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# THE EFFECT OF DIFFERENT BRINING CONCENTRATIONS ON THE QUALITY OF DRIED REDFISH (*Sebastes marinus*)

Lucia Akinyi Ouma,
Directorate of Livestock, Fisheries and Veterinary Services,
County Government of Kiambu, Kenya
luciaakinyi@yahoo.com

Supervisors:

Jónas Baldursson: jonasb@matis.is
Cécile Dargentolle: cecile@matis.is
Aðalheiður Ólafsdóttir: adalheiduro@matis.is
Matís, Iceland

## ABSTRACT

Dried fish provides much-needed protein for people living in urban towns and centers in Kenya. However, most of the traditional sun-dried products available in the Kenyan market are not satisfactory for human consumption. The fish is dried on the open ground which compromises the safety and quality of the product. The objective of this study was to develop a method to produce good quality low brine and dried fish. Redfish (*Sebastes marinus*) was selected for the study due to its similarity with tilapia. Brining at 5% brine for 1hr 15min (BD1) and 1hr 45min (BD2) and 12% for 15min (BD3) and 45min (BD4) were selected as the best brining conditions. Sensorial attributes, microbiological and physico-chemical parameters of dried fish were determined using standard protocols. All the dried fish samples had water content and water activity less than 15% and 0.60 respectively. The Total viable count (TVC) and Specific spoilage organism (SSOs) decreased after drying to below 5logCFU/g and 2logCFU/g respectively, while the salt concentration increased. The results showed that the TVC, SSOs, water content and water activity values of the brined and dried redfish fillet samples decreased with increasing brine concentrations and time. BD3 had the highest intensity in odour (rancidity, TMA, spoilage), CD had the highest flavour for the same. However, BD1 was low in rancidity, TMA, spoilage odour and flavour. In conclusion, due to its low salt concentration, lower spoilage odour and flavour, and low microbial levels, brining in 5% brine solution for 1hr 15min at ambient temperature is deemed suitable for producing quality and safe low-brined and dried redfish. The same conditions are also suggested to be tried in Kenya with the tilapia fish species.

**Key words:** Brine, dried redfish, microbial load, sensory attributes

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**LIST OF ABBREVIATIONS**

$a_w$ – Water Activity

CFU – Colony-Forming Units

FAO – Food and Agricultural Organization of the United Nations

FDA – United States Food and Drug Administration

GDA – Generic Descriptive Analysis

ISO – International Organization for Standardization

LOG – Logarithm

SSOs – Specific Spoilage Organisms

TMA – Trimethylamine

TVC – Total Viable Count

USD – United States Dollar

# 1 INTRODUCTION

## 1.1 Fisheries in Kenya

Fish is an important source of local employment and foreign currency earnings in Kenya (Kituu et al., 2009). Fish meant for the domestic market is sold fresh, dried or processed for consumption (FAO, 2016). However, Kenya also exports dried and smoked fish to the West African region. The total annual production of fish in Kenya in 2019 was approximately 147,000 metric tons, valued at USD 237 million (Munguti *et al*., 2021). About 92% comes from Lake Victoria, and the rest from the Indian Ocean (4%), inland lakes and rivers (3%) and aquaculture (1%) (Abila, 2003, FAO, 2016).

Dwindling wild fish catches in freshwater systems and growing population, has led to an increase of aquaculture in Kenya from less than 5,000 tonnes in 2009 to around 15,000 tonnes in 2016 (Ogello and Munguti 2016, Opiyo *et al*., 2018). The growth of aquaculture is credited to governmental intervention through programs such as the Economic Stimulus Programme (ESP) that aimed to improve the livelihood of rural farmers. Nile tilapia (*Oreochromis niloticus*) is the dominant species cultured in Kenya, accounting for 75% of total production, followed by African catfish (*Clarias gariepinus*,18%) and other species (7%) (Opiyo *et al*., 2018). However, there was no organized market channel for the anticipated increase of farmed fish in place and the government did not put more effort to increase consumption to match production in ESP, leading to a majority of farmers abandoning fish farming (Nduku, 2015). The government of Kenya together with the International Fund for Agriculture (IFAD) developed a similar program in 2018; Aquaculture Business Development Programme (ABDP), while improving on some previous mistakes. The initiatives taken by the government to promote aquaculture, coupled with a review of past research studies, still reveal a strong focus on production.

Fish from both natural sources and aquaculture are an important source of highly nutritive food (Onyango *et al*., 2017). Fish is valued for its high-quality protein compared to those of meat and egg (Ojutiku *et al*., 2009). Many ethnic communities in Kenya did not consume fish before the 1980s, but fish is now a sought-after delicacy in almost all parts of the country (Abila, 2005). The silver cyprinid (*Rastineobola argente*a), Nile perch (*Lates niloticus*), Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) are the most widely consumed types of fish in Kenya, but tilapia is by far the most preferred (Lattice, 2016).

Tilapia is a good source of phosphorus, niacin, selenium, and vitamin B12. and potassium. Tilapia is low in saturated fat, calories, carbohydrates and sodium. The population of Kenya was estimated at 47.6 million as of 2019 (KNBS, 2020).The average per capita annual fish consumption in Kenya is ‹5 kg per person per year, as compared to the global average of 20 kg per person per year (Munguti *et al*., 2021). The contribution of fish to overall animal protein intake in Kenya is at 5.7%, which is still below the animal protein intake in Eastern Africa of 19 per cent of total protein intake (11 gram/capita/day) (Opiyo *et al*., 2018).

## 1.2 Problem Statement

The physical and organoleptic qualities of most of the traditional sun-dried products available in the Kenyan market are not satisfactory for human consumption and have molds. These products also earn low profits for fish traders. Dried tilapia in Kenya is mainly processed at

Lake Turkana and small amounts at Lake Victoria. This dried tilapia is of low quality since it is sun-dried on the bare ground where the product is exposed to soil, vermin, birds, and insects, whichcompromises the safety and quality of the fish (Keyombe *et al*., 2018). Due to high temperatures and strong winds around L. Turkana, the fish is normally hard on the outside, but inside is not dry, which fast microbial growth (Keyombe *et al*., 2018).

A study by Onjong *et al* (2018) on the microbiological safety of tilapia from L. Victoria and L. Naivasha value chains also showed that sun dried, salted and dried tilapia had high microbial activity. During the sun-drying stage, no precautions are taken to prevent insect access, so it is not uncommon that fly larvae infest the fish and cause spoilage.

## 1.3 Justification

Dried fish provides much-needed protein for people living in urban towns and centers in Kenya, for those who cannot get fresh fish and also those who like the taste of dried fish. There is a strong market for dried tilapia fish in the Democratic Republic of Congo and recently Kenya has started penetrating the South Sudan market, notwithstanding the growing domestic market. Consumers are now more health conscious and are demanding quality and safe products, free of spoilage. Against the above background, if fish is going to play a major role in both providing the much-needed protein to urban dwellers and contribute to the national economy, knowledge on production of a well-dried fish product is required.

Brining fish before drying helps to reduce the water activity, which shortens the drying time while at the same time resulting in a safer dried product. The present study seeks to test brining at varying salt concentrations and durations to assess the effects on the sensory and microbial quality of redfish.

Redfish was chosen for this study due to its comparable composition to Nile tilapia and its availability in Iceland, where the study was conducted. Redfish has 3.4% lipid and 78.9% water content (Jónsdóttir, 2014) while tilapia has 2.8% lipid and 81% water content (Ruiz-Alonso *et al*., 2021). Knowledge of optimal brining concentration and time and drying methods will help improve the value addition of salted and dried fish in Kenya thereby increasing the economic benefits to the fish traders and improving the nutritional status of the people. The study will help in achieving the Kenyan government's agenda on food security. The government aims to reduce food insecure Kenyans and malnutrition among children under 5 years of age. It also aims to increase average income of farmers and agriculture sector contribution to GDP. The initiatives taken by the government of Kenya to promote aquaculture in the country such as the Aquaculture Business Development Programme will result in an increase in aquaculture production, and this will need to be processed into various products.

