EFFECTS OF POST HARVEST HANDLING ON QUALITY AND SENSORY ATTRIBUTES OF SARDINES: A CASE STUDY OF MUSOMA DISTRICT

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ABSTRACT

Sardines in Tanzania are small pelagic fish eaten in a dried form mainly by the poor and middle-income groups. The main objective of this research was to assess the influence of postharvest handling of sardines from Lake Victoria and its effects on the quality and sensory attributes of the final product. Cross-sectional and factorial designs were used to collect data for field survey and laboratory analyses, respectively. Ninety three respondents were involved in the survey to assess post harvest handling practices in the study area. The study identified unhygienic handling practices, insufficient drying time, poor storage, poor packaging and distribution as the contributing factors for spoilage. Sardines were dried by traditional and improved methods at different levels of salt concentrations (0, 6, and 10%) and loading densities (5 and 10kg/m^2). After drying for 36h the proximate composition of dried sardines by (1) traditional method was 16.43-74.5% moisture, 57.79-64.9% protein, 14.78-17.1% fat, 14.2-23.09% ash and 3.8-4.34% carbohydrate; and (2) improved method was 15.13-74.5% moisture, 59.05-64.9% protein, 15.64-17.1% fat, 14.2-20.66% ash and 3.8-4.65% carbohydrate. The improved method showed relatively low microbiological count (3.75 -5.02 Log CFU/g) compared to the traditional method (4.24-6.13 Log CFU/g). For the sensory evaluation no significant difference ($P > 0.05$) observed between the improved method and commercial sardines from Lake Tanganyika and Lake Nyasa in terms of colour, taste, smell and general acceptability. However, a significant difference ($P< 0.05$) in colour, texture and general acceptability was observed in traditional dried sardines and commercial sardines from Lake Victoria and the Indian Ocean. Commercial sardines from Lake Tanganyika and Nyasa were similar to sardines dried by the improved method in this study and were highly accepted in all sensory attributes. For both methods, sardines dried by the improved method had higher nutrient contents than those from the traditional method.

DECLARATION

I, Joseph Peniel Nguvava, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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DEDICATION

This Research work is dedicated to my parents Mr. Peniel Nguvava and Madam Nasikiwa Joseph, my wife Magreth Godson and children for their love, support in diverse ways and always being there for me.

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LIST OF ABBREVIATIONS

AOAC	Association of Official Analytical Chemists
CFU	Colony forming unit
FAO	Food and Agriculture Organisation of the United Nations
FDA	Food and Drugs Administration
g	Gram
GHP	Good Hygiene Practice
GMP	Good Manufacturing Practices
HDPE	High Density Polyethylene
ICMSF	International Commission on Microbiological Specifications for Foods
ISO	International Standards Organisation
IM	Improved Method
Kg	Kilogram
LDPE	Low density polyethylene
LVFO	Lake Victoria Fisheries Organisation
MRCO	Mara Regional Commissioners' Office
OIA	Office of International Affairs Washington D.C,
PCA	Plate Count Agar
TBS	Tanzania Bureau of Standards
TM	Traditional Method
TVC	Total viable count
WHO	World Health Organisation

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Worldwide, total fish catch is estimated at about 140 million tonnes (FAO, 2006). Over one billion people rely on fish as their primary source of animal protein (Obodai *et al.*, 2011). However, in Lake Victoria the total fish catch is estimated at around one million tonnes per annum making it one of the world's most important inland fisheries (LVFO, 2008). The quality of fish and its usefulness is affected by the capture method, handling practices, processing methods, distribution techniques and storage conditions (Davies. 2009).

Fishing makes a considerable contribution to the economies of the fishing countries. In Africa, over 60% of fish production is supplied to domestic and regional markets, as well as export-oriented processing units, of which artisanal fishery accounts for the majority of fish catch (Akande and Diei-Ouadi, 2010). Small-scale fisheries of developing countries are very important because they provide a nutritious food which is often cheaper than meat and therefore, accessible to a larger number of people (Kabahenda *et al*, 2009). Generally, fish is a rich source of protein, fat, mineral (like calcium and iron), vitamin A and valuable omega-3 fatty acids contributing to food and nutrition security (Akande and Diei-Ouadi, 2010). According to FAO (2004), 15% of the world supply of animal proteins is derived from fish. Despite of such nutritional importance fish is highly perishable food, which could be rendered unfit for human consumption within twelve hours of capture at tropical temperature condition (Fellows and Hampton 1992; Kuje *et al*. 2011). Spoilage begins as soon as the fish dies; therefore, hygienic handling should be employed to extend its shelf life (FAO, 2004; Ghaly *et al*., 2010).

Lake Victoria is a very important source of fresh water fish in East Africa. It has more than 290 fish species and among these, the commercially important in Tanzania include Nile perch (*Lates nilotics* L), Tilapia (*Oreochromis nilotics* L) and Sardines (*Rastrineobola argentea*), the small-sized fish species (Abila, 2000). Among the fish species, nowadays sardines contribute a large portion of fish catch from the lake in terms of weight, but it is as yet less researched (Ghaly *et al.*, 2010). It is estimated that about 545 000 tonnes of sardines are harvested from Lake Victoria per annum. Most of the catch is sun-dried and marketed for either human consumption or for industrial processing into animal feed (LVFO, 2008). Currently, sardines are dried on rocks, nets and beach with limited application of new and modern technology to improve quality of products in the post-harvest chain. Consequently, current traditional sun-drying method is associated with a lot of quality problems like product spoilage through fat hydrolysis and protein proteolysis (Dampha, 1992; Venugopal, 2002).

Traditional method is characterised by lack of control over the drying rate, resulting into under-drying or over-drying and subsequently expose the product to insect infestation and physical contaminants like dust which compromise quality (Akinola *et al*., 2006). The physical and quality losses are respectively estimated to be 20 and 70%, especially during the wet season (Akande and Diei-Ouadi, 2010). Normally traditional dried sardines are perceived by consumers as inferior quality product and commonly eaten by the low income people (LVFO, 2008; Akande and Diei-Ouadi, 2010). Deterioration of sardine products mainly occurs as a consequence of microbiological activity and chemical changes during processing and storage (Owaga *et al*., 2009). Quality of sardines and its products is mostly affected by storage conditions such as temperature, moisture and humidity (Nguyen *et al*., 2007). This may result into low market value (LVFO, 2008).

Although catch rates are high during the rainy season, fishing effort may be reduced when processors cannot dry the fish (FAO, 2010).

The use of modern and improved preservation and processing methods such as smoking, drying, chilling, freezing, salting, and canning greatly minimize the spoilage of sardines (Eyabi, 1998; Kumolu and Ndimele, 2011). In all these processes, drying is commonly used for preservation purposes (Obodai *et al.*, 2011). Combination of drying and salting arrests deterioration and enhances keeping quality of sardines (Berkel *et al*., 2004). Besides, salting allows fishermen to stay out fishing for longer periods (Berkel *et al*., 2004; Turan *et al.,* 2007). Despite of the benefits, combination of drying and salting method is not common in Tanzania, particularly in Musoma District. In Africa, fish is seldom salted before drying and if done semi-spoiled fish or low-quality raw materials are used (Duncan and Salagrama, 1998; Akande and Diei-Ouadi, 2010). While postharvest handling of sardine entails different handling practices to achieve sound end product, this study investigated the effects of traditional and improved drying methods on quality and sensory attributes of sardines from Lake Victoria.

1.2 Problem Statement

A big portion of the sardines caught get spoiled and become unfit for human consumption. It is estimated that about 70% of the catch is spoiled and rejected at the market (Bille and Shemkai, 2006). Postharvest losses of fish are to the large extent attributed by loss of quality due to direct physical and nutritional losses with negative impacts on consumer acceptability. The factors contributing to such big postharvest losses among others include poor processing and handling techniques of fish along the fish value chain. However, studies to assess the effects of postharvest handling practices

of sardines and their implication on the sensory attributes of the sardines for human consumption are very limited.

1.3 Justification of the Proposed Study

The proposed study assessed the fishing practices employed by fishermen and fish processors during harvesting, transportation, processing and packaging of sardines and the effects of post harvest handling of sardines. To prevent post harvest losses of sardines, improved methods and good handling practices are required. The developed improved method in this study will significantly reduce post-harvest losses along the sardine value chain and improve quality and safety of the products. The findings of this study could benefit all stakeholders including consumers, and policy makers. High quality sardines could create further marketing opportunities both locally and internationally. Instead of sardines being perceived as poor man's diet; high quality sardines could access the shopping baskets of the high income earners. Also, the results could be used by policy makers to formulate laws and by-laws that can promote application of the improved methods and good handling practices to minimize post harvest losses. Since, fishing and fish processing are the major economic activities of people living along the Lake Victoria, reduction of post harvest losses through application of good handling practices and improved processing methods and manufacture of high quality sardines for both domestic and export market will definitely increase their income and improve livelihood. It could also result into more employment opportunities.

1.4 Objectives of the Study

1.4.1 Main objective

The main objective of this study was to assess the influence of post-harvest handling practices of sardines from Lake Victoria and its effect on the quality and sensory attributes of the end product.

1.4.2 Specific objectives

The specific objectives addressed in this study were;

i. To identify the main handling practices of Lake Victoria sardines along the value-chain in Musoma District.
ii. To develop an improved method of drying sardines
iii. To assess nutrient contents of sardines dried by traditional and improved methods
iv. To determine microbial quality of sardines processed by traditional and improved methods.
v. To compare the sensory attributes of sardines processed by traditional, improved methods and commercial available sardines from Lake Victoria, Lake Nyasa, Lake Tanganyika and Indian Ocean.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Lake Victoria Fishing Practices

Lake Victoria has an area of about 68 900 km^2, the largest fresh water body in Africa. Tanzania occupies 51 percent of this Lake, Kenya and Uganda share the remaining fraction by 6 % and 43 percent, respectively (LVFO, 2008). It was estimated that about 98 015 fishers were fishing on the Tanzania portion of the lake, using about 29 732 canoes (Salehe, 2008). Among fish species commonly found in the Lake Victoria, Nile perch, Tilapia and Sardines are the most predominant and economic valuable ones (Abila, 2000). Fishing in Tanzania is dominated by artisanal fishers commonly faced by considerable challenges in their living and working conditions.

