the scores for most of the organoleptic characteristics of biscuit produced.

Elbandy (2015) recommended that the use of fish powder in biscuit fortification should therefore be up to 6 % of wheat flour blend. In this study, panelists rated the control biscuit (0 % fish powder) with higher acceptability scores (8.17) possibly because of the absence of adverse taste and aroma. Mohammed, Sulieman, Soliman, and Bassiuny (2014) revealed that fishy odour naturally increases with increasing percentage of fish powder. This confirms the sensory outcome of the current study. Fish powders, with lower fat content, have been found to have a minimal fishy odour when used in bakery products Abraha *et al.* (2018).

Consumer Acceptability of Instant Cereal Mix Prepared from Fish Powder

One way to improve fish consumption is through diversifications of the methods of usage and this should include the development of new fish derived products, which have many health benefits (Kadam, & Prabhasankar, 2010). This includes fortification of cereal products with fish protein concentrates or fish powder, which according to Abraha *et al*. (2018) and Chambers and Bowers (1993), increases their nutritional value and affect sensory attributes, especially appearance, aroma, taste, flavour, and texture.

In this study, an instant cereal mix fortified with fish powder was prepared from various combinations of rice flour, fish powder, milk powder and sugar in various proportions as complimentary. There were significant differences ($p < 0.05$) between the sensory attributes of the Control (0 % fish powder) product and instant cereal mix fortified with the fish powder. Generally, it was observed that the sensory score by panellists decreased with

increasing percentages of fish powder used. Elbandy (2015) had reported similar results. Riyanti, Dwi, and Nur (2013) had also suggested that the strong fishy aroma of the fortified products can be reduced and made more acceptable if fortification levels are at low percentages. A study by Tangke, Daeng, and Katiandagho (2021), showed that panellists gave higher acceptability scores for porridge fortified with lower 1 % tuna bone meal than those with higher percentages These findings confirm the response from panellists to the fish fortified instant cereal mix in this study.

Consistency (a rheological property in relation to texture and flow of a food material) is an important attribute, since it determines the amount of food young children would consume, because they have affinity for lighter and smooth gruel which are easier to swallow (Tiencheu *et al*., 2016). The consistency ratings of the fish fortified products were within acceptable limits as that of the control. The addition of the fish powder did not have much effect on the consistency of products in this study. This is contrary to that of Tangke *et al*. (2021) who stated that fortified tuna bone meal significantly influences the quality of texture of porridge.

The Overall Acceptability test gave the sample with no fish fortification (control product) the highest ratings for overall acceptability of 7.37. This was comparable to those fortified with 3 % Anchovies and 3 % Atlantic bumper fish powder which had ratings of 6.49 and 6.75 respectively for overall acceptability.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATION

This chapter summarises the outcome of the study, the conclusions drawn from the results as well as suggested recommendations after the study. All these are consistent with the study objectives.

Summary

The objective of the study was to use improved sun-drying and solar drying methods in the production of dried anchovies (*Engraulis encrasicolus*) and Atlantic bumper fish (C*hloroscombrus chrysurus*) powder and incorporate them into new food formulations.

Generally, the study used a quantitative research design with experimental approach. The results obtained revealed that solar dryer had a significantly faster drying rate for the two fish samples than the sun drying methods. However, due to the high solar dryer temperature, the dried fish were brittle in texture and less whitish in colour compared to the sun dried fish which were springier with a brighter white colour.

The low moisture contents recorded for solar dried samples led to the concentration of the other nutrients except for crude fat content which was reduced due to evaporation by the high drying temperatures of the solar dryer. Histamine and heavy metal concentrations for all the samples were within acceptable limits.

The solar-dried samples had the least microbial load compared to the other dried samples as well as the fresh samples. This was likely to be due to protection of samples from the environment as well as the high temperatures

during the drying process. Samples dried on Raised Concrete Platform with Netted Drying racks had a form of protection from contamination by the environment due to the elevation of the drying surface from the ground, hence had a minimal microbial load which were within acceptable limits compared to samples dried on the bare ground and raised concrete platform without any form of covering. Comparing the artisanal fish samples from processing sites to that of the raised concrete platform with netted drying racks, it was observed that seasonal changes as well as processing method had a significant effect on the nutritional as well as the microbial quality of dried fish.