## 1.4 Goals and Objectives

The overall goal of this project is to gain more knowledge on how to improve the quality of brine-dried fish which can be transferred back to Kenya, through training of women fish traders and creating consumer awareness. This will increase the income of the fish traders thereby reduce poverty, it will also increase food security in the country and improve the protein nutritional status of the people.

The specific objectives of the study were:

- Evaluate effect of different brine concentrations on quality of dried redfish using sensory, physicochemical and microbiological analysis
- Evaluate effect of different brining durations on the quality of dried redfish using sensory, physicochemical and microbiological analysis

# 2 LITERATURE REVIEW

## 2.1 Fish Spoilage

Several factors contribute to spoilage of preserved fish (Mustapha et al., 2014). Fish is perishable because it provides a favorable growth medium for microbes after harvest. It spoils fast because of its high moisture content and water activity.

## 2.2 Quality of raw materials

Dried fish products in developing countries are usually processed from fish of poor quality, and this is especially true for dried salted fish products. Only a few processors look at the quality of raw material used for salted–dried fish. However, because of increased awareness of the need for quality and safe products, processors are improving the quality and processing of such products to the standard requirement of buyers in order to compete with similar products from other regions or countries (Agustini et al., 2009). Fresh raw materials and good handling practices during salting, drying, and desalting are important to improve the quality and shelf life of dried and salted fish (Oliveira et al., 2012).

### *2.2.1 Microbial contamination*

The pathogenic bacteria, *Echerichia coli,* which causes diarrhea, *Shigella spp.,* which have a very low infective dose, and *Listeria monocytogenes*, which has a mortality rate of 30% in food poisoning cases, were identified as major foodborne pathogens in Nile tilapia from freshwater value chains in Kenya (Onjong *et al*., 2018). Some pathogenic bacteria found in fish, sediments and water from aquaculture farms in Central region of Kenya include *Escherichia coli*, *Salmonella spp* and *Shigella boydii* (Karimi, 2015).

Microbiological activity is greatly influenced by temperature. At low temperatures (0°C-5°C), *Schewanella putrefaciens*, *Photobacterium phosporeum*, *Vibrionaceae*, *Aeromonas spp* and *Pseudomonas spp* are the main causative agents of spoilage. At high storage temperatures (20°C-30°C) different species of *Vibrionaceae*, *Enterobacteriaceae* are mainly responsible for spoilage (Huss, 1994). Salting, drying and smoking processes take place at ambient temperature. Salted or dried fish spoil due to growth of halophilic bacteria or molds. These microorganisms can also be introduced with salt or contamination in handling during processing (Gram and Huss, 1996).

The five most common bacteria causing human diseases through the consumption of contaminated fish and fish products are *Vibrio spp*., *Listeria monocytogenes, Yersinia spp*., *Salmonella* and *Clostridium botulinum* (Novoslavskij *et al*., 2016). The muscles and internal organs of healthy fish can be contaminated when immunological resistance of the fish is

compromised. Fish skin and gills can be contaminated with harmful bacteria due to exposure to contaminated water (Guzman et al., 2004). The digestive tract can also be contaminated through contaminated feed or water. The growth of microorganisms occurs after the death of fish, making it highly perishable (Ojutiku *et al*., 2009).

### *2.2.2 Water content*

The water content in fish is important because it affects their sensorial quality, microbiological stability, physical characteristics, and shelf life (Silva *et al*., 2008). Fish is a highly perishable food because of its high water content which favours microbial growth (Mahmud *et al*., 2018). Fish contains about 60-80% water depending on the species (Ghaly *et al*., 2010). During drying the water content and water activity are reduced and hence slow down microbial growth which will preserve the fish for a longer time (Modibbo *et al*., 2014).

However the drying should not be carried out too rapidly to avoid case hardening or too slowly to allow microorganisms to survive and grow (Mahmud *et al*., 2018). Case hardening is a condition whereby the surface of the fish becomes dry and hard, preventing movement of water from deeper layers to the surface, while the center remains wet, which leads to rapid spoilage (Ghaly *et al*., 2010).

### *2.2.3 Water activity ($a_w$)*

Water activity ($a_W$) is a measure of how much water in a food is free, i.e., unbound, and thus available to microorganisms to use for growth. It is therefore important with regard to food safety (Ghaly *et al*., 2010). Water activity determines the chemical and microbiological growth rate in foods and their stability. Most enzymes will be inactivated at $a_w$ below 0.85 except lipase which is still active at $a_w$ 0.1. However, at $a_w$ below 0.91 most bacteria cannot grow, and yeast will not grow at $a_w$ below 0.80 (Agustini *et al*., 2009). A water activity of 0.60 or lower prevents growth of all microorganisms and thus fish with an $a_w$ less than 0.6 are microbiologically stable (Abbas *et al*., 2009).

Fish spoilage can be prevented by controlling water activity. The control of water activity in fish is accomplished by drying, adding chemicals, sugars and salt, or a combination of both methods (Ghaly *et al*., 2010). The characteristic low water activity of dried foods makes them shelf stable and able to be stored and distributed unrefrigerated. Whereas dried fish products have different $a_w$ values which impact their shelf life, inadequate drying can result in pathogen growth & toxin formation and must be avoided (FDA, 2021). Inadequate drying of fishery products can cause growth of *Staphylococcus aureus* and *C. botulinum* in the final product, which can lead to consumer illness. A water activity of 0.85 or below will prevent the growth and toxin production of all pathogenic bacteria, including *S. aureus* and *C. botulinum*. *S. aureus* grows at a lower water activity than other pathogenic bacteria and is considered as the target pathogen for drying for shelf-stable products (FDA, 2021).

## 2.3 Fish Preservation Methods

If fish is not sold fresh, preservation methods must be applied to extend shelf life (Tawiri and Abowei, 2011). A good food preservation technique should prevent microbial spoilage of food without affecting its quality and nutritional value (Ghaly *et al*., 2010). Many processes are used to preserve fish including sun drying, solar drying, canning and smoking. About 25|-30% of the world's fish catch is consumed in dried, salted and smoked forms or a combination of these processes. However, in developing countries smoking and drying are the best alternatives (Aba

and Ifannyi, 2013). Fish preservation in Kenya has transitioned from use of traditional methods to newer techniques (Oduor-Odote *et al*., 2010). The main methods of fish processing and preservation in Kenya are salting, drying, deep frying and smoking (Kituu *et al.,* 2009). Smoked, sun-dried or salted products are traded in remote rural areas and major urban centers (Oduor-Odote *et al.*, 2010).

### *2.3.1 Salting*

Salting not only extends the shelf life of fish but also gives desirable sensorial qualities (*Saritha et al*., 2012). Salting aims to reduce water activity ($a_w$) which inhibits the growth of spoilage bacteria, molds and inactivates autolytic enzymes. Most spoilage bacteria in fish cannot survive for extended periods above 12% salt wet basis (Mujaffar and Sankat, 2015). Salt has traditionally been used in curing and preservation of meat and fish due to its capacity to improve the water holding capacity of proteins (Kituu *et al*., 2009).