In Lake Victoria, there are about 1 490 fish landing sites (i.e. Kenya 297, Tanzania 596 and Uganda 597) which are the focal points of socio-economic activities for the fishing communities. The sites, however, have poor infrastructure, 31% accessible by all weather roads and only 5% supplied with electricity. This shows that many landing sites are inaccessible and cooling facilities are not always available (LVFO, 2008). Lake Victoria had an estimated standing fish stock biomass of 1.2 million tonnes where Nile perch ranked highest (38%) followed by sardines (24%) and lastly tilapia (7%) while the remaining 32% is for other fish species such as *Clarias, Labeo, Barbus spp.* etc. (Kizaa *et al.,* 1993; Salehe, 2008). A great portion of the Nile perch catch goes to fish processing factories for export while sardines and tilapia are mainly serving the local and regional markets.

2.2 Fish Handling and Transportation

Being a perishable product, fish spoils very fast once harvested if not properly handled. Spoilage of fish takes place within 12 hours in the high ambient temperatures of the tropics (Kabahenda *et al*., 2009; Kuje *et al*., 2011). Fresh fish storage time can be increased by using good fishing techniques (to avoid damage/bruises) and immediate onboard cooling/icing (Brigitte *et al.*, 2004). Good hygienic practices including cleaning and disinfection of equipment (i.e. fishing gears), boat/vessel and storage facilities are very important to control quality of sardines (Okonkwo *et al.*, 1993; Henson and Mitullah, 2004; FAO/WHO, 2009). When there is no supply of ice, fish should be transported to the shore as quick as possible and must be kept in a clean boat and in the shade in order to limit the rate of spoilage (Brigitte *et al.*, 2004). In some occasion, fishes are cleaned with potable water to reduce initial microbial load, but the method used to clean fish depends primarily on the size and kind of fish. For smaller fish species like sardines and others less than 10 cm in size; only the intestines are removed to reduce microbial load (Esser *et al.*, 2007).

Traditional fisheries may be commercial or subsistence, but each has in common a small cash income. Fishermen often live in isolated off shore villages and may also be engaged in subsistence agriculture. The wealth of fishermen is mainly fishing gears (boat, motors, nets, and lines), which are sometimes subjected to rapid depreciation and loss (OIA, 2003). In most occasions fishermen either construct their own boats and assemble their gears or purchase them from village experts. In some cases, their small boats are powered with outboard gasoline motors, although sail and paddle power are common (Henson and Mitullah, 2004). However, fishing is mainly done with no facilities for cold storage to permit early chilling (OIA, 2003; Henson and Mitullah, 2004). Artisanal vessels handle relatively small amounts of fish as compared with industrial vessels and

fishing journeys are shorter usually less than one day and very often only a few hours (Gibbon, 1997; Ponte, 2005). Harvesting of sardines is commonly done in shallow waters close to the shoreline using seine nets similar to mosquito-nets by the aids of canoe or boat (Ssebisubi, 2011).

Fishing activities for sardines are usually done at night when the moon is down. The sardines are attracted to the 3-5 lanterns set out by each sardine boat (LVFO, 2008). Fishermen leave the beach in the dark of the night and work all night long hauling up the sardines which have been caught by the nets in the light of the lanterns where casting and hauling the net is done in every 30 minutes (LVFO, 2008; Ssebisubi, 2011). The catch is a result of insects and light which attract sardines and in each haul is estimated at 20 kg (Ssebisubi, 2011). Sardines' fishing is considered a tedious job which needs one to be physically fit. Very few middle aged or old men participate in the fishing operations (Jansen *et al*., 1999). Akinneye (2007) reported that small fishing boats lack structures to store and protect the catch from spoilage agents. However, storing the harvest on the bottom of the boat and covered by plastic sheets or vegetation will prevent spoilage resulting from high temperatures (Ssebisubi, 2011). Also, spoilage will be delayed when fish is stored in shade awaiting the actual drying process (OIA, 2003). Delays in processing up to about six hours will still give reasonable quality for small pelagic fish, provided the fish are consumed without delay (OIA, 2003).

Most of the sardines catch is sun or smoke-dried then marketed for human consumption (LVFO, 2008). After drying, the product is packaged in polyethylene bags (e.g. Obadai *et al*., 2011) and transported on trucks, pick-ups, and/ or bicycles to the markets (LVFO, 2008). The form of transport varies with market destination; hired trucks are being used for regional markets, pick-ups for local distant markets and bicycles for the nearby fish

markets (LVFO, 2008). Compared to other fish species sardines fetch relatively low prices, this may be due to poor quality (Ssebisubi, 2011).

2.3 Factors Contributing to Damage and Spoilage of Fish

Food spoilage refers to damaging of the original nutritional value, texture, and flavour of the food to the extent that it becomes unsuitable to eat (Bataringaya, 2007; Boran and Karacam, 2011). Different metabolic processes can render fish undesirable or unacceptable for human consumption due to changes in sensory characteristics (Burkepile *et al.*, 2006). Fish spoilage is a rather complex process and is caused by a number of inter-related reactions (Gram and Dalgaard, 2002). Bacteria get access to the fish through gills, blood vessels, lining of the belly cavity and even through the skin. In the fish, bacteria grow very rapidly producing undesirable odours and flavours as a result of fat oxidation and protein degradation (Johnston *et al.*, 1994; Gram and Dalgaard, 2002; Venugopal, 2002; Bataringaya, 2007; Diei-Ouadi and Mgawe, 2011). Fresh, frozen and cold smoked fish are considered unacceptable when total bacterial count is beyond 10^7 CFU/g (ICMSF, 1986; TBS 402, 1988; Huss, 1994).

It is important that icing on board is done as soon as fish is caught and kept properly chilled until it reaches the stage of processing (Masetta and Kasiga, 2007). Therefore, combination of various factors including infestation and damage by insects and pests such as blowflies (*Diptera calliphoridae*), poor quality raw material, poor handling and unhygienic conditions during harvesting and processing of fish, microbiological spoilage and biochemical reactions, affects the final quality of processed fish (Esser *et al.*, 2007; Diei-Ouadi and Mgawe, 2011**).** Cleaning of fishing boats and other gears at fishing grounds is of paramount importance to limit the rate of deterioration of fish, however, it is usually done by using contaminated water from the lake (Henson and Mitullah, 2004;

Ponte, 2005). Obodai *et al.* (2011) stated that storage, handling and packaging techniques such as use of old news prints, cement papers and polyethylene bags are all potential sources of contamination of fish. Food borne illness usually arises from improper handling, preparation, and storage of foods. Thus, GHP before, during, and after food preparation can reduce the chances of contracting an illness.

Distribution of fish on the local and regional markets to a large extent is done without refrigeration and is accompanied by significant post-harvest losses and deterioration (LVFO, 2008). Much of the sardines channelled to animal feed manufacturing factories are of the inferior quality, not properly dried, and partly covered with sand (LVFO, 2008). Lack of financial capital and human resources (knowledge and experience) associated with inadequate quality raw materials are the most contributing factors to deficient quality of fish and fishery products (Burkepile *et al*., 2006).

2.4 The Nutritional Significance of Fish in the Diet

Fish is a good source of high quality protein and contains many vitamins and minerals. Fish can be classified as either white, oily or shellfish. White fish, like haddock and seer contain very little fat (usually less than 1%) as compared to oily fish, such as sardines which contain 10-25% and fat-soluble vitamins (A, D, E and K) (FAO, 2004). Nutrients composition in fish, however, varies greatly from species to species and from individual to individual depending on age, sex, environment and season (Huss, 1995; Sushchik *et al.*, 2007; Tzikas *et al.*, 2007). Furthermore, the variations in proximate composition of fish are related to the feed intake (Denstadli *et al.*, 2006). Boran and Karacam (2011) noted the increase of protein and fat contents during the periods of heavy feeding of fish. Also fish have starvation periods for natural or physiological reasons (spawning or migration) or because of external factors such as shortage of food. In this case, fat content

gradually decreases and followed by a decline in protein (Venugopal, 2002; Boran and Karacam, 2011). Therefore it is important to investigate the proximate composition of fish throughout the year (Zlatanos and Laskaridis, 2007).

2.4.1 Protein

The amount of protein in fish is usually somewhere between 15 and 20 %, but values lower than 15 or as high as 28 % are occasionally reported in some species (Sablani *et al*., 2003). All proteins, including those from fish, are chains of chemical units linked together to make one long molecule (Gram and Dalgaard, 2002). These units are about twenty types and called amino acids, and some of them are essential in the human diet for the maintenance of good health. However, if a diet is to be fully and economically utilized, amino acids must not only be present but also occur in the correct proportions (Gram and Dalgaard, 2002).

Fish protein generally contains high concentrations of two essential amino acids called lysine and methionine, in contrast to cereal proteins (Miles and Chapman, 2006). Thus, fish and cereal protein can supplement each other in the diet (FAO, 2011). Early *et al.* (2001) reported that the crude protein content of solar dried sardine ranged from 39 to 65% depending on the quality of initial raw sardines used. The protein contents of fish dried by smoking kiln and electric oven as obtained by Dumay *et al*. (2006), Chukwu and Shaba (2009) were 53.10 and 67.21% on dry weight basis, respectively.

2.4.2 Fat

Taking all species into account, the fat content of fish can widely vary than water, protein or mineral content. Whilst the ratio of the highest to the lowest value of protein or water content encountered is not more than three to one, the ratio between highest and lowest

fat values is more than 300 to one (Zlatanos and Laskaridis, 2007). There is usually considerable seasonal variation in the fat content of fatty fish; Sardines, sprats and mackerel also exhibit this seasonal variation in fat content (Zlatanos and Laskaridis, 2007).