The consumer acceptability results of the products (biscuit and instant cereal mix) prepared from fish powder showed that due to fishy smell and aroma, consumers preferred products with a low fish concentration. Biscuit and instant cereal mix prepared from 5 and 3 % fish powder, respectively, had comparable acceptability scores as that of the control products which did not contain fish powder.

Conclusions

This study has shown that solar drying of anchovy and Atlantic bumper fish has a better drying rate and produces dried fish of better microbiological and nutritional quality compared to sun drying of fish. However, when the fish is sun dried on a raised concrete platform with netted drying racks, it produces dried fish of comparable microbial and nutritional quality to the solar dried fish. Fish dried on raised concrete platform with netted drying racks also had significantly better microbial and nutritional

quality compared to fish obtained from traditional processorswho dry fish on the bare ground.

In the consumer acceptance studies of biscuit and instant cereal mix fortified with dry fish powder, only the products with low fish proportions, 5 % for biscuit and 3 % for cereal mix were found acceptable. At higher percentages, the products were found unacceptable due to fish odour and taste. Fish handling as well as drying methods can greatly affect the microbiological quality, hence safety as well as the nutritional quality of fish.

Recommendations

Based on the results obtained from the current study, it is recommended that there is the need for the adoption of the raised concrete platform with netted drying racks by processors since it produces dried fish which are superior in quality and safety to those dried on the bare ground (traditional method). In addition, dry processing using the raised concrete platform with netted drying racks method has less drudgery and losses are reduced compared to traditional drying on the bare ground.

Further research can be carried out to minimize or eliminate the unpleasant fishy odour associated with fish fortified products. This will help to increase the base of fish fortified products as well as increase the acceptability of fish product by consumers.

This research can be replicated with larger fish species so as to arrive at a more comprehensive result concerning the drying efficiency of the raised concrete platform with netted drying racks. Adoption of drying fish on raised

concrete platform with netted drying racks should be promoted and surveys carried out to assess its adoption.

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APPENDICES

Appendix 1 - *Study Questionnaire on Consumer Acceptability of Fish Fortified Biscuit*

CONSUMER ACCEPTABILITY TEST (BISCUIT)

Name:……..Date:……Tel:.....

Background Information (Please tick the appropriate box)

Age Group

18-25 [ ] 26-35 [ ] 36-45 [ ] 46-55 [ ] 56-65 [ ] 65+ [ ]

Gender

Male [ ] Female [ ]

Educational Level

Primary [ ] Secondary [ ] Tertiary [ ]

Marital status

Single [ ] Married [ ] Widowed [ ] Divorced [ ]Separated [ ]

General Information on biscuit/cookies

Frequency of consumption of **biscuit/cookies**

Never [ ] Once a month [ ] Once a fortnight [ ] Once a week [ ] Once a day [ ]

Instruction: You have been served **seven biscuit** samples. Please examine and give your degree of likeness using the scale below. Please remember to

rinse your mouth with a slice of cucumber and then water before moving on to the next sample. Thank you.

Scale/Interpretation
9. Like Extremely
8.Like Very Much
7. Like Moderately
6. Like Slightly
5. Nether Like nor Dislike
4. Dislike Slightly
3. Dislike Moderately
2. Dislike Very much
1.Dislike Extremely

Attributes	**Sample Code**						
Aroma							
Crispiness							
Taste							
After-taste							
Overall Acceptability							

Which of these products would you buy if it is on the market.

Please give reasons for your choice in ‘i’ above

……

…….....

Appendix 2: *Study questionnaire on consumer acceptability of fish fortified instant cereal mix*

Consumer acceptability test (fish-rice instant mix)

Name:…….. Date:……

Tel:.....

Background Information (Please tick the appropriate box)

Age Group

18-25 [ ] 26-35 [ ] 36-45 [ ] 46-55 [ ] 56-65 [ ] 65+ [ ]

Gender

Male [ ] Female [ ]

Educational Level

Primary [ ] Secondary [ ] Tertiary [ ]

Marital status

Single [ ] Married [ ] Widowed [ ] Divorced [ ]

Separated [ ]

General Information on cereal

Frequency of consumption of cereal

Never [ ] Once a month [ ] Once a fortnight [ ] Once a week [ ]

Once a day [ ]

Instruction: You will be served **seven** samples (four initially and three later on) of an instant cereal mix prepared from fish and rice. Please examine and give your degree of likeness using the scale below. Please remember to rinse your mouth with a slice of cucumber and then water before moving on to the next sample. Thank you.