There are different methods of salting, such as dry salting and brine salting. Brine salting has been shown to have several advantages compared with dry salting, including shorter processing time due to more rapid salt uptake, and higher weight yield due to better control of salt uptake and water loss in muscle (Yang *et al*., 2020). Kenyans are low consumers of salt, averaging 4 grams a day as per the Ministry of Health recommendation of salt intake levels below 5 grams which is in line with World Health Organization recommendation (Ndanuko *et al*., 2021).

Salt uptake in brining depends on several factors such as species, fish dimension, weight, muscle thickness, muscle characteristics, composition, physiological state, salting method, brine concentration, brining time, and fish-to-salt ratio (Jittinandana *et al*., 2002, Sobukola and Olatunde, 2011). Salt uptake by fish increases with increasing temperature up to an optimum. However, fatty and thick fish fillets tend to absorb salt slowly and the thicker the fish fillet the slower the rate of salt uptake towards the center of the fish. Salt replaces the water in fish hence there is less water to be reduced by drying (Tawiri and Abowei, 2011).

### *2.3.2 Drying*

Drying preserves fish by inactivating enzymes and removing water content which stops bacterial and mold growth, and prevents spoilage of the fish (Alahmad *et al*., 2021). The rate of water removal (drying rate) is dependent on the surface area of the fish, air speed, relative humidity and temperature of the surrounding air. The lower the relative humidity, the faster the drying rate while increased air speed also results in faster drying rates (Tawiri and Abowei, 2011). Excess drying of fish results in breaking down of the fish during handling, since fish can become brittle and liable to physical damage when handled roughly (Tawiri and Abowei, 2011). Drying temperature of temperate fish is 25-30$^{o}$C, while for tropical fish it is 35-45 $^{o}$C (Waterman, 1976). Drying temperate fish above this range will lead to protein denaturation while drying tropical fish below the range may cause spoilage.

Dried fish dishes are common across most cultures: Mediterranean cuisine, Asian culinary delights and African food. Examples include; bacalao-salted and dried cod and obambo-dried tilapia in Kenya. Traditional sun-drying has been practiced in many parts of the world as a preservation method and the drying techniques vary with type, nature, size and fish condition.

Fish drying methods vary among different countries depending on the species used and the type of product desired, with the water content in the final product ranging from 10% to 30%. The two methods of drying are natural (open sun-drying, solar drying which include solar tent/tunnel/cabinet dryers) and artificial/mechanical which include hot air dryers and vacuum dryers (Alahmad *et al*., 2021). Due to the abundance of sunshine, sun-drying has been the method of choice for producing dried fish in many tropical regions including Africa, Southeast Asia and Latin America. This method of drying is weather dependent and also has an increased risk of losses due to spoilage and contamination (Sefa-Dedeh, 2003). A study by Onyango *et al*. (2017), shows that sun-drying is the most common form of fish preservation along Lake Victoria, Kenya. Kenya Marine and Fisheries Research Institute (KMFRI) also had similar findings in Lake Turkana, Kenya indicating that 80% of the preserved fish were sun-dried (Keyombe *et al*., 2018). Traditional dried products are often of poor quality due to improper handling and processing which result in spoilage (Ogongo *et al*., 2015).

Solar drying, which is the use of equipment to collect the sun's radiation for drying applications, was proven to be more efficient and hygienic compared with the traditional open-air sun drying (Mujaffar and Sankat, 2015). Comparing drying of usipa (*Engraulicypris sardella*), utaka (*Copadichromis spp*) and ndunduma (*Diplotaxodon limnothrissa*) in Malawi using traditional open sun drying and solar tent dryers, showed the solar tent dried fish to be of higher quality than open sun-dried fish in terms of ash content, moisture content, microbial load and shelf life (Banda *et al*., 2017, Chiwaula *et al*., 2017).

However, in both open sun and solar drying, the temperature of drying cannot be controlled, and this can sometimes lead to 'case hardening.' Due to the inconsistent and sometimes poor quality of naturally dried fish, artificial drying has become more popular since the drying conditions (temperature, air velocity, relative humidity and drying time) can be controlled. Use of artificial dryers improves product quality and reduces potential insect infestation and contamination (Alahmad *et al*., 2021).

# 3 METHODOLOGY

## 3.1 Raw Materials

Fresh, chilled redfish (*Sebastes marinus*) fillets were used in this experiment. For the pre-trial, 51 chilled, skinless redfish fillets weighing approximately 150-200g were received in the laboratory from Hafið fiskverslun, a local fish retailer. The fillets were received on day three after fishing. The raw fillets were examined before the brining process, by smelling to determine whether they had the sweet odour of fresh redfish, homogeneous even colour with no discoloration or yellowish colour, and photos were taken. Four control fillets were not brined but kept at ambient temperature while brining the rest of the fillets.

## 3.2 Experimental Design

### *3.2.1 Pre-trial*

Before the main experiment, a pre-trial was conducted to identify the best brine concentrations and brining times to be used in the main experiment to give a palatable product. The pre-trial was carried out from 13th to 17th December 2021. Brining was done at ambient temperature (approximately 20°C ±2), in triplicate and at a fish-to-brine ratio of 1:3. Four brine concentrations were made (5%, 12%, 18% and 25%) by mixing salt into 8 liters of water and stirred until the salt was dissolved. The salt concentrations of the solutions were confirmed with a refractometer and the temperature of the solutions was taken before brining. Temperature loggers were also put inside the brine during the brining process. The loggers measured temperature every 1 minute and 30 seconds.

Twelve fillets were placed in each of the buckets anda weight was placed on top of the fillets to keep them immersed in the brine. Three fillets were removed from each bucket at different times (15 min, 45 min, 1hour 15 min and 1hour 45 min), and salt concentrations and temperatures of the brine solutions were measured at that time. Following brining, all the fillets, including the un-brined control fillets, were placed on stainless steel expanded metal racks inside containers, covered with polythene to prevent excessive drying and left to drain for 24 hours at 4°C to allow brine equilibration and uniform distribution of salt inside the fillet. After draining, the fillets were checked for changes in colour, texture, odour, gaping or the presence of a surface salt layer and photos were taken. The saltiness of the brined fillets was assessed by cooking the whole fillets, including control; in aluminium trays for 6 minutes, in a pre-warmed oven at 95-100°C with air circulation, steam and cooling to about 40°C. The cooked fillets were tasted and the most palatable ones identified. Local consumers in Kenya prefer fish that is not too salty, hence the choice has to be moderately or mildly salty.

### *3.2.2 Main experiment*

The experiment followed the plan shown in Figure 1. Three fillets were removed for sensory evaluation and the remaining 60 were divided into the five groups. Four combinations of salt concentration and brining time were chosen based on the results of the pre-trial. The fillets were tagged to identify the different treatment groups and the control was untagged. Two brine concentrations were made (5%, 12%) by mixing salt into 14.4 litres of water (to reach a final ratio 1:3 fish:water (w:w)) and stirred until the salt was dissolved. Two groups were brined in 5% solution for 1hr15min and1hr45min, and two groups in 12% brine for 15min and 45min. After brining, the fillets were transported to Harðfiskasalan fish drying company, to be dried for 7 days. After drying the fillets were transported back to Matís. The dried fillets were kept at 28±2°C for 7 days to mimic the normal temperature and time it takes before the dried fish reaches consumers. Physico-chemical, microbiological and sensory analysis were done for the raw fillets and the dried fillets.