According to Kolakowska and Sikorski (2010) fish lipid content can be divided in to four basic groups: lean < 2% fat (cod, haddock, hake, and blue whiting); medium-fat 2% - 7% (sole, flatfish, tuna, roach, wild salmon, and rainbow trout); fat: 7% - 16% (sardines, herring, sprat, mackerel, salmon, and carp); and highly fat: >16% (eel, capelin, catfish, and carp). Boran and Karacam (2011) reported the variation of fat content from 0.2 -25%. Fat is essential source of essential fatty acids and serve as carriers of fats soluble vitamins. Sardines are rich source of omega-3 polyunsaturated fatty acids and they are extremely low in contaminants such as mercury (Zlatanos and Laskaridis, 2007; Hajar, 2009). According to Akinneye (2007) the highest fat content (12.73 – 60.30%) was observed in fish samples that were smoked while the least 12.13–26.42% was recorded for fish samples that were sun dried.

Bouriga *et al.* (2008) and Bataringaya (2007) pointed out that fat oxidation is an autocatalytic chain reaction, which takes place through four main stages: initiation, propagation, chain branching and termination. The primary products of fat oxidation, fat hydroperoxides, are generally considered not to have a flavour impact but can cause brown and yellow discolouration of the fish tissue (Bataringaya, 2007). The volatile secondary oxidation compounds, aldehydes and ketones, derived from breakdown of primary oxidation compounds are responsible for rancid flavour and odours. Free fatty acids formed after degradation by enzymatic hydrolysis are not only important from the

point of view of oxidation products, but also have been reported to have a direct sensory impact in fish and fish products (Nilsang *et al*., 2005).

2.4.3 Carbohydrates

The amount of carbohydrate in white fish muscle is generally too small (<0.5%, fwb) (Anthony *et al*., 2000). In white fish the amount is usually less than 1%, but in the dark muscle of some fatty species it may occasionally be up to 2% in wet weight basis. Some molluscs, however, contain up to 5% of the carbohydrate glycogen (FAO, 2004). However, Nurnadia (2011) found the mean amount of carbohydrate in *Fringescale sardinella* to be 3.07 $\pm$ 0.63% and other species of pelagic fish were observed to contain no carbohydrate.

After death glycogen present in living fish is rapidly converted to lactic acid (Islam and Joadder, 2005). Also available carbohydrate is very important in Maillard browning reactions (Anthony *et al*., 2000). These reactions can influence quality indices of fish including colour/appearance, flavour, texture, nutrition, safety, and processing suitability (Boran and Karacam, 2011).

2.4.4 Water content

Fish contains about 60 – 80% by weight water depending on the species (Ghaly *et al*., 2010). Fatty and lean fish contain 65% and 80% water, respectively (Chukwu and Shaba, 2009; Boran and Karacam, 2011). With such high levels of water content, bacteria can grow rapidly. Different dehydration methods like sun drying, smoking and salting can be employed to lower the moisture content of fish to various degrees (60-10%) in the final product (Chukwu, 2009). Akinneye (2007) reported the moisture content ranging from 9.79 to 16.42% for fish species including sardines dried by oven, sun and smoking. Bille

and Shemkai (2006) observed the following nutritional composition for sardines which were sun-dried and spiced-smoked (Table 1).

Table 1: The mean proximate composition of the sun-dried and spiced sardines

Attributes	Sun-Dried Sardine	Spiced-Smoked Sardine
Moisture	2.40 ± 0.2^{a}	1.81 ± 0.30^{b}
Dry Matter	97.60 ± 0.2^{a}	98.90 ± 0.30^{b}
Protein	47.75 ± 1.63^{a}	48.32 ± 1.81^{a}
Fat	14.06 ± 0.5^{a}	14.86 ± 0.40^{a}
Ash	18.66 ± 0.5^{a}	19.29 ± 0.60^{b}

Source: Bille and Shemkai (2006). Means for the same attributes followed by the same letter are not significantly different ($P > 0.05$)

2.5 Methods of Fish Processing

In order to arrest fish spoilage, different processing methods are applied in the tropics. Some techniques are based on temperature control by using ice, refrigeration or freezing; while others based on the control of water activity through drying, salting, smoking and freeze-drying (Eyoo, 1993; FAO/WHO, 2009; Abbas *et al*., 2009). Most often a combination of different processing techniques is used to preserve fish.

Different processing methods have different effects on nutritional composition of fish (Chukwu, 2009). Fish processed by heating, freezing and exposure to high concentration of salt lead to chemical and physical changes (Tao and Linchum, 2008). These chemical and physical changes increase digestibility of protein due to protein denaturation, but reduce content of thermolabile compounds and polyunsaturated fatty acids (Tao and Linchum, 2008; Chukwu, 2009). Therefore, the quality of fish dried using different methods cannot be the same. The combination of salting and drying normally achieve the best results. Salting the fish is not essential but has many advantages and is therefore strongly recommended before drying (Brigitte *et al.,* 2004). Salting ensures among other

things, that during drying the micro-organisms at the surface are inhibited and insects and other vermin are kept away (Brigitte *et al.*, 2004; Oparaku, 2010).

However, fatty fish is difficult to convert into a good salted and/or dried product. The problem is that fat forms a barrier to salt penetration and/or loss of moisture (FAO, 2005). In order to ensure properly dried product, weighing the fish before and after the drying process to determine whether the fish is dry enough is necessary. If during drying process the weight of the fish does not decrease further, it is regarded sufficiently dry (Diei-Ouadi and Mgawe, 2011). Drying to moisture content 15% and below prevents the growth and proliferation of many spoilage organisms, but mould growth is completely suppressed at 10% moisture content (Junaid *et al.*, 2010).

Doe (2002) categorized dried fish products into fully and partly dried products. The previous have been dried until their moisture content is close to uniform and water activity is close to or below 0.75 and have a shelf-life between one week and several months. Partly dried fish have a shelf-life of up to one week and are usually kept refrigerated before consumption.

In general, natural drying of fish needs about 3-10 days and product obtained is difficult to bend (Doe, 2002; Brigitte *et al.*, 2004; Junaid *et al.*, 2010). Since dried fish can pick-up moisture from the air in humid conditions, packing in airtight containers is very important (Nketsia-Tabiri and Sefa-Dedeh, 2000). In addition airtight packaging delays the onset of rancidity in fatty fish. Strong and airtight food grade plastic bags can be used. Plastic bags provide protection against insects and moisture; however, should not be placed in the direct sun or in warm places (Brigitte *et al.*, 2004).

2.5.1 Chilling and Freezing

Spoilage of fish is directly related to temperature. Reduction in temperature to required level i.e. 4 ^{o}C / 7^{o}C prior to processing will maintain the quality of fish for longer periods of time. Although it is an effective method of preservation, getting ice, could be difficult and expensive as most ice-making machines require fuel or electricity (Balachandran, 2001). According to Berkel *et al*. (2004) fresh fish can be stored by chilling between -1 and 4^{o}C to inhibit the growth of microorganisms and freezing at -18 to -30°C to completely stop bacterial growth. However, at very low temperatures, all biochemical, chemical, physical and microbiological processes are slowed down so decaying can occur but at a much slower rate (Gram and Dalgaard, 2002). The functions of ice as pointed by Ghaly *et al*. (2010) include: (a) maintaining uniform low temperature, (b) reducing autolysis and bacterial degradation and (c) providing a gentle washing/cleaning effect during melting. To increase the storage life of the product, it is important to lower the temperature very quickly so as to preserve its quality. Good quality sardines are achieved if they are frozen as soon as possible after catching (Balachandran, 2001).

2.5.2 Sun drying

Sardine drying along Lake Victoria is still a primitive process which has been practiced for centuries. The drying process is considered to be a physical process where tonnes of sardines are spread over the lake shore on the sand and dried in the sun (FAO, 2004). The heat of the sun and movement of air remove moisture which causes the fish to dry (Brigitte *et al.,* 2004). In order to prevent spoilage, the moisture content needs to be reduced to 15 per cent or less (Kabahenda *et al.,* 2009). Reducing water content facilitates the retardation of enzymatic, microbial activities and many chemical processes which are responsible for fish spoilage (Chukwu, 2009; Abbas *et al*., 2009).

Sun-drying at the beach, on grass or bare rocks does not allow very much control over drying conditions, and it also exposes the fish to insects or vermin attack and allows contamination by sand and dirt (Kabahenda *et al*., 2009). Sun-dried sardines accounting for about 70% of the total annual harvest are rejected in the market due to poor quality (Bille and Shemkai, 2006; LVFO, 2008; Akande and Diei-Ouadi, 2010). Rejected sardines are however diverted to animal feed production or used as baits for catching bigger fish, such as the Nile perch (Berkel *et al*., 2004).

Simple solar driers can eliminate much of the spoilage that occurs with traditional drying methods but are relatively expensive. These driers usually have a wood or bamboo-frame table, covered with plastic or glass to produce an enclosed chamber. Since there is opening at the top and bottom of the drier, air will be heated and flow around the fish (Green and Schwarz, 2001). Fish exposed to this flow of heated air will rapidly lose moisture, reducing drying time by much as half over open air drying (Sablani *et al.,* 2003). Ssebisubi (2011) reported that, drying of fish on raised platforms with non-rust netting surfaces take about 12 to 24 hours, resulting into quality product.

2.5.3 Salting

Salting of fish is done to reduce the moisture content and inhibits growth of spoilage microorganisms (Andres *et al*., 2005). Fish salting involves three methods: dry, wet salting and brining. The first two methods result in fish with a relatively high salt content, the third method is usually used if one wants fish with a relatively low salt content (Brigitte *et al.,* 2004; FAO/WHO, 2009). For the best results, good quality fish should be used. Spoiled and poor quality fish could not be improved by salting and is certainly not storable for long (Eyoo, 1993; Diei-Ouadi and Mgawe, 2011).

High salt concentration may give fish strong salty taste and contribute to loss of nutrients. Combination of salting and smoking or drying is an effective method to preserve fish (Brigitte *et al.*, 2004; Abbas *et al*., 2009). However, salted sun-dried fish is prone to fat oxidation due to exposure to light and oxygen (Egbal *et al.*, 2010). Most bacteria and fungi including pathogens cannot survive in a highly salty environment. Particularly, pathogens cannot survive at 6-10% salt concentration (FAO, 2010). Microbial cells in such condition will become dehydrated through osmosis and die or become temporarily inactivated (Chaougy *et al.*, 2008).