Scale/Interpretation
9. Like Extremely
8. Like Very much
7. Like Moderately
6. Like Slightly
5. Nether Like nor Dislike
4. Dislike Slightly
3. Dislike Moderately
2. Dislike Very much
1.Dislike Extremely

Attributes	**Sample Code**						
Aroma							
Consistency							
Taste							
After-taste							
Overall Acceptability							

Which of these products would you buy if it is on the market?

Please give reasons for your choice in ‘i’ above

……

…….....

Appendix 3 – *ANOVA Tables*

One-way ANOVA for Moisture content (%) in Anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	5887.67	1471.92	174516.92	0.000
Error	5	0.04	0.01		
Total	9	5887.72			

One-way ANOVA for Fat content (g/100g) in Anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	2.35414	0.58854	55.34	0.000
Error	5	0.05318	0.050		
Total	9	2.40732			

One-way ANOVA for Protein content (g/100g) in Anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	5365.55	1341.39	193194.63	0.000
Error	5	0.03	0.01		
Total	9	5365.59			

One-way ANOVA for Ash content (g/100g) in Anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	27.8744	6.96859	799.38	0.000
Error	5	0.0436	0.00872		
Total	9	27.9179			

One-way ANOVA for Fe content (mg/100g) in Anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	1688.58	422.145	335.90	0.000
Error	5	6.28	1.257		
Total	9	1694.86			

One-way ANOVA for P content (mg/100g) in Anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	19495760	4873940	6749.29	0.000
Error	5	3611	722		
Total	9	19499370			

One-way ANOVA for Calcium content (mg/100g) in Anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	7397730	1849433	13106.58	0.000
Error	5	706	141		
Total	9	7398436			

One-way ANOVA for As content (mg/100g) in Anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	0.654865	0.163716	124.88	0.000
Error	5	0.006555	0.001311		
Total	9	0.661420			

One-way ANOVA for histamine content (ppm) in Anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	0.002217	0.000554	942.30	0.000
Error	5	0.000003	0.000001		
Total	9	0.002220			

One-way ANOVA for moisture content (g/100g) Atlantic bumper fish

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	4757.28	1189.32	1274.58	0.000
Error	5	4.67	0.93		
Total	9	4761.95			

One-way ANOVA for fat content (g/100g) in Atlantic bumper fish

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	10.029	2.5074	2.96	0.132
Error	5	4.234	0.8468		
Total	9	14.264			

One-way ANOVA for protein content (g/100g) in Atlantic bumper fish

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	4711.18	1177.79	1506.79	0.012
Error	5	3.91	0.78		
Total	9	4715.08			

One-way ANOVA for ash content (g/100g) in Atlantic bumper fish

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	53.846	13.46	12.90	0.008
Error	5	5.217	1.043		
Total	9	59.062			

One-way ANOVA for Fe content (mg/100g) in Atlantic bumper fish

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	302.674	75.6685	165.06	0.000
Error	5	2.292	0.4584		
Total	9	304.966			

One-way ANOVA for P content (mg/100g) in Atlantic bumper fish

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	14352870	3588217	18.04	0.004
Error	5	994245	198849		
Total	9	15347115			

One-way ANOVA for Ca content (mg/100g) in Atlantic bumper fish

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	208953	52238.4	205.89	0.000
Error	5	1269	253.7		
Total	9	210222			

One-way ANOVA for histamine content (ppm) in Atlantic bumper fish

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	0.000506	0.000126	83.73	0.000
Error	5	0.000008	0.000002		
Total	9	0.000513			

One-way ANOVA for As content (mg/100g) in Atlantic bumper fish

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	1	0.000000	0.000000	1009.86	0.001
Error	2	0.000000	0.000000		
Total	3	0.000000			

One-way ANOVA for P content (mg/100g) in Atlantic bumper fish

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	12126118	3031529	181003.39	0.000
Error	5	84	17		
Total	9	12126201			

One-way ANOVA for Moisture content (g/100g) in fresh anchovies from processing site and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	2.66947	0.667368	92.00	0.000
Error	5	0.03627	0.007254		
Total	9	2.70574			

One-way ANOVA for fat content (g/100g) in fresh anchovies from processing site and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	2.00942	0.50236	47.43	0.000
Error	5	0.05295	0.01059		
Total	9	2.06238			

One-way ANOVA for protein content (g/100g) in fresh anchovies from processing site and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	2.03110	0.507776	51.19	0.000
Error	5	0.04960	0.009920		
Total	9	2.08070			