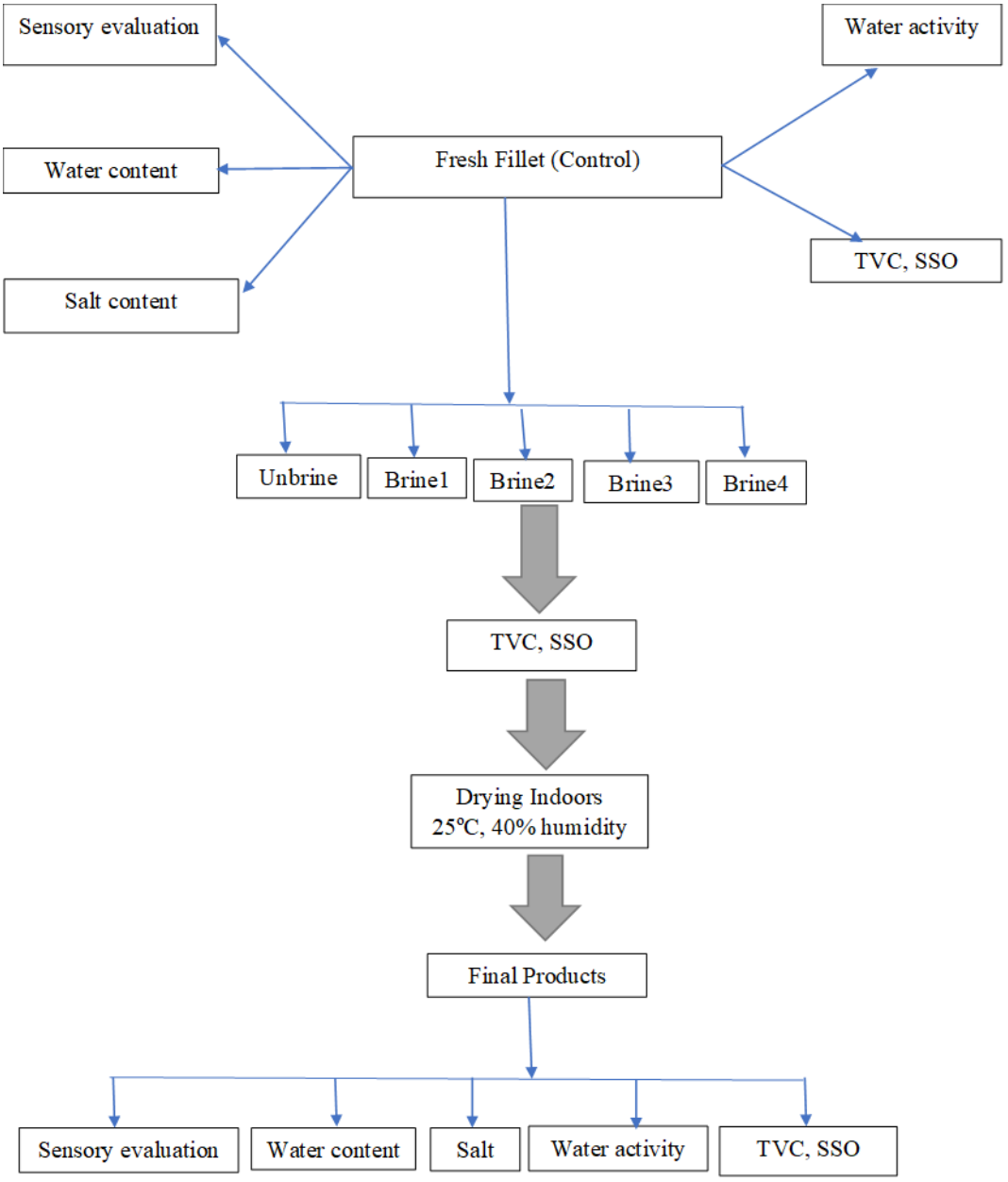


Figure 1: Flow diagram of main experiment procedure and measurement plan.

## 3.3 Analysis

### *3.3.1 Sensory analysis*

Both the raw material (fresh redfish fillets) and the final dried products were analysed using sensory evaluation.

Sensory analysis to assess freshness of fillets was carried out during one session in a well-lit and ventilated sensory room, where the room temperature was20°C±2. A panel of three trained tasters familiar with the sensory evaluation of redfish was used to assess the freshness of the raw materials using the Torry scale for cooked medium fat fish according to Shewan *et al* (1953). Portions of about 40 g from the fillets were put in aluminium boxes and steamed for 6 min in a pre-warmed oven at 95 - 100°C with air circulation and cooled to about 40°C before

being presented to the tasters. The Torry scale ranged from 10 (good quality) to 3 (bad quality) and is shown in Table 1. The sensory panel also gave a short description of some attributes including appearance, flavour, odour and texture attributes.

Table 1: Torry score sheet for cooked medium fat fish (Shewan et al., 1953).

| Score | Odour | Flavour |
|---|---|---|
| 10 | Initially weak odour of boiled cod liver, fresh oil, starchy | boiled cod liver<br>Watery, metallic. |
| 9 | Shellfish, seaweed,<br>boiled meat,<br>oil, cod liver | oily, boiled cod liver<br>Sweet, meaty<br>characteristic. |
| 8 | Loss of odour,<br>neutral odour | Sweet and characteristic flavours<br>but reduced in intensity. |
| 7 | Woodshavings, woodsap,<br>vanillin | Neutral |
| 6 | Condensed milk,<br>boiled potato | Insipid |
| 5 | Milk jug odours<br>boiled clothes- like | Slight sourness, trace of "off"-flavours, rancid |
| 4 | Lactic acid, sour milk<br>TMA | Slight bitterness, sour,<br>"off"-flavours, TMA<br>rancid |
| 3 | Lower fatty acids (eg acetic or butyric acids) composed grass, soapy, turnipy, tallowy | Strong bitter, rubber,<br>slight sulphide<br>rancid |

For the sensory evaluation of dried redfish fillets, eight trained tasters who were familiar with the attributes to be analysed were used. However, one taster was not able to taste five of the samples and was removed from the data for flavour and texture, therefore 8 tasters evaluated odour and 7 evaluated flavour and texture. Each sample group was evaluated in duplicate. The dried fillets were soaked in hot water for 15 minutes in a small pan then washed in warm water.

The fillets were boiled in water for 1hr 30min and cooled to about 40°C and cut into smaller pieces. The cut pieces of dried fillets were then transferred to aluminium boxes, sealed and coded randomly with three-digit numbers. The cooked sample fillets were served in random order to the tasting panel in a well-lit and ventilated sensory room for sensory evaluation using GDA 15cm linear scale according to Lawless and Heymann (2010), using some selected spoilage characteristics (Table 2). Five samples were served at each time and tasters were allowed to rest for a short while between each sampling time. Each taster was provided with unsalted crackers and water to rinse their palates after each sampling. The assessment was carried out in a sensory laboratory equipped with separate booths for each individual taster. Tasters entered the data into individual computers and mean scores were determined.

Table 2: Generic Descriptive Analysis scale for cooked dried redfish fillet.

| **sensory attribute** | **scale anchors** | **definition** |
|---|---|---|
| ODOUR | | |
| processing | none \|\| much | processing odour, dried fish |
| rancid | none \|\| much | rancid odour |
| TMA | none \|\| much | TMA odour, amine |
| spoilage | none \|\| much | total spoilage odour |
| FLAVOUR | | |
| processing | none \|\| much | processing flavour, dried fish |
| rancid | none \|\| much | rancid flavour |
| TMA | none \|\| much | TMA flavour, amine |
| spoilage | none \|\| much | total spoilage flavour |
| salty | none \|\| much | salty flavour, basic taste |
| TEXTURE | | |
| soft | firm \|\| soft | softness in first bite |
| juicy | dry \|\| juicy | juicy: releases liquid when chewing, dry: draws liquid from mouth |
| tender | tough \|\| tender | tenderness when chewing |
| rubbery | none \|\| much | rubbery, elastic texture |

### *3.3.2 Microbiological analysis*

Microbiological analysis of fish products evaluates the presence of bacteria to ascertain the hygienic quality of the fish. The total number of bacteria, specific spoilage organisms, and pathogenic bacteria present in a fish product is used as an indicator of the quality of the product. Total Viable Counts (TVC) and Specific Spoilage Organisms (SSOs) tests were performed to determine and quantify the microbial activity on the fish samples. Analysis was done on fresh fish, brined fish and dried fish.