However, the halophiles i.e. salt loving, would spoil salted product even at a concentration of 6-10%, hence further removal of water by drying is needed to inhibit them (FAO, 2004). Chawla *et al*. (2006) reported a reduction in water activity of fresh fish from 0.95-0.80 with addition of 10% (w/w) sodium chloride as part of a hurdle technology. The major setback for the use of sodium chloride is its pro-oxidant activity which accelerates the development of lipid oxidation and thus the deterioration of value added products, but its use controls autolytic spoilage as it inactivates autolytic enzymes in fish species (Chawla *et al*., 2006; Chaougy *et al.*, 2008; Ghaly *et al.*, 2010). Egbal *et al*. (2010) noted a decrease in contents of protein, fat and ash in salted fish. Use of pure NaCl is recommended because crude NaCl (which contains impurities such as chlorides, sulfates, calcium, and heavy metals) accelerates lipid oxidation during fish processing and will adversely affect the overall quality of the finished product (Chaougy *et al.*, 2008; Egbal *et al*., 2010).

2.6 Acceptability of Salted Dried Fish Products by Consumers

Salt-dried fish products are highly appreciated because of storage stability, nutritional stability and their characteristic taste, texture and aroma (Lorentzen, 2010). However, diet

of salted dried fish has been associated with heart conditions and this has influenced consumer acceptability (Kose, 2010; Turk *et al*., 2010). The penetration of salt into fish muscles depends on fat content, temperature, type and concentration of salt (FDA, 2001). Some histamine-forming bacteria are reported to be halotolerant or halophilic but efficient dry salting processes are unlikely to allow such bacteria to grow due to low water activity value of 0.75 achieved under this condition (Kose, 2010). Such conditions are effective to prevent histamine formation and pathogenic bacteria at both room and cold temperatures.

Salted products present low pathogen risk especially when salt-dried to water activity below 0.8 (Kose, 2010). Consumer preferences for dried fish vary significantly. However, increased intake of salt- dried fish, can lead to a rise in blood pressure with age and the development of hypertension which are the major risk factors for cardiovascular disease (Appel *et al.,* 2001; Mitchell *et al.,* 2009).

A study by Abeer (2009) revealed that sensory evaluation of solar and salted fish products were highly acceptable by consumers compared with fresh and smoked products. To guarantee consumers' acceptability of salted fish, more convenient and innovative products should be manufactured (Unlusayin *et al*., 2010).

2.7 Summary of Literature Review

This literature review has shown that postharvest handling practices of Sardines remains a common problem in the developing countries including Tanzania. It further demonstrated that the traditional methods of handling sardine significantly contribute to poor quality products with short keeping time. Therefore, in order to retain the quality of fish, improved postharvest handling methods should be employed. For instance, the combination of salting, drying, icing, and smoking methods could result into good quality

products. Salting the fish prior to drying is recommended as the best pre-treatment method of fish before further processing. In addition, good hygienic practices along the fish handling chain are necessary to guarantee quality and safety of the products. Therefore, combination of salting and drying of sardines was applied in this study to enable manufacture of high quality sardines and prevent postharvest losses.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location

The study was conducted in Musoma District, which is among the six districts of Mara Region. Mara Region is in the northern part of Tanzania. It is located between latitude 1^{o} and 2^{o} 31' South of the Equator and between longitude 33^{o} 10' and 35^{o} 15' East of Greenwich. The region is bordered by the Republic of Kenya to the North, Kagera Region to the West, Mwanza and Shinyanga Regions to the South and Arusha to the East. It is also flanked by Lake Victoria on the Northern –West (MRCO, 1998).

3.2 Study Design

The study was divided into two parts, field survey and laboratory analysis.

3.2.1 Field survey

A cross-sectional design was used to obtain an overall picture of information about fishing practices, handling, processing, packaging, and transportation techniques.

3.2.2 Laboratory analyses

A factorial experimental design was employed for the treatment of samples. Three factors were investigated: processing method involving 2 levels (traditional and improved methods); salting comprising of 3 levels (0%, 6% and 10% w/w); and loading density having 2 levels (5 kg/m^2 and 10 kg/m^2). Three variables were assessed and used to compare the different treatments: proximate composition, microbiological contamination and sensory attributes.

3.3 Data Collection Methods

3.3.1 Raw material sampling methods

Fresh sardines were purchased from fishermen at Makoko fish landing site situated about 10 km from Musoma town, in Mara Region, in March, 2011. Processing of sardines was then conducted on the landing site immediately after delivery. Samples from commercial available sardines were collected from different markets in Morogoro and Dar es Salaam. The control sample was iced immediately after being taken off the nets at the fishing ground. A total of 361 kg of sardines were used in this experiment, including the control.

3.3.2 Improved drying method

In this study, improved fish drying rack was constructed from wooden poles and wire mesh. Four wooden poles were joined together to form a rectangular box, which was raised one meter above the ground level. Between these poles different supporting poles were used in order to prevent the surging effect. The drying rack was 1200 cm long, 200 cm wide, and 30 cm depth. Then a clean polythene sheet was tied on the sides of the rack. The rack was partitioned into squares with ropes; sardines were spread according to salting concentrations (0, 6 and 10%) and loading densities (5 and 10 kg/m^2). Two independent experiments were performed in which two parameters; salt concentration and loading density were varied under traditional and improved methods. Samples were drawn at the intervals of four hours for total duration of thirty six hours and in each interval 500 g of sardines were taken. Sardines were over-turned every two hours to ensure uniform drying process. Samples were packed in sealed polyethylene packets and taken to the Government Chemist Laboratory Agency, Mwanza branch and laboratories of Department of Food Science and Technology, Sokoine University of Agriculture for analysis of proximate composition and sensory attributes, respectively.

3.3.3 Traditional dying method

Fresh sardines purchased from fishermen were salted in three different salt concentrations (0, 6, and 10%). The bare ground area reserved for drying was also portioned into squares where sardines spread according to different loading densities of 5 and 10 kg/m^2. Samples of 500 g were drawn from the squares in intervals of four hours for total drying time of thirty six hours. Then samples were packed in polyethylene bags and taken to the Government Chemist Laboratory Agency, Mwanza branch for proximate composition and microbial analysis. Also samples were taken to the Department of Food Science and Technology Laboratory, Sokoine University of Agriculture for sensory evaluation. The control (fresh) samples were immediately packed in polyethylene packets and sealed properly then kept chilled at 4^oC and transferred for analysis at Government Chemist Laboratory Agency, Mwanza.

Previous studies by Andres *et al*. (2005), Brigitte *et al.* (2004) and FAO/WHO (2009) demonstrated that concentrations of salt up to 20% are sufficient to kill most species of unwanted bacteria and moulds. However, such high salt concentration can compromise consumers' acceptability. Therefore, for this study, 5-10% salt concentrations were selected. Loading densities were arbitrary chosen so as to establish the relationship between the compactness of fish per unit area, the drying time and its influence against the quality of dried products.

3.3.3 Sample size determination and questionnaires administration

The study population composed of 1077 fishermen, 658 fish processors and 13 fishery officers (MRCO, 2005). A representative sample for the study area was obtained basing on Boyd's formula n/N x100 = C, where C represents a figure greater or equal to five percent of the fishermen, sardine processors and fishery officers, N is the total number of

(fishermen, processors and fishery officers) and n is the sample size (Boyd *et al.*, 1981.Quantitative methods were used for primary data collection by observation, face-to-face interviews. Three sets of questionnaires were administered to each category of stakeholders including fifty four fishermen, thirty three sardine processors and five fishery officers. Purposeful sampling was done for the divisions with high and intensive sardines harvesting. Three divisions were selected and simple random sampling was used to select wards where fishermen and processors of sardines were interviewed. Example of sample size calculation for fishermen was obtained as follows: n= 5 x N/100, But Number of fishermen (N) = 1077, Therefore sample size (n) = 5 x1077/100 =54.

3.3.4 Proximate analysis

The proximate composition (moisture, protein, fat and ash) of the raw and processed sardines samples used in the present experiments was determined using standard methods (AOAC, 1995). All samples were analyzed in duplicates and concentrations were reported on dry weight basis, except for moisture content.

3.3.4.1 Percentage moisture determination

Moisture analysis was performed by the automatic moisture balance analyzer device (Moisture Balance Analyzer ADAM, AMB 310 United Kingdom) where 5 g samples were used for moisture determination by drying at 105^{o}C for two hours to constant weight, where the equipment displayed the reading in percentage of weight lost, which is equal to the amount of water evaporated. The remaining weight of each sample was recorded by tarring the percentage displayed which presented the weight of dry sample that remained. This weight was also used to confirm the readings on the device if was accurate, using the formula:

$$\% \text{ Moisture content} = \frac{\text{Loss in weight after drying (g)}}{\text{Initial weight of sample (g)}} \text{ x } 100 \quad \text{.....(i)}$$

3.3.4.2 Percentage ash determination

Ash was determined according to AOAC (1995) method 923.03. One gram of dried and milled sample was placed into a pre-heated and pre-weighed crucible and incinerated in a muffle furnace at 550^{o}C for 4 hours until grey ash was obtained**.** Total ash was calculated as difference between weight of sample before and after incineration.

$$\% \text{ Ash} = \frac{(F - E) \text{ x } 100}{D} \quad \text{..... (ii)}$$

Where;

D = weight of dry sample taken before incineration (g)

E = weight of empty pre-heated and pre-weighed crucible (g)

F= weight of pre-heated and pre-weighed crucible with sample after incineration (g)

3.3.4.3 Percentage crude protein determination

Crude protein was determined by using Kjeldahl method (AOAC, 1995), Official method 920.87. Dried samples (0.25 g) were weighed into digestion tubes. About10 g of Kjeldahl catalyst tablet (mixture of 9 g potassium sulphate and 0.5 g copper sulphate) was added into each tube with samples. Five ml of (98%) concentrated sulphuric acid was added to each tube containing samples and digested using Tecator digestion system 12 (model 1009 digester) for 3 hours to obtain a clear greenish solution digest. The digest was cooled and one tube after another was assembled into a distillation unit (HACH) for distillation followed by titration. A blank test was included in each sample run. Hence,

the calculation for the total Nitrogen and crude protein in sardine samples were worked out as follows:

$$\%N = \frac{0.014077x(\text{titre in ml} - \text{blank in ml})}{\text{weight of sample (g)}} \text{ X Nomality of HCl x 100} \quad \text{..... (iii)}$$