One-way ANOVA for ash content (g/100g) in fresh anchovies from processing site and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	11.3634	2.84085	266.83	0.000
Error	5	0.0532	0.01065		
Total	9	11.4166			

One-way ANOVA for Fe content (mg/100g) in fresh anchovies from processing site and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	346.799	86.700	50.59	0.000
Error	5	8.569	1.714		
Total	9	355.369			

One-way ANOVA for: P content (mg/100g) in fresh anchovies from processing site and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	871701	217925	64.38	0.000
Error	5	16925	3385		
Total	9	888626			

One-way ANOVA for Ca content (mg/100g in fresh anchovies from processing site and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	1312341	328085	122.81	0.000
Error	5	13357	2671		
Total	9	1325698			

One-way ANOVA for As content (mg/100g) in fresh anchovies from processing site and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	0.5624	0.14060	3.21	0.116
Error	5	0.2187	0.04374		
Total	9	0.7811			

One-way ANOVA for histamine in fresh anchovies from processing site and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	0.000207	0.000052	9.02	0.017
Error	5	0.000029	0.000006		
Total	9	0.000236			

One-way ANOVA for P content (mg/100g) in fresh anchovies from processing site and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	807698	201924	267.84	0.000
Error	5	3769	754		
Total	9	811467			

One-way ANOVA for: Ca content (mg/100g) in fresh anchovies from processing site and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	1447363	361841	1358.00	0.000
Error	5	1332	266		
Total	9	1448695			

One-way ANOVA for moisture content (g/100g) in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	16.6868	4.17171	429.47	0.000
Error	5	0.0486	0.00971		
Total	9	16.7354			

One-way ANOVA for fat content (g/100g) in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	2.20855	0.552138	57.96	0.00
Error	5	0.04763	0.009527		
Total	9	2.25618			

One-way ANOVA for protein content (g/100g) in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	59.1786	14.7946	2246.80	0.000
Error	5	0.0329	0.0066		
Total	9	59.2115			

One-way ANOVA for ash content (g/100g) in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	22.0917	5.52292	552.34	0.000
Error	5	0.0500	0.01000		
Total	9	22.1417			

One-way ANOVA for Fe content (mg/100) in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	21.951	5.4878	20.32	0.003
Error	5	1.350	0.2700		
Total	9	23.301			

One-way ANOVA for P content (mg/100g) in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	132180	33044.9	460.52	0.000
Error	5	359	71.8		
Total	9	132539			

One-way ANOVA for Ca content (mg/100g) in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	908213	227053	872.87	0.000
Error	5	1301	260		
Total	9	909513			

One-way ANOVA for As content (mg/100g) in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	0.111391	0.027848	172.85	0.000
Error	5	0.000806	0.000161		
Total	9	0.112197			

One-way ANOVA for histamine content in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	0.000126	0.000031	14.51	0.006
Error	5	0.000011	0.000002		
Total	9	0.000136			

One-way ANOVA for moisture content (g/100g) in fresh Atlantic bumper fish from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	8.786	2.1964	3.03	0.000
Error	5	3.619	0.7238		
Total	9	12.405			

One-way ANOVA for fat content (g/100g) in fresh Atlantic bumper fish from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	7.028	1.757	1.70	0.284
Error	5	5.153	1.031		
Total	9	12.181			

One-way ANOVA for protein content (g/100g) in fresh Atlantic bumper fish from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	5.033	1.2582	1.45	0.341
Error	5	4.328	0.8656		
Total	9	9.361			

One-way ANOVA for ash content (g/100g in fresh Atlantic bumper fish from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	4.289	1.072	1.01	0.483
Error	5	5.321	1.064		
Total	9	9.610			

One-way ANOVA for Fe content (mg/100g) in fresh Atlantic bumper fish from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	346.799	86.700	50.59	0.000
Error	5	8.569	1.714		
Total	9	355.369			

One-way ANOVA for P content (mg/100g in fresh Atlantic bumper fish from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	871701	217925	64.38	0.000
Error	5	16925	3385		
Total	9	888626			

One-way ANOVA for Ca content (mg/100g in fresh Atlantic bumper fish from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	1312341	328085	122.81	0.000
Error	5	13357	2671		
Total	9	1325698			

One-way ANOVA for As content (mg/100g in fresh Atlantic bumper fish from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	0.5624	0.14060	3.21	0.116
Error	5	0.2187	0.04374		
Total	9	0.7811			