The sample fish was minced, and 20 g mixed with 180 g of dilution buffer (peptone water) in a stomacher for 1 minute at normal speed. Successive ten-fold dilutions were done on the sample buffer as needed and used for TVC and SSOs tests. 1ml of 1/10 sample dilutions was transferred with pipettes to petri dishes, melted iron agar poured on the plates with the sample dilutions and the content mixed. After solidification the plates were again covered with a thin layer of iron agar and incubated at 22$^{o}$C for 48 hours. The data was expressed as a logarithm

of the number of colony forming units of the samples (log CFU/g)(white representing TVC and black representing SSOs) .

### *3.3.3 Water content*

Water content was measured according to ISO 6496:1999. Water content was measured in fresh and dried fish samples. The measurements were done in duplicates. An empty small porcelain bowl was weighed. Approximately 5.0 g of homogenized sample was placed in the small porcelain bowl and weighed again. The porcelain bowl of sample was left to dry for 24 hours in the oven at 103±2 °C. The bowl was removed from the oven and allowed to cool to ambient temperature in a desiccator for about 30 minutes and weighed. The water content was calculated as follows:

$$W = \frac{m2 - m3}{m2 - m1} * 100(\%)$$

Where: m1 is the mass of the bowl (g)
m2 is the mass of the bowl with test portion (g)
m3 is the mass of the bowl with the dried test portion (g).

### *3.3.4 Water activity ($a_w$)*

An Aqualab Water Activity Meter was used to measure the water activity in fresh and dried fish samples. Approximately 2 g of the sample was put into a water activity cup and put into the water activity meter. The $a_w$ value was taken after the readings stabilised. The measurements were done in duplicate.

### *3.3.5 Salt content*

Salt content was determined by the method of Volhard according to the Salt-(chlorine as salt) method (AOAC, 1937). Salt content was measured in fresh and dried fish samples.

## 3.4 Data analysis

The data was subjected to single factor analysis of variances (ANOVA) using Excel (2016) to determine significant differences between the different sample treatments. Differences between sample means were analysed by t-test. Pearson correlation was also conducted to determine if there was any relationship among the microbiological and physico-chemical parameters of the tested samples. Statistical analysis on sensory data was carried out using a GLM (general linear model) ANOVA corrected for testers' use of scale. Duncan's post hoc test was used to analyse statistical differences between sample groups. Statistical significance was set at a p= 0.05 .

# 4 RESULTS

## 4.1 Pre-Trial

All the received fillets were of good quality and had the characteristic sweet odour and even colour of fresh redfish with no discoloration or yellowish colour. However, after 24 hours and cooking the fillets, there were differences in appearance and taste (Appendix 1).

After 24 hours the control fillets were brownish in colour, fillets brined for 15 min in 5% brine concentration were also brownish indicating that the duration was too short for the fillets to absorb the salt. As the brine concentration increased and as the duration of brining also increased, the fillets turned whiter in colour. The control and the fillets in lower brine concentration had more gaping and were mushier after 24 hours' storage than the fillets brined for the same length of time in higher concentrations. Within the same brine concentration, fillets brined for a longer time had less gaping and were firmer to the touch than the ones brined for a shorter time. There was no gaping in the fillets in 18% and 25% brine concentrations.

From the temperature loggers, the temperature ranged between 15.6$^{o}$C and 19.6$^{o}$C during brining. The lower (5%) brine concentration had an initial temperature 17.1$^{o}$C while 25% brine concentration was 16.1$^{o}$C, however at the end of the process they both stabilized at 19.6$^{o}$C. There was a small difference in salt concentration in the brine solutions during the process, with the variation mostly at the beginning of the process before stabilizing at the end.

After cooking the fillets that had been brined at 25% were too salty regardless of brining time. The salt taste increased with increasing brine concentration at same brining time and with brining time within the same brine concentration. Though there was no gaping in the fillets in 18% and 25% brine concentrations, they were ruled out due to their unpalatability. Salt concentration in food influences its palatability and can motivate intake or terminate food intake. Consumption of high levels of salt has some health implications and due to the current trend of low sodium diets, fish with high salt content may not be acceptable to consumers.

Kenyan consumers have a preference for dried fish that is golden in colour and has less gaping. Hence the fillet that is selected for drying should still have its normal colour and not have too much gaping. Fillets brined in 5% brine concentration for 1hour 15min and 1hour 45min, were firm to touch, moderately salty, not brownish or yellowish in colour or chewy and were chosen. Fillets brined in 12% for 15 min and 45min were also chosen since they were moderately salty and there was no big variation between their appearance before and after brining (Figure 2).

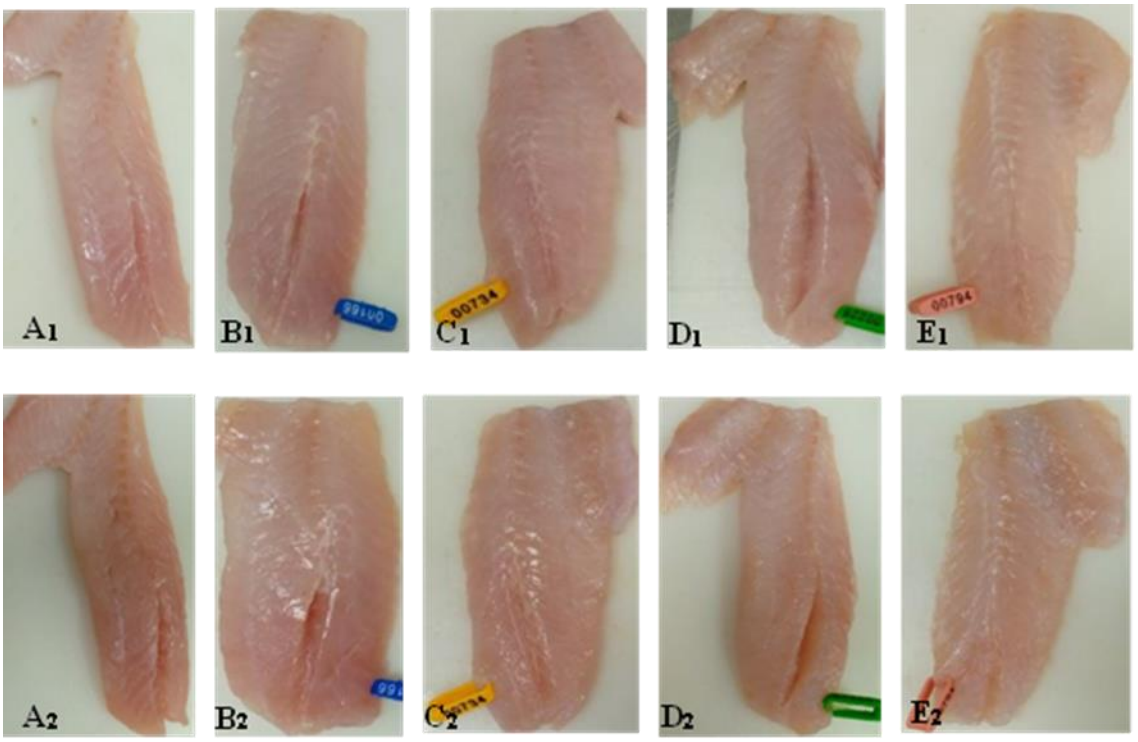


Figure 2: Redfish fillets before (1) and after (2) brining and 24 hours storage. A-Control, B-5% 1hr15min, C-5% 1hr45min, D-12% 15min, E-12% 45min.