Where;

% Protein = % N x Factor (6.25) ..... (iv)

3.3.4.4 Percentage crude fat determination

Total fat was extracted by Soxhlet ether extraction method (AOAC, 1995) using procedure outlined in official method 920.85. Three grams of the dry milled sardine sample were used for crude fat determination. The sample was placed into extraction thimble, plugged with cotton wool and assembled to the Soxhlet apparatus. Petroleum ether (100 ml) was used for continuous reflux for 8 hours. Petroleum ether was then evaporated near to dryness. Pre-weighed flasks containing fat were dried in the oven at 80^{o}C for 3 hours, cooled in a desiccator and weighed. Then % crude fat calculated as follows:-

$$\%\ \text{Crude fat} = \frac{[W\ (g) - F\ (g)]x\ 100}{S\ (g)} \quad \text{..... (v)}$$

Where;

W = weight of pre-heated and pre-weighed flask with crude oil after drying in the oven (g)

F = weight of empty pre-heated and pre-weighed flask (g)

S = weight of dry sample taken for analysis (g)

3.3.4.5 Percentage carbohydrate content

The carbohydrate content in this study was determined as percentage difference (AOAC 1995) using the following formula;

%Carbohydrate =100% - (% protein + % fat + % ash)..... (vi)

3.3.5 Determination of microbiological quality of sardines

Microbial contamination was determined by the methods described by FAO (1992). One parameter, the total plate count was analyzed. The plate count agar (Tryptone Glucose Yeast Agar CM0325) manufactured by OXOID Ltd, UK was used as the growth medium.

3.3.5.1 Sample preparation for microbiological analysis

The total microbial load was determined using nutrient agar prepared according to the guidelines of the manufacturer. Serial dilution was done using physiological salt solution containing NaCl and $NaHPO_4$ (1.45 g, 10 g, and 6.25 per 2.5 litres) as diluents. The aim was to maintain the microorganisms in their physiological state to prevent plasmolysis resulting from osmosis.

A volume of 450 ml of Butterfield's phosphate buffer was added into a blender jar containing 50 g of analytical sample and blended for two minutes at 11 000 rpm. Samples of sardines (10g) were aseptically homogenized with a stomacher (Bug Mixer, Interscience, London, United Kingdom) for 3 min (11 000 rpm) in peptone water (90 ml). This resulted into a suspension of 10^{-1} dilution. A serial dilution (up to 10^{-6}) of original homogenate was made promptly by transferring 1 ml of previous dilution into 9 ml of sterile diluents, and all the dilutions shaken 25 times for 7 seconds.

3.3.5.2 Total plate count (viable count)

Samples of sardines (10g) were aseptically homogenized with a stomacher (Bug Mixer, Interscience, London, United Kingdom) for 3 min in peptone water (90 ml). The homogenate was serially diluted from 10^{o} to 10^{-6} and used for enumeration of microorganisms. Samples of 0.1 ml of the following tenfold serial dilution were spread in duplicates on the surface of dried media in Petri dishes. Total bacterial counts were determined by spread-plating on to Plate Count Agar (PCA) and incubated at $35\pm2\ ^{o}C$ for 48 h. The Total viable counts (TVC) were counted as colonies formed by microorganisms. After incubation, the number of colonies on a dilution plate showing between 30 and 300 colonies were determined and the number of microorganisms was computed by using ISO 4833:2003 (ISO, 2003) formula.

$$N = \frac{\sum C}{V(n1 + 0.1n2)d} \quad \text{.....(vii)}$$

Where,

N = Number of colonies per ml or g of product

ΣC = the sum of all colonies counted on the plates containing 30-300 colonies;

n_1 = number of plates counted in the lower dilution;

n_2 = number of plates counted in the higher dilution;

d = value corresponding to the dilution from which the first counts were obtained

V = volume of inoculums used.

3.3.6 Sensory evaluation

The samples obtained from traditional and improved methods and commercial available sardines from Lake Tanganyika, Lake Victoria, Lake Nyasa and Indian Ocean were evaluated for colour, taste, smell, texture and overall acceptability on a 5-point hedonic scale. Grading of this scale described as 5 like very much, 4 like slightly, 3 neither like nor dislike, 2 dislike slightly and 1 dislike very much Martinsdottir *et al*., 2001). Thirty semi- trained students and staff from Sokoine University of Agriculture, Morogoro, Tanzania, constituted a sensory evaluation panel. Necessary precautions were taken to prevent carry-over flavour during tasting by ensuring that the panellists washed their mouths after each stage of sensory evaluation by potable water.

3.4 Statistical Analysis

3.4.1 Data from administered questionnaires

Data gathered from key informants were analyzed by using Software of Statistical Programme of Statistical Package for Social Sciences (SPSS 16.0). Descriptive statistics namely frequencies, percentages, cross tabulation and means were employed to determine the relationship between variables of information gathered.

3.4.2 Proximate composition, microbial quality and sensory attributes

Data for proximate composition, microbiological quality and sensory attributes were analyzed by Statistical Analysis System (SAS) software 2004 according to 2x3x2 factorial design where the terms of fix effects and interactions of method*concentrations, method*loading density and method* time for proximate composition were examined at one instance from each test group. One way analysis of variance was computed to determine the significant differences between the factors. Mean separation was done by Duncan's multiple range test at $P<0.05$ significant level.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Demographic Characteristics of the Respondents

Table 2 presents a summary of demographic characteristics of the respondents in the study area. The survey indicated that out of 87 respondents, 56 (64%) were male and 31 (36%) were female. Eighty one percent of male are involved in fishing, and 64% of females are processors (Table 2). This concludes that fishing is mainly done by men and majority of women are involved in processing. Similarly, it was reported that majority of women were engaged in fish smoking and other fishing related activities such as assembling of fish nets, cleanliness, and birds/predator scaring but actual fishing was conducted by men (Madanda, 2003; Omwega *et al.* 2006; Akande and Diei-Ouadi, 2010). Nature of work is the determining factor for division of work (Jansen *et al.*, 1999). The age of respondents ranged from 18 to 60 years; however, many respondents were aged from 31-50 years (54%) and 18-30 years (38%). In addition, 73.6% of respondents were married, while 2.3 % were separated or widowed (Table 2).

Majority of respondents aged from 31-50 years (62.9%) were fishermen, whereas those aged from 18-30 years were processors (51.5%). According to Jansen *et al.* (1999), fishing for sardines is a tedious work; therefore, one engaged in fishing has to be physically fit. While average age for people to engage in fishing activities is 34 years, even younger people (18-30 years) are active in fishing (Omwega *et al*., 2006); and fishers may be active up to 46 years (Olale *et al.*, 2010).

Table 2: Respondents' characteristics of fishermen (N=54) and processors (N=33) fish processors (N=33

Category	Subcategory	Fishermen (n=54)		Processors (n=33)		Total	
		n	Percent	n	Percent	n	Percent
Sex	Male	44	81	12	36	56	64
	Female	10	19	21	64	31	36
Age	18-30	16	29.6	17	51.5	33	38
	31-50	34	62.9	13	39.4	47	54
	51-60	3	5.5	3	9.1	6	6.8
	Above 60	1	2	0	0	1	1.2
Marital status	Single	11	20.3	4	12.2	15	17.2
	Married	41	75.9	23	69.8	64	73.6
	Separated	1	1.9	1	3	2	2.3
	Living with partner	1	1.9	3	9	4	4.6
	Widowed	0	0	2	6	2	2.3
Education level	No formal education	6	11.1	1	3	7	8
	Primary school education	42	77.8	28	84.8	70	80.5
	Secondary school education	6	11.1	4	12.2	10	11.5

n = frequency of respondents

Also it shows that, majority of fishermen and processors have primary education (80.5%), with few having secondary (11.5%) and informal (8%) education (Table 2). Previous studies have also found that fishers possessed low levels of formal education, with the majority having attained only a basic education (Omwega *et al.,* 2006; LVFO, 2008; Olale *et al.,* 2010). Educated personnel could use appropriate fish handling practices in value chain processes (Davies, 2009; Akande and Diei-Ouadi, 2010) reducing post harvest losses and improving quality.

4.2 Sardine Fishing Practice

4.2.1 Types and ownership of fishing gears and their cleaning programme

Table 3 shows that the main fishing gears used were seine nets (100%), boats (88.9%) powered by gasoline engine, pressure lamp (88.9%), racks for holding lamp (37%) and canoes with wooden paddles (11.1%). These fishing gears were owned either by purchasing (27.8%) from village craftsmen or hired (72.2%) from other fishers. The cost of buying complete set of fishing gears ranged from Tshs. 3.9-5 million and hiring varied from Tshs. 20 000-250 000 a month. Since, fishing activity is commonly done by artisanal fishermen, characterised by lack of financial capital to purchase fishing gears, majority depends on hiring. Some fishermen may construct their own boats and assemble their gears or purchase them from village artisans. The small boats are powered with outboard gasoline motors, although sail and paddle power are common in some areas (OIA, 2003).

Table 3: Types and ownership of fishing gears and cleaning programme (N=54)

Category	Sub-Category	Frequency	Percent
Fishing equipment /gears	Boat	48	88.9
	Engine	39	72.2
	Seine net	54	100
	Pressure lamp	48	88.9
	Rack for lamp	20	37
	Canoe	6	11.1
Ownership	Bought	15	27.8
	Hired	39	72.2
Cleaning programme	Daily	43	79.6
	Weekly	6	11.1
	Every fortnight	2	3.7
	Monthly	3	5.6

These boats should be designed and constructed with smooth surfaces with minimal projections, cracks–free and blunt inner corners to prevent harbouring microorganisms and dirt (Berkel *et al*., 2004; Masetta and Kasiga, 2007). Also fishing boat construction should facilitate ample drainage. About eighty percentages of respondents clean their fishing gears on daily basis; 11.1% weekly, 3.7% fortnightly and 5.6% monthly basis. Fishing gears should be designed and handled in such a way that could facilitate cleaning and drying to minimize contamination. After each haul, fishing gears should be properly cleaned to reduce multiplication of spoilage bacteria and pathogens (Nguyen *et al*., 2007).