One-way ANOVA for histamine in fresh Atlantic bumper fish from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	0.00021	5.2E-05	9.02	0.017
Error	5	2.9E-05	6E-06		
Total	9	0.00024			

One-way ANOVA for P content (mg/100g) in fresh Atlantic bumper fish from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	807698	201924	267.84	0.000
Error	5	3769	754		
Total	9	811467			

One-way ANOVA for Ca content (mg/100g) in fresh Atlantic bumper fish from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	1447363	361841	1358.00	0.000
Error	5	1332	266		
Total	9	1448695			

One-way ANOVA for moisture (g/100g) in dried Atlantic bumper fish from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	6.761	1.6902	2.18	0.207
Error	5	3.870	0.7740		
Total	9	10.631			

One-way ANOVA for fat content (g/100g) in dried Atlantic bumper fish from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	10.161	2.5401	3.02	0.128
Error	5	4.205	0.8409		
Total	9	14.365			

One-way ANOVA for protein content (g/100g) in dried Atlantic bumper fish from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	33.146	8.2864	18.65	0.003
Error	5	2.222	0.4443		
Total	9	35.367			

One-way ANOVA: Ash content (g/100g) in dried Atlantic bumper fish from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	40.309	10.0772	16.37	0.004
Error	5	3.079	0.6157		
Total	9	43.388			

One-way ANOVA for Fe content (mg/100g) in dried Atlantic bumper fish from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	346.799	86.700	50.59	0.000
Error	5	8.569	1.714		
Total	9	355.369			

One-way ANOVA for P content (mg/100g) in dried Atlantic bumper fish from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	871701	217925	64.38	0.000
Error	5	16925	3385		
Total	9	888626			

One-way ANOVA for Ca (Mg/100g) in dried Atlantic bumper fish from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	1312341	328085	122.81	0.000
Error	5	13357	2671		
Total	9	1325698			

One-way ANOVA for As (Mg/100g) in dried Atlantic bumper fish from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	0.5624	0.14060	3.21	0.116
Error	5	0.2187	0.04374		
Total	9	0.7811			

One-way ANOVA for histamine content (ppm) in dried Atlantic bumper fish from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	0.000207	0.000052	9.02	0.017
Error	5	0.000029	0.000006		
Total	9	0.000236			

One-way ANOVA for P content (mg/100g) in dried Atlantic bumper fish from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	807698	201924	267.84	0.000
Error	5	3769	754		
Total	9	811467			

One-way ANOVA for Ca content (mg/100g) in dried Atlantic bumper fish from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	1447363	361841	1358.00	0.000
Error	5	1332	266		
Total	9	1448695			

One-way ANOVA for AEROBIC MESOPHILES count in dried anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	9.99101	2.49775	2364.97	0.000
Error	5	0.00528	0.00106		
Total	9	9.99629			

One-way ANOVA for TC count in dried anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	1	0.44935	0.44935	25.70	0.037
Error	2	0.03497	0.01748		
Total	3	0.48431			

One-way ANOVA for Mold count in dried anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE_	1	5.34891	5.34891	1836.71	0.001
Error	2	0.00582	0.00291		
Total	3	5.35473			

One-way ANOVA for Entobacteriaceae count in dried anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	3	10.4690	3.48965	1147.29	0.000
Error	4	0.0122	0.00304		
Total	7	10.4811			

One-way ANOVA for *B. cereus* count in dried anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	1	0.14666	0.14666	11.20	0.079
Error	2	0.02618	0.01309		
Total	3	0.17284			

Appendix LXVI: One-way ANOVA for S. aureus count in dried anchovies

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE_5	1	2.26372	2.26372	203.27	0.005
Error	2	0.02227	0.01114		
Total	3	2.28599			

One-way ANOVA for AEROBIC MESOPHILES count in dried Atlantic bumper

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	11.9688	2.99220	488.21	0.000
Error	5	0.0306	0.00613		
Total	9	11.9995			

One-way ANOVA for TC count in dried Atlantic bumper

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE_1	2	3.17321	1.58660	821.27	0.000
Error	3	0.00580	0.00193		
Total	5	3.17900			

One-way ANOVA for Mold count in dried Atlantic bumper

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	1	1.32194	1.32194	334.60	0.003
Error	2	0.00790	0.00395		
Total	3	1.32984			

One-way ANOVA for *S. aureus* count in dried Atlantic bumper

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	1	1.29528	1.29528	99.31	0.010
Error	2	0.02609	0.01304		
Total	3	1.32136			