### 4.2 Main experiment

At the start of the experiment, the temperature of the 5% and 12% brine concentration solutions were 23.6ºC and 15.7ºC respectively. At the end of the brining period (45 min) for 12%, it only reduced slightly to 15.2ºC. However, for the 5% brine concentration the temperature reduced drastically to 19.6ºC at the end of the brining period. There was a small difference in salt concentration in the brine solutions during the process, with the variation mostly at the beginning of the process before stabilizing at the end. However, the salt concentration in the brine solutions stayed within their range ±0.5%. At the end of brining all the fillets were firm, had no gaping and were the same colour as before. After drying, the fillets were hard and golden in colour (Figure 3). However, after cooking the fillets softened and became dark in colour (Appendix 2).

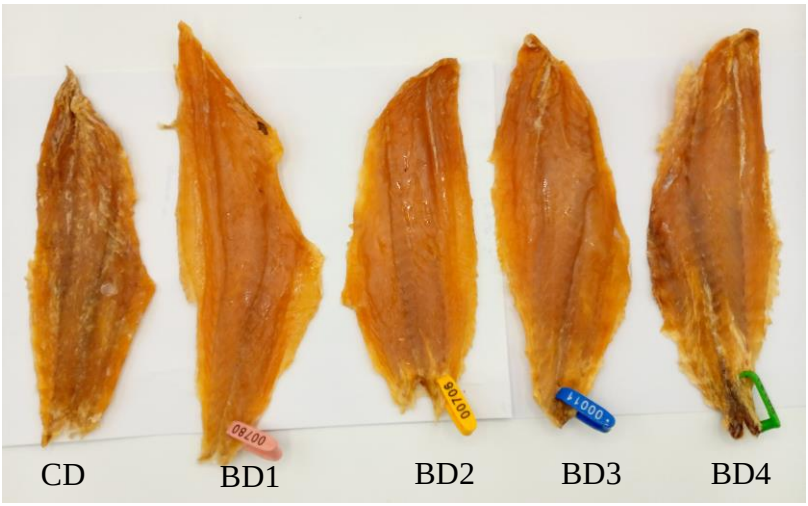


Figure 3: Pictorial of dried redfish fillets. CD-control, BD1-5% 1hr 15min, BD2-5% 1hr 45min, BD3-12% 15min, BD4-12% 45min

### 4.3 Sensory analysis

The cooked raw material was evaluated as being very fresh with a Torry score of 10. The tasters first evaluated the fish individually and then discussed the results to reach a consensus on the descriptions. The fish was described as having a characteristic appearance for fresh boiled redfish, boiled fresh cod liver odour, sweet metallic watery flavour and intact soft texture.

In this study there was generally no significant difference between the sensory evaluations of CD and BD sample groups. The average score of the attributes were determined from the total scores of all the tasters (Appendix 3). Odour, flavour and texture attributes were not significantly different for all the different treatments (Figure 4). However, CD had slightly higher scores than all the BD sample groups for odour and flavour attributes. BD1 had low intensity of spoilage, TMA and rancid odour, while the odour intensity was highest in BD3. The flavour of spoilage, TMA and rancidity was highest in CD, however BD1 had the lowest flavour of TMA, spoilage and rancidity. Among the higher brine concentration, the rancidity, TMA and spoilage odour and flavour scores decreased with brining time. However, for the lower brine concentration, the TMA, rancidity and spoilage odour and flavour scores increased with brining time. CD and BD1 had lower scores for salty taste. CD and BD1 had a higher rubbery texture than the samples, were also less juicy but were soft on the first bite compared to the other sample groups.

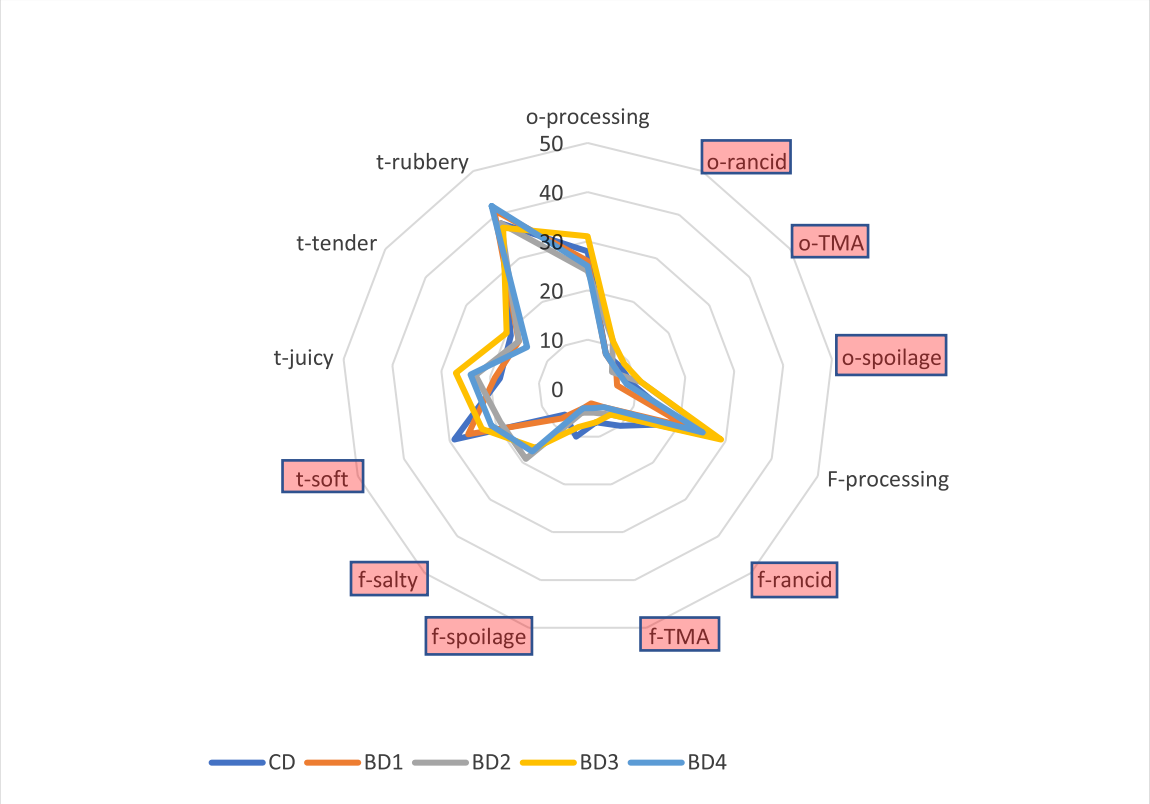


Figure 4: Sensory profile of dried redfish fillets. (o-=odour, f-=flavour, t-=texture)

### 4.4 Microbiological analysis

Initial TVC level for the fresh fillet (C) was slightly above the acceptable limit of 5.0 log CFU/g but decreased after brining to 4.81 log CFU/g in BD1 samples (Figure 5). However, for the other treatments, the TVC increased to 5.94, 5.86 and 6.11 log CFU/g for BD2, BD3 and BD4 respectively. There were significant differences ($p<0.05$) in the TVC and SSOs counts in all the samples. The SSOs for the control fish was 2.38 log CFU/g and increased for all the treatments except for BD3 where it decreased to 2.30 log CFU/g. The TVC levels for the BD4 was significantly higher (p-value <0.05) than all the other samples.