This study found that cleansing agents commonly used are brushes, and plain water; detergents are occasionally used, indicating that microorganisms and organic debris may not be completely removed. Similarly, Ponte (2005) reported that at fishing-grounds, cleaning of fishing boats and other fishing gears is not a daily practice and when done contaminated water from the lake is used. Good hygienic practices are very important during harvesting of fish, storage and transport for further processing to control microbial contamination and spoilage (Okonkwo *et al.*, 1993; Nguyen *et al*., 2007). Inadequate cleaning and sanitation of equipment (containers, knives, contact surfaces etc.) is a potential source of bacterial contamination in fish processing (Reij and Aantrekker, 2004; FAO/WHO, 2009).

4.2.2 Storage Practice of Sardines

Fish are normally chilled, cooled in water and/or left in ambient conditions before processing. The fishing duration per night varied between four (5.6%) to twelve (7.4%) hours, with majority taking 8(38.9%) and 10(33.3%) hours (Table 4). If properly handled fish will start to deteriorate 12 hours after harvest (Kabahenda *et al*., 2009; Kuje *et al*., 2011). The results indicate that majority of fishermen (92.6%) take less than twelve

hours in fishing, then if good hygienic conditions are observed fish will maintain its freshness until off-loaded. However, prevailing handling practices may accelerate fish spoilage. Similarly, Gibbon (1997) reported that fishing takes less than one day and very often only a few hours. Using good fishing techniques to ensure the fish is barely damaged and cooling on board can increase the storage life of fresh fish. Also, Table 4 shows that 63.0% of fishermen stored their harvest immediately after fishing, 14.8% after three hours, 5.6% after six hours, 13% after nine hours, and 3.7% after twelve hours.

Table 4: Fishing duration and storage practices (N=54)

Category	Sub-Category	Frequency	Percent
Duration of fishing	Four hours	3	5.6
	Six hours	8	14.8
	Eight hours	21	38.9
	Ten hours	18	33.3
	Twelve hours	4	7.4
Storage time after harvest	Immediately after harvest	34	63
	Three hours after harvest	8	14.8
	Six hours after harvest	3	5.6
	Nine hours after harvest	7	13
	Twelve hours after harvest	2	3.7
Storage place	Plastic basins	3	5.6
	Covered/heaped on the ground	32	59.3
	On board	19	35.2
Storage problems	Rotting	31	83.8
	Insect	10	27
	Moist conditions	12	32.4
	Off flavour	23	62.2

Storing fish six or more hours after harvest if not properly cooled and handled in sanitary environment it will deteriorate and become unfit for human consumption (OIA, 2003; Bataringaya, 2007). Shorter time lapse prior to refrigeration reduces physical and quality losses. All respondents affirmed that sardines were stored at ambient temperatures;

this storage practice may facilitate spoilage. Multiple hauls of fishing gears, catch exposure to high temperatures, lack of storage facilities on board canoes, and long distances from fishing grounds are the causes of physical and quality losses (Akande and Diei-Ouadi, 2010).

Furthermore respondents declared that sardines are commonly heaped on the ground and covered with polyethylene sheet (59.3%), left on board (35.2%) until off-loaded ready for drying process, or put in the plastic basins (5.6%). However majority of respondents are aware that heaping of sardines on the ground at ambient temperature accelerates the rate of deterioration. Besides, soil is the source of both spoilage and pathogenic microorganisms which may subsequently contaminate the product (Olsen and Hammack, 2000). The keeping quality of fresh fish can be improved via good handling practices including chilling (Brigitte *et al.*, 2004).

This study identified the major storage problems of sardines as rotting (83.8%), development of off-flavour (62.2%), deterioration induced by moist conditions during drying (32.4%) and insect infestation (27%) (Table 4). The quality of the final product depends on various factors involving poor quality fish as a result of inadequate fishing and handling practices, unhygienic processing conditions, infestation and insect damage, and microbiological and biochemical reactions leading to spoilage (Al-Jufaili and Opara, 2006; Esser *et al.*, 2007). Although catch rates are high during the rainy season, fishing effort is reduced when processors cannot dry the fish (FAO, 2010).

4.3 Harvest and Spoilage Rate of Sardines before Processing

This study revealed that majority of fishermen had a daily capacity to harvest 501-1000 kg (38.9%) and 1001-1500 kg (35.2%) of sardines (Table 5). About 67% of fishermen

reported less than 100 kg daily spoilage of sardines, 25.9% experience 101-200 kg and 5.6% observed 201-300 kg spoilage. Furthermore the spoiled sardines were either discarded (18.5%), mixed with fresh sardines (11.1%) and/ or sold as animal feed (70.4%).

Table 5: Sardines spoilage and handling of spoiled sardines (N=54)

Category	Sub-Category	Frequency	Percent
Estimated weight harvested per day (kg)	Below 500	9	16.7
	501-1000	21	38.9
	1001-1500	19	35.2
	1501-2000	2	3.7
	Above 2000	3	5.6
Estimated weight spoiled per day before processing (kg)	Below 100	36	66.7
	101-200	14	25.9
	201-300	3	5.6
	Above 300	1	1.9
Handling of spoiled sardines	Discard spoiled sardines	10	18.5
	Mixed with fresh sardines	6	11.1
	Sold as animal feeds	38	70.4
Transportation	By boats	44	81.5
	By canoes	10	18.5

Poor fishing and handling practices along the fish supply chain are the main causes of spoilage (Okonkwo *et al.*, 1993; Gram and Dalgaard, 2002; Brigitte *et al.*, 2004). Mixing spoiled and fresh sardines is a malpractice and it can accelerate fish spoilage, therefore, it should be avoided.

Spoiled sardines contribute to about 70% of raw materials for animal feed processing companies as the product rejected from the market (Bille and Shemkai, 2006; LVFO, 2008; FAO, 2011). To combat this spoilage problem during transportation, chilling or salting on board should be emphasised.

About 81.5% of sardines were ferried by boats and only 18.5% were transported by canoes from fishing grounds to the landing sites (Table 5). Besides, vehicles used by fishermen to transport fish from landing sites to processing areas were not provided with cooling facilities. Transporting sardines in ambient conditions may favour spoilage (Diei-Ouadi and Mgawe, 2011; Ssebisubi, 2011). Although the total catch of sardines was 57 872 kg per day, about 4273 kg (7.4%) get spoiled before processing (Table 6). The total daily processing capacity of fish processors was 36 452 kg. The average quantity of sardine spoiled during processing was 1306 kg, equivalent to 3.6%. In general, total sardines spoilage amounted to 11%, where (7.4%) occurred during fishing practices and (3.6%) in processing parse (Table 6).

Table 6: Harvest and estimated post harvest loss of sardines

Category	Production weight (kg)	Spoiled weight (kg)	Percent spoilage
Loss during Fishing	57872	4273	7.4
Loss during Processing	36452	1306	3.6

The major contributing factors to such spoilage include improper cleaning of fishing gears (i.e. no detergents/disinfectants) and lack of cooling facilities. According to Brigitte *et al*. (2004), Masetta and Kasiga (2007) to limit the rate of deteriorations, fish should be transported to the shore as quick as possible and must be kept in a clean boat and in the shade and if possible should be iced.

4.4 Sardines Processing Practices

Table 7 shows that all processors source sardines from fishermen, 15.2% from own catches and 21.2% from middlemen. All sardines obtained were exclusively processed by

traditional sun drying method. The daily capacities of processors are less than 1000 kg (51.5%), 1001 - 2000 kg (36.4%), and 2001 - 3000 kg (9.1%) and above 3000 kg (3%).

Table 7: Processing practices of sardines (N=33)

Category	Sub-category	Frequency	Percent
Source of sardines	Fishermen	33	100
	Own harvest	5	15.2
	Middleman	7	21.2
Processing method	Sun-drying only	33	100
Amount of sardine processed per day (kg)	Less than 1000	17	51.5
	1001 - 2000	12	36.4
	2001 - 3000	3	9.1
	More than 3000	1	3
Sardines spoiled during processing (kg)	Less than 10	14	42.4
	20-Nov	5	15.2
	21 - 30	3	9.1
	More than 30	11	33.3
Causes of spoilage	Insects	5	15.2
	Birds	7	21.2
	Moulds	2	6.1
	Bacteria	19	57.6
Processing time	One day(6-8) hours	30	90.9
	Two days	1	3
	Three days	2	6.1
Ensuring dryness	Touching if no surface moisture	33	100
	Colour change (silvery to brown)	10	30.3
Packaging	Polyethylene bags	28	96.6
	Hard paper boxes	3	10.3
	Wood woven baskets	2	6.9
	Plastic containers	6	20.7
Market	Production site	17	51.5
	Local market	8	24.2
	Hawking	1	3
	Town market	7	21.2

Also it shows that the major agents of spoilage were bacteria (57.6%), birds (21.2%), insects (15.2%) and mould (6.1%). However, cured fish are generally stored only at

ambient temperature in cool, dry and well-ventilated premises. Similarly, FAO (2004) reported that tonnes of sardines are spread over the lake shore on the sand and dried in the sun. Similarly, extension officers reported sun drying by spreading sardines on the ground as the major processing method in the study area. They also admitted that during rainy season post harvest losses was very high due to insufficient drying of sardines. The amount of spoilage is attributed to large extent by improper handling of sardines where by insect infestation, pests, moulds and microorganisms are favoured (Brigitte *et al*., 2004).

To arrest spoilage problem, intervention on simple improved drying rack and salt application are the best option to fishers and processors in the study area. Salting ensures, among other things that during drying the micro-organisms at the surface are inhibited and insects and other vermin are kept away (Kabahenda *et al.,* 2009). It also shows that processing of sardines mainly takes 6 – 8 hours (90.9%) (Table 7). Degree of dryness of sardines was checked by touching (100%) and observing colour changes (30.3%) from silvery to brownish colour.

In order to ensure the product is properly dried, weighing the fish before and after the drying process is necessary. The fish is regarded as sufficiently dry when the weight of the fish remains constant (Diei-Ouadi and Mgawe, 2011)**.** Depending on fish species, naturally dried fish needs about 3-10 days to dry if conditions are good and there is no disruption from rain (Brigitte *et al.,* 2004). For this case, processed sardines with relatively higher moisture content may be distributed to the market resulting into poor product keeping quality and acceptability to consumers. According to Junaid *et al.* (2010) fish should be dried to the moisture content of 15% in order to preserve its keeping quality.