One-way ANOVA for Enterobacteriacea count in dried Atlantic bumper

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	2	5.46000	2.73000	2127.89	0.000
Error	3	0.00385	0.00128		
Total	5	5.46385			

One-way ANOVA for *B. cereus* count in dried Atlantic bumper

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	1	0.316372	0.316372	201.84	0.005
Error	2	0.003135	0.001567		
Total	3	0.319507			

One-way ANOVA for AEROBIC MESOPHILES in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	17.4625	4.36563	427.77	0.000
Error	5	0.0510	0.01021		
Total	9	17.513			

One-way ANOVA for TC count in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	3	3.65206	1.21735	113.91	0.000
Error	4	0.04275	0.01069		
Total	7	3.69481			

One-way ANOVA for mold count in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	1	0.09846	0.09846	0.16	0.724
Error	2	1.19507	0.59753		
Total	3	1.29352			

One-way ANOVA for *B. cereus* in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	3	4.9895	1.66316	46.66	0.001
Error	4	0.1426	0.03565		
Total	7	5.1320			

One-way ANOVA for *S. aureus* count in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	3	3.35120	1.11707	111.14	0.000
Error	4	0.04021	0.01005		
Total	7	3.39140			

One-way ANOVA for Enterobacteraceae count in dried anchovies from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	8.39988	2.09997	309.17	0.000
Error	5	0.03396	0.00679		
Total	9	8.43384			

One-way ANOVA for APC in fresh anchovies from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	12.6530	3.16324	1252.61	0.000
Error	5	0.0126	0.00253		
Total	9	12.6656			

One-way ANOVA for TC count in fresh anchovies from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	2	0.334524	0.167262	86.68	0.002
Error	3	0.005789	0.001930		
Total	5	0.340313			

One-way ANOVA for *S. aureus* count in fresh anchovies from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE_2	3	1.85491	0.618305	172.98	0.000
Error	4	0.01430	0.003575		
Total	7	1.86921			

One-way ANOVA for Enterobacteracea count in fresh anchovies from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	3.9747	0.99367	46.76	0.000
Error	5	0.1063	0.02125		
Total	9	4.0809			

One-way ANOVA for APC in dried Atlantic bumper from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	10.6311	2.65778	125.75	0.000
Error	5	0.1057	0.02114		
Total	9	10.7368			

One-way ANOVA for TC count in dried Atlantic bumper from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	3	2.43506	0.811687	319.38	0.000
Error	4	0.01017	0.002541		
Total	7	2.44523			

One-way ANOVA for mold count in dried Atlantic bumper from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	2	2.92550	1.46275	83943.47	0.000
Error	3	0.00005	0.00002		
Total	5	2.92556			

One-way ANOVA for *B. cereus* count in dried Atlantic bumper from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	1	4.63998	4.63998	31937.29	0.000
Error	2	0.00029	0.00015		
Total	3	4.64027			

One-way ANOVA for *S.aureus* count in dried Atlantic bumper from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	2	3.7717	1.88586	47.21	0.005
Error	3	0.1199	0.03995		
Total	5	3.8916			

One-way ANOVA for Enterobacteraceae in dried Atlantic bumper from processing sites and RCP+NDR samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	3	4.1429	1.38098	17.35	0.009
Error	4	0.3184	0.07960		
Total	7	4.4613			

One-way ANOVA for APC in fresh Atlantic bumper from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	2.18205	0.54551	34.12	0.001
Error	5	0.07995	0.01599		
Total	9	2.26200			

One-way ANOVA for TC count in fresh Atlantic bumper from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	0.46266	0.115664	21.65	0.002
Error	5	0.02671	0.005343		
Total	9	0.48937			

One-way ANOVA for *B. cereus* count in fresh Atlantic bumper from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	1	4.45252	4.45252	2934.68	0.000
Error	2	0.00303	0.00152		
Total	3	4.45556			

One-way ANOVA for *S. aureus* count in fresh Atlantic bumper from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	2	0.625854	0.312927	438.02	0.000
Error	3	0.002143	0.000714		
Total	5	0.627998			

One-way ANOVA for Enterobacteraceae in fresh Atlantic bumper from processing sites and experimental fresh samples

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SAMPLE	4	0.80844	0.202111	39.80	0.001
Error	5	0.02539	0.005078		
Total	9	0.83383			

Appendix 4 - *3D Impression of Raised Concrete Platform with Netted Drying Racks*