After drying the TVC levels decreased in all the samples to below 5.0 log CFU/g, however CD was slightly higher at 4.77 log CFU/g. BD3 had lower TVC levels and salt concentration than BD4. However, all the samples had SSOs levels below 2.0 log CFU/g.

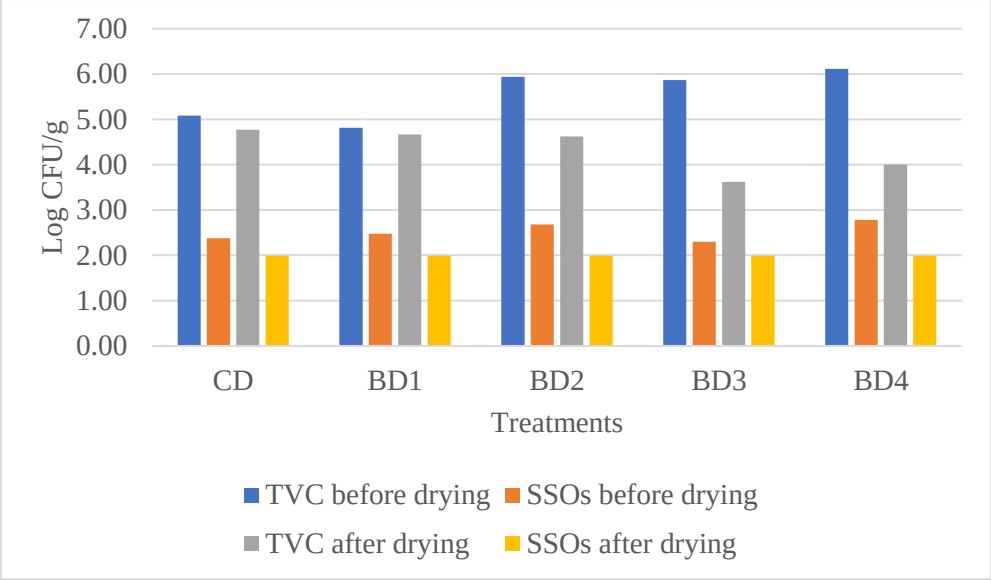


Figure 5: Changes in TVC and SSOs levels in redfish fillets after brining and drying.

### 4.5 Physico-chemical analysis

Fillets used in this study were still fresh, having a water content of 73.29% which is within the range of 70-84% water for a fresh fish. After drying this water content reduced drastically to below 15% for all the samples (Table 3). However, there was a significant difference (p-value=0.0005) in water content between CD and BD samples. BD4 samples had the highest water content (14.71%) and CD the lowest (10.275%). The water activity of the fresh fish at 0.985 was also an indication of freshness but this reduced after brining and drying to less than 0.6. Significant difference (p=0.00003) was also observed in water activity among the dried samples. CD samples had the lowest (0.495), while BD1 had the highest (0.585) water activity. However, no significant differences were found between brine dried samples of the same brine concentration. All the samples had relatively low salt content, BD4 had the highest (5.9%). The salt content of the fresh fish was very low and increased with the treatments, from 0.2% to 5.9%.

Table 3: Physical-chemical properties of dried redfish fillets.

| | **Fresh fish (Control)** | **CD** | **BD1** | **BD2** | **BD3** | **BD4** |
|---|---|---|---|---|---|---|
| **water content (%)** | 73.29(±0.40) | 10.275(±0.11) | 14.34(±0.68) | 12.65(±0.28) | 12.91(±0.44) | 14.71(±0.08) |
| **water activity ($a_w$)** | 0.985(±0.007) | 0.495(±0.007) | 0.585(±0.007) | 0.500(±0.000) | 0.545(±0.007) | 0.580(±0.000) |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Salt content (%)** | 0.2 | 1.3 | 3.2 | 4.8 | 5.3 | 5.9 |

In general, there was a positive correlation among the parameters, water content, water activity, SSOs and TVC using Pearson correlation test (Appendix 4). However, there was a negative correlation between salt content and water content ($r$ = -0.65, $p < 0.05$), salt content and water activity ($r$ = -0.61, $p < 0.05$), salt content and SSOs ($r$=-0.69, $p < 0.05$) and salt content and TVC ($r$=-0.83, $p < 0.05$).

## 5 DISCUSSION

This study focused on the quality and safety of brined and dried redfish, however not much literature was found on the same therefore references are made from similar work with other fish species.

Salting inactivates the micro-organisms in fish except the halophiles that need salt to grow. This explains why after brining the number of TVC was higher in the brined samples than the fresh sample. However, the reduction in BD1 could be that the salt concentration was still not optimal for the growth of halophiles. Similarly Yang *et al* (2020) observed that the TVC in grass carp meat increased during brine salting with 6%, 8%, and 10% salt additions, from 3.81 log CFU/g to 5.49 log CFU/g, 5.15 log CFU/g and 4.79 log CFU/g, respectively after reaching saturation level in 4 hours. However not all micro-organisms are spoilage organisms, which further explains why the SSOs levels were still low even with high TVC levels. (Fernandes, 2018) observed that the SSOs levels were lower than the TVC levels in blue whiting after marination with sucrose.

Salt removes water from bacteria through osmosis, which leads to cell death. Therefore, a higher salt concentration decreases the number of non-halophilic micro-organisms in salt and dried fish products. This explains why BD3 and BD4 had lower TVC levels than BD1 and BD2. Hwang *et al* ( 2012) also noted decreasing TVC (5.2, 3.92,1.96) in salted dried milkfish samples using different salt concentrations (0%, 5%, 15%). However, the slightly higher TVC levels in BD4 than BD3 could be linked to the halophiles that grow in salt conditions since BD4 had higher salt concentration than BD3.

Drying results in osmotic dehydration of water from fish, which leads to higher concentration of salt. The explains why BD4 and BD3 had higher salt concentrations than BD1 and BD2, though their brining time was shorter. Nuwanthi *et al* (2016) also noted that dried *Sardinella gibbosa* treated with a higher salt concentration (10%) had a higher salt content than samples treated with a lower concentration (5%).

Drying reduces the water content in fish, therefore killing or inactivating the micro-organisms. Water content is a quality indicator of dried fish products . When the water content is high, it favors microbial growth, therefore a well dried fish of 15% water content will not favour the

growth of bacteria and moulds. The water content achieved in this study of less than 15% shows that the samples were well dried and shelf stable. This is comparable to findings by Nuwanthi *et al* (2016) that showed a reduction of water content of dried *S. gibbosa* from 70.41% to 11.66% and 14.38% content for 5% and 10% salt treated samples.

The microbial stability of dried fish products is dependent upon their water activity. Low water activity does not favour the growth of microorganisms, since there is very little free water available for growth. Bacteria cannot grow below aw 0.91, yeast below 0.75 and moulds below 0.70. Therefore the achieved $a_w$<0.6 in this study indicates that the samples were microbiologically stable and can be stored at ambient temperature for prolonged time without affecting their stability This was also reported by Mohamed *et al* (2011) who observed that dried tilapia fillets of $a_w$ value of 0.58 were stable during six months storage period.

Organoleptic tests are used in conjunction with bacterial counts to assess the extent of spoilage and are important in determining consumer acceptability of food. Salting is known to affect the texture of fish meat. This is mainly due to the destruction of extracellular matrix structure (collagen) and the resulting changes of intracellular myofibrillar protein (Martinez *et al*., 2011). This may explain why the BD1 was perceived by the sensory evaluators to be softer and more tender than the other brined samples since it had the lowest salt content in the meat. Yang *et al* (2020) observed that the hardness of grass carp meat increased with salt concentrations, with 10% salt brined meat being harder than 6% brined meat.