For packaging, sardines are mainly packaged in polyethylene bags (96.6%), plastic containers (20.7%), hard paper boxes (10.3%) and bamboo baskets (6.9%) (Table 7). All these packaging containers were reused without further treatments programmes (like cleaning and sanitisation) to ensure that they are free from contamination. Packaging of sardines into containers was done unhygienically as people compress the product by using their dirty bare feet which may contaminate the product. High density polyethylene material is not recommended for packaging and storage of sardines in tropical conditions because it permits moisture uptake and may accelerate product deterioration (LVFO, 2008; Obodai *et al.*, 2011; Siah, and Tahir, 2011). Therefore, airtight packaging should be encouraged. To prevent the possibility of contamination, deterioration and the growth of pathogenic and spoilage micro-organisms packaging of fish products should be done in hygienic condition and without delaying (FAO/WHO, 2009). In addition, packaging material must be strong to protect the product from damage, blackening and rancidity (Ssebisubi, 2011). The dried fish should then be stored in a cool and dry environment.

In terms of marketing, 51.5% of sardines were sold at production site, 24.2% in the local market nearby the processing area, 21.2% town market and 3% sold to hawkers. Majority of processors are unable to sell their products due to distant markets, poor infrastructure and lack of reliable transportation facilities. A study by LVFO (2008) found that processing and fishing sites are located in areas with poor infrastructure and inaccessible to market by customers. Similarly, Kadigi *et al.* (2007) reported that majority of fishers and boat-owners sell their landed catch at their home beach characterised by few customers.

4.5 Laboratory Analytical Results

4.5.1 Effects of salt on nutrient composition of sardines

Salt concentration has various effects on nutrient composition of treated sardines. The moisture content at 0%, 6% and 10% salt strength were 30.10, 28.70 and 30.90, respectively (Table 8). However, the moisture content in unsalted fresh sardines was 74.5%. There was no significant difference in moisture content at 0% and 10% salt concentration ($P>0.05$), while lowest value was at 6%. Normally, it is expected that as the salt concentration increases in curing fish, much of moisture content in fish will be drawn out hence lesser moisture content of the final product. On contrary, higher moisture content was obtained at high (10%) salt concentration. Possibly this could be due to formation of salt crust at higher concentration and slower the rate of moisture removal by evaporation since the osmotic pressure exerted by solute outside the surfaces of fish is impaired (Nketsia-Tabiri and Sefa-Dedeh, 2000; Bellagha *et al.,* 2007). Various studies reported that dry salting produces considerable loss of constituent water due to heavy uptake of salt in the fish muscles (Nketsia-Tabiri and Sefa-Dedeh, 2000; Unlusayin *et al*., 2010). Water usually accounts for about 65-80% of the weight of a fresh fish (Berkel *et al*., 2004; FAO, 2004).

Table 8: Effects of salt on nutrient composition of sardines (n=2)

Concentration of salt (% w/w)	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)
Fresh sardines	74.5	64.9	17.1	14.2	3.8
0	30.10^{ab}	61.45^{a}	16.48^{a}	17.18^{c}	4.89^{a}
6	28.70^{b}	57.33^{b}	15.21^{b}	22.53^{b}	4.93^{a}
10	30.90^{a}	56.48^{c}	13.94^{c}	25.92^{a}	3.67^{b}

Means with different superscript within the same column are significant different at $P< 0.05$.

w/w = weight of salt expressed as g/kg of sardines.

The protein content in sardines at 0%, 6% and 10% salt levels were 61.45, 57.33 and 56.48, respectively (Table 8). The protein content (64.9%) of unsalted fresh sardines was relatively higher than salted probably due to less denaturation and hydrolysis of protein. The protein content differed significantly in all three levels of salt concentrations ($P<0.05$), indicating that it decreases with increasing salt concentrations. According to Unlusayin *et al.* (2010) and Egbal *et al.* (2010) protein in fish decreases with increased salt strength. This could be due to leaching of water soluble proteins like myogen and salt soluble fractions myosin (Munasinghe, 1999; Unlusayın *et al*., 2001) or denaturation at high salt concentration i.e. 8-10% (Andres *et al*. 2005). The high salt concentration causes protein loss by the osmotic effect of the salt in dried fish (Ooizumi *et al.,* 2003).

The fat content was 16.48%, 15.21%, 13.94% and 17.1% at 0%, 6%, 10% salt concentrations and fresh sardines, respectively (Table 8). The results of fat content differed significantly in all three levels of salt concentrations ($P<0.05$). Like protein, fat content decreased with increase in salt concentrations. The highest fat content was obtained at 0% and lowest at 10% salt concentration. Since drying is done in open air, hydrolysis and oxidation of fat may be favoured, hence account to the decrease in fat content. The fat content obtained in this study are within the ranges 10-25% reported by FAO (2004) in fat fish including sardines. At higher levels of salt concentrations fat exude with moisture in salting processes (Chukwu and Shaba, 2009). Fish oils are very susceptible to atmospheric oxidation and have little protection from such damage in salted-dried fish (Medina-vivanco *et al.*, 2006).

The ash contents were 17.18%, 22.53% and 25.92% at 0%, 6% and 10% salt concentrations, respectively (Table 8). Fresh sardines had 14.2% ash content. There was a significant difference in ash content among three levels of salt concentrations used in

drying sardines (P<0.05). The fact behind this is that, increasing mineral salt by salting technique directly increases ash content in fish including sardines. Also, Unlusayin *et al.* (2010), Nketsia-Tabiri and Sefa-Dedeh (2000) noted an increase in ash content from19.4 to 27.7% for fish treated by dry salting and brining at 8% and 20% (w/w) respectively. According to Ariyawans (2000) ash content in salt free fish should not exceed 14%. This is comparable to ash content of fresh sardines (Table 8).

The carbohydrate contents were 4.89, 4.93 and 3.67% at 0%, 6% and 10% salt concentrations, respectively. The carbohydrate content found in fresh sardine was 3.8%. There was no significant difference (P>0.05) for carbohydrate at salt concentrations of 0 and 6% but differed significantly at salt concentration of 10% (P<0.05). Also, previous studies on sun dried salted fin fish reported a decrease in carbohydrate content with increase in salt concentration (Patterson and Ranjitha, 2009; Egbal *et al*., 2010). From a nutritional point of view, however, it would be best to use as little salt as possible. The higher values of carbohydrates in both improved and traditional methods could be due to the subtraction method used to calculate the carbohydrate content.

4.5.2 Effect of drying methods, salt concentrations and loading density on nutrient composition of sardines

Table 9 shows a significant difference (P< 0.05) in the overall mean moisture content between sardines dried by traditional (31.09%) and improved (28.71%) methods. The moisture content was higher (74.5%) in fresh unsalted sardines than in traditional but the lowest was observed in improved drying technique. Theoretically, the rate of drawing out moisture from fish muscles is expected to be proportional to strength of applied salt during curing process. However, in both methods, the highest moisture content was achieved at 10% salt concentration and the lowest at 6% (Table 9).

Table 9: Drying methods and levels of salt and loading densities on nutrient composition (n=2)

Method	Treatment Salt concentration (%)	Parameters Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)
Fresh sardines	0	74.5	64.9	17.1	14.2	3.8
Improved	0	29.17^{e}	62.77^{a}	16.93^{a}	15.29^{f}	5.01^{a}
	6	27.58^{f}	57.39^{c}	15.9^{c}	21.67^{d}	5.04^{a}
	10	29.37^{d}	57.02^{e}	14.08^{e}	25.04^{b}	3.91^{d}
	Mean	28.71^{B}	59.05^{A}	15.64^{A}	20.66^{B}	4.65^{A}
Traditional	0	31.02^{b}	60.14^{b}	16.02^{b}	19.07^{e}	4.77^{c}
	6	29.81^{c}	57.27^{d}	14.52^{d}	23.39^{c}	4.82^{b}
	10	32.44^{a}	55.95^{f}	13.81^{f}	26.82^{a}	3.43^{e}
	Mean	31.09^{A}	57.79^{B}	14.78^{B}	23.09^{A}	4.34^{A}
	Loading density (kg/m^2)					
Improved	5	26.79^{d}	59.45^{a}	16.03^{a}	20.07^{d}	4.45^{b}
	10	30.63^{b}	58.65^{b}	15.24^{b}	21.25^{c}	4.86^{a}
	Means	28.71^{B}	59.05^{A}	15.64^{A}	20.66^{B}	4.65^{A}
Traditional	5	32.10^{a}	58.08^{c}	14.89^{c}	22.80^{b}	4.23^{c}
	10	30.08^{c}	57.49^{d}	14.68^{d}	23.39^{a}	4.45^{d}
	Means	31.09^{A}	57.79^{B}	14.78^{B}	23.09^{A}	4.34^{A}

Means within columns superscripted by the letters of the same lower case are not significantly different at $P>0.05$.

The reason behind this phenomenon is that crust formation can occur on the surfaces of sardines and blocks osmosis by making the surface less permeable hence lowers the evaporation of moisture (salt burn).

Sardines dried by traditional method at 10% salt concentration had the highest moisture content (32.44%) than sardines dried by improved method (27.58%) at 6% salt concentration. In this case improved method at 6% salt concentration observed to be the best drying combination for achieving desired moisture content in short time. With respect to loading densities, there was a significant difference ($P< 0.05$) in the overall

mean moisture content between sardines dried by traditional (31.09%) and improved (28.71%) methods (Table 9).

Similarly means superscripted by the same upper case letter are statistically similar at P>0.05. Therefore improve method at 5 kg/m^2 loading density was observed as the best processing combination in achieving desired moisture content in short time. The improved method had lower overall mean moisture content than traditional, showing that improved method is more effective. The highest mean score of 32.10% moisture content was observed in traditional method at loading density of 5 kg/m^2 and the lowest mean score was 26.79% in improved method at the same loading density. At 10kg/m^2 loading density, moderate moisture contents of 30.63% and 30.08% were obtained for improved and traditional methods, respectively.