Spoilage, TMA and rancidity odours and flavours are determining factors in the spoilage of dried fish and are the attributes that consumers look for in their dried fish. Salt is known to inhibit bacterial growth thereby reduce spoilage. While salt has been used as a preservative in fish, it is also an accelerator of lipid oxidation. This leads to rancidity, TMA and finally spoilage, and is the main reason for quality change and short shelf-life of fish during storage. This is seen with BD1 which had low values for rancidity, TMA and spoilage odours and flavours, which may be due to the low salt content in the samples. However they also had a significant difference in the taste of salt. The same results were presented by Guizani *et al* (2014) on studying the effect of brine concentration on lipid oxidation and fatty acids on hot smoked tuna. They realized the lipid oxidation (PV- values and TBARS) of 10% brined tuna samples was higher than 5% brined samples. When salting fish, there has to be a balance between using enough salt to reduce $a_w$ and eliminate the non-halophiles while not increasing the halophiles and lipid oxidation.

## 6 CONCLUSION

This study aimed to determine the bacteriological and chemical quality of dried redfish produced with different brine concentrations and brining time. Due to its lower salt concentration, low spoilage odours and flavours, and microbial levels below the acceptable limit, brining in 5% brine solution for 1hr 15min at ambient temperature was found to be the most suitable method for producing quality and safe brined and dried redfish.

## 6.1 Recommendations

- The brining conditions employed in this study need to be repeated back in Kenya with tilapia fish to get the most ideal conditions.
- The conditions should then be recommended to fish processors in Kenya to improve quality of locally produced dried fish.
- Indoor drying of fish and temperature regulation at 35-45$^{o}$C should be recommended to fish processors in Kenya in order to avoid fish contamination or spoilage of fish from open sun drying due to high water content inside the dried fish.
- A study on the effect of this brining and drying condition needs to be tested on the nutritional composition and storage stability of the dried fish.
- Dried redfish can be marketed as a cheaper alternative to dried cod.

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**APPENDICES**

**Appendix *1:* Pre-trial assessment of redfish fillets.**

| Brine concentration | Duration of brining | Before brining | After brining/24hours | After cooking |
|---|---|---|---|---|
| 0%-Control fillet | None | pink-white colour, no gaping | brownish colour, excess gaping, very soft, mushy | not salty, very chewy |
| 5% | 15minutes | pink-white colour, no gaping | brownish colour, gaping, very soft, mushy | mild salt, very chewy |
| | 45minutes | pink-white colour, no gaping | white colour, gaping, very soft | mild salt, very chewy |
| | 1hour 15minutes | pink-white colour, no gaping | pink-white colour, some gaping, firm | moderate salt, not chewy |
| | 1hour 45minutes | pink-white colour, no gaping | pink-white colour, some gaping, firm | moderate salt, not chewy |
| 12% | 15minutes | pink-white colour, no gaping | pink-white colour, some gaping, soft | moderate salt, chewy |
| | 45minutes | pink-white colour, no gaping | pink-white colour, some gaping, firm | moderate salt, chewy |
| | 1hour 15minutes | pink-white colour, no gaping | pink-white colour, some gaping, firm | moderate salt, chewy |
| | 1hour 45minutes | pink-white colour, no gaping | pink-white colour, no gaping, firm | too salty, not chewy |
| 18% | 15minutes | pink-white colour, no gaping | very white colour, gaping, soft | too salty, not chewy |
| | 45minutes | pink-white colour, no gaping | very white colour, no gaping, firm | too salty, not chewy |
| | 1hour 15minutes | pink-white colour, no gaping | very white colour, no gaping, firm | too salty, not chewy |
| | 1hour 45minutes | pink-white colour, no gaping | very white colour, no gaping, very firm | too salty, not chewy |
| 25% | 15minutes | pink-white colour, no gaping | very white colour, no gaping, very firm | too salty, not chewy |
| | 45minutes | pink-white colour, no gaping | very white colour, no gaping, firm | not tasted |
| | 1hour 15minutes | pink-white colour, no gaping | very white colour, no gaping, very firm | not tasted |
| | 1hour 45minutes | pink-white colour, no gaping | very white colour, no gaping, very firm | not tasted |

**Appendix 2: Main experiment assessment of redfish fillets.**

| Brine concentration | Duration of brining | Before brining | After brining | After drying | After cooking |
|---|---|---|---|---|---|
| 0%-Control fillet | None | pink-white colour, no gaping | pink-white colour, no gaping, firm | very light golden in colour with mostly white precipitation on whole fillet, very hard | non appealing colour, a bit hard to the touch |
| 5% | 1hour 15minutes | pink-white colour, no gaping | pink-white colour, no gaping, firm | nice golden colour, slightly white colour on edges, hard | very good colour, very soft to touch, |
| | 1hour 45minutes | pink-white colour, no gaping | pink-white colour, no gaping, firm | golden colour, slightly white on edges, very hard | excellent colour, very appealing, very soft to touch |
| 12% | 15minutes | pink-white colour, no gaping | pink-white colour, no gaping, firm | slightly darker in colour, white colour on edges, very hard | dark in colour, non-appealing, soft in touch |
| | 45minutes | pink-white colour, no gaping | pink-white colour, no gaping, firm | dark in colour, white colour on edges, very hard | good colour, appealing, soft to touch |

**Appendix 3: Generic Descriptive Analysis results for cooked dried redfish.**

**Average values of 8 trained panelists (score scale: 0-100).**

| sensory attribute | CD | BD1 | BD2 | BD3 | BD4 | p-value |
|---|---|---|---|---|---|---|
| *ODOUR* | | | | | | |
| processing | 28 | 26 | 24 | 31 | 25 | 0.812 |
| rancid | 8 | 8 | 11 | 11 | 8 | 0.916 |
| TMA | 8 | 7 | 6 | 9 | 7 | 0.958 |
| spoilage | 9 | 6 | 11 | 11 | 8 | 0.876 |
| *FLAVOUR* | | | | | | |
| processing | 20 | 22 | 28 | 29 | 25 | 0.506 |
| rancid | 10 | 5 | 7 | 7 | 5 | 0.546 |
| TMA | 7 | 3 | 5 | 7 | 4 | 0.350 |
| spoilage | 10 | 4 | 5 | 8 | 4 | 0.286 |
| salty | 7 | 8 | 19 | 16 | 17 | 0.145 |
| *TEXTURE* | | | | | | |
| soft | 29 | 26 | 19 | 23 | 21 | 0.496 |
| juicy | 18 | 19 | 23 | 27 | 24 | 0.420 |
| tender | 19 | 17 | 17 | 20 | 15 | 0.765 |
| rubbery | 38 | 41 | 38 | 37 | 42 | 0.992 |

**Appendix 4: Correlation coefficients among total viable count (TVC), specific spoilage organisms (SSOs), water content, water activity (aw) and salt content in dried redfish fillets samples brined with different salt concentrations.**

| | water content (%) | water activity($a_w$) | Salt content (%) | TVC (log CFU/g) | SSOs (log CFU/g) |
|---|---|---|---|---|---|
| water content (%) | 1 | | | | |
| water activity ($a_w$) | 0.988208752 | 1 | | | |
| Salt content (%) | -0.657993745 | -0.613287869 | 1 | | |
| TVC (log CFU/g) | 0.541445109 | 0.484406768 | -0.834573819 | 1 | |
| SSOs (log CFU/g) | 0.99797739 | 0.978581466 | -0.691658984 | 0.562968365 | 1 |