The moisture content for both methods and salt concentrations differed significantly (P< 0.05). Traditional method indicated high moisture content than improved method. This shows that improved method is more effective in drying than traditional. Improved method had good air circulation and drip loss as compared to traditional. High rate of air circulation within the product facilitates the moisture pick-up and leaves the product dry (Kabahenda *et al*., 2009). In addition, Sablani *et al.* (2003) observed that sardines placed in the top layer of open rack drier, dried faster than the bottom layer due to relatively higher air circulation through the product. Overall, in both methods, 5 kg/m^2 loading density showed lower moisture content than 10 kg/m^2. Compared to 10 kg/m^2 loading density, 5 kg/m^2 loading has few sardines per unit area allowing good air circulation which results in high drying rate. Improved drying method allows uniform drying of the product.

The overall mean protein content of sardines dried by improved method (59.05%) differed significantly ($P<0.05$) to sardines dried by traditional (57.79%) method (Table 9). The highest protein content was obtained in improved (62.77%) and traditional (60.14%) method at 0% salt concentration and the lowest were respectively, 57.02% and 55.95% at 10% salt concentration (Table 9). The protein content for fresh sardines was 64.9%. In both methods protein contents decreased with increase in salt concentrations but relatively lower values were observed in traditional than improved methods. The phenomenon is probably due to denaturation and leaching of soluble proteins which was more pronounced in traditional method. Similar findings were reported by (Patterson and Ranjitha (2009) and Alcicek and Atar (2010) where salted dried fish showed a decrease in protein content as the strength of salt increased.

With respect to loading densities, there was a significant difference ($P< 0.05$) in the overall mean protein content between sardines dried by improved (59.05%) and traditional (57.79%) methods. Fresh sardines showed the highest protein content than dried sardines by improved and traditional methods. However, the highest protein content (59.45%) and (58.08%) were observed in dried sardines at 5 kg/m^2 loading density by improved and traditional methods respectively. The lowest protein content (57.49%) was observed at 10 kg/m^2 in traditional method. These findings are in agreement with those reported by Early *et al.* (2001) and Chukwu and Shaba (2009) who found that the crude protein content of solar salted dried sardines ranged from 39 to 65%. The protein content of fish, however, varies greatly from species to species and from individual to individual depending on age, sex, environment and season or because of external factors such as shortage of food (Huss, 1995; Sushchik *et al.,* 2007; Tzikas *et al.,* 2007; Boran and Karacam, 2011).

The mean protein content was higher for improved method as compared to that of traditional processing method, indicating high retention of protein by improved method. The lower protein content in traditional method is due to presence of proteolytic enzyme which degrades connective tissues in sardines dried by traditional than in the improved methods (Venugopal, 2002; Boran and Karacam, 2011). The presence of proteolytic enzymes in sardines dried by traditional method was probably due to high water activity for elaboration of these enzymes in fish muscles.

The overall mean fat content differed significantly ($P< 0.05$) between sardines dried by improved (15.64%) and traditional (14.78%) methods (Table 9). At 0% salt concentration the fat content was high in both methods (improved, 16.93%, traditional, 16.02%), while low fat content was obtained at 10% (improved, 14.08%, traditional, 13.81%). However, compared to improved method, traditional method indicated lower fat content. It shows that fat content decreases with increasing salt strength. This could be due to loss of fat with moisture extrusion, hydrolysis and oxidation which take place during processing of fish. The fat content of sardines dried by improved method at loading densities 5 and 10 kg/m^2 was 16.03 and 15.24%, respectively. While the fat content of sardines dried in traditional method at loading densities 5 and 10 kg/m^2 was 14.89 and 14.68%, respectively. This shows that the highest fat content was found in improved drying method at loading density of 5 kg/m^2 and the lowest in traditional method at loading density of 10 kg/m^2. It shows that fat content decreases with increasing loading densities. According to Kolakowska and Sikorski (2010), fat content in sun-dried sardines ranged from 7% to 16%. The low fat content observed in sundried sardines could be associated with fat oxidation (Akinneye, 2007). However, seasonal variation, physiological condition and fish species influence the fat content of fish muscles (Venugopal, 2002; Boran and Karacam, 2011).

The overall mean ash content differed significantly ($P< 0.05$) between sardines dried by improved (20.66%) and traditional (23.09%) methods (Table 8). Ash content in fresh sardines was 14.2%. At 0% salt concentration the ash content was low in both methods (improved, 15.29%, traditional, 19.07%), while high ash content was obtained at 10% (improved, 25.04%, traditional, 26.82%). Although, high ash content was noticed in traditional method, both methods showed an increase in ash content with increasing salt concentration. The high ash content in traditional method was probably due contamination with extraneous materials. With regards to loading density, the highest ash content (23.39%) was obtained in traditional at 10 kg/m^2 and the lowest in improved (20.07%) at 5 kg/m^2 drying methods. Drying by spreading fish on bare rocks and on shore lacks control over the product hence leads into contamination with sands and other foreign materials (Bouriga *et al.,* 2008; Kabahenda, 2009). Besides, addition of salt increases ash content in processed sardines (Chukwu, 2009).

There was no significant difference in mean carbohydrate content ($P> 0.05$) among sardines dried by improved and traditional methods. The overall mean carbohydrate contents obtained in improved and traditional methods were (4.65%) and 4.34%, respectively (Table 9). This study indicated high carbohydrate content than that reported in *Fringescale sardinella* 3.07 $\pm$ 0.63% (Nurnadia, 2011) and other fish species <0.5%, fwb (Anthony *et al*., 2000). However, in this study, carbohydrate was not actually analysed, but calculated by difference method; therefore, any degradation in fat, protein and moisture content has direct effect on the carbohydrate content obtained. The higher carbohydrate content was due to low moisture and ash contents in improved method as compared to traditional method.

Furthermore, improved method indicated best results in almost all parameters analysed where by lowest moisture at (6% salt concentration and 5 kg/m^2 loading density) and ash contents were achieved (Table 9). Similarly, highest values for protein, fat were obtained in improved method at 0% salt concentration and 5 kg/m^2 loading density (Table 9). The low nutritive value in traditional method was probably due to improper handling and unhygienic mode of drying the sardines. According to Chukwu (2009) different processing and drying methods (i.e. exposure to high salt concentration) have different effects on nutritional compositions of fish such as protein denaturation and reduction of thermolabile compounds and polyunsaturated fatty acids. Therefore, the qualities of fish dried using different methods cannot be the same. Plate 1 and 2 illustrate the drying methods carried out in the study area.

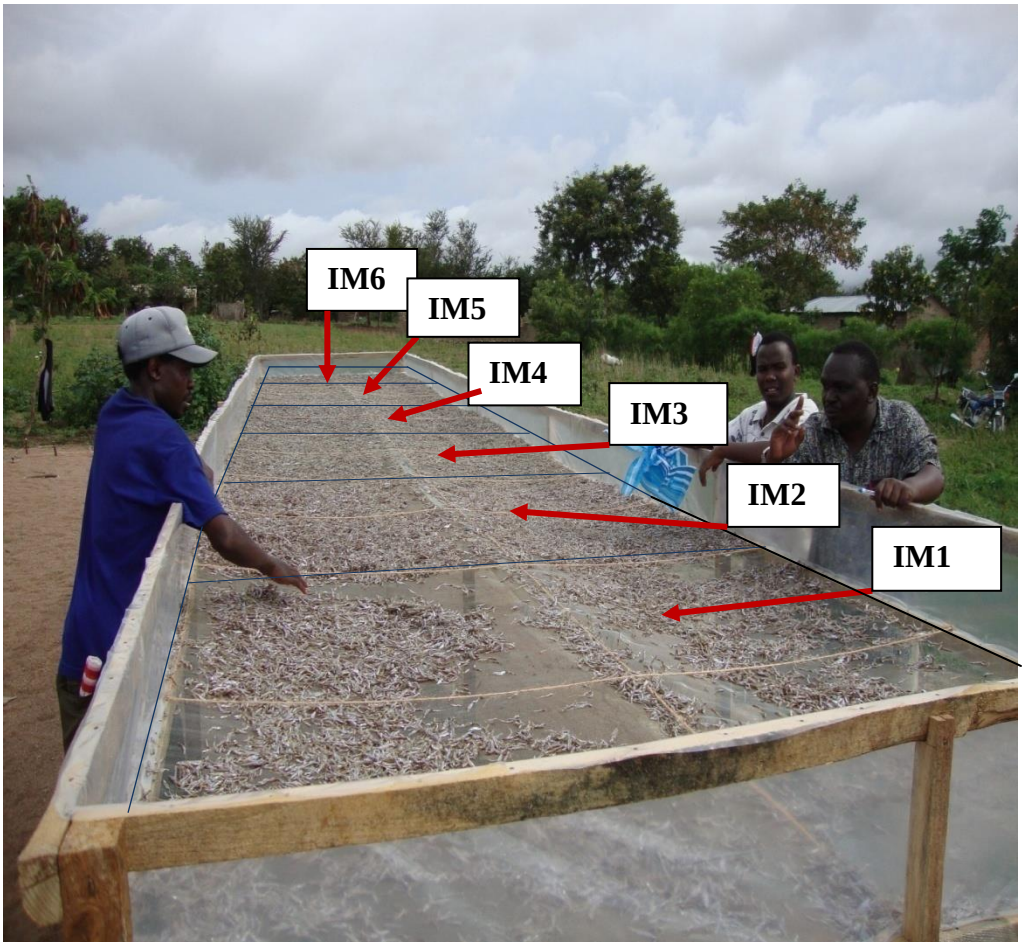

Plate 1: Sardines drying by improved rack method with different levels of salt concentrations and loading densities

IM = Improved Method

IM1 = Improved 0% salt concentration and 5 kg/m^2 loading density

IM2 = Improved 0% salt concentration and 10 kg/m^2 loading density

IM3 = Improved 6% salt concentration and 5 kg/m^2 loading density

IM4 = Improved 6% salt concentration and 10 kg/m^2 loading density

IM5 = Improved 10% salt concentration and 5 kg/m^2 loading density

IM6= Improved 10% salt concentration and 10 kg/m^2 loading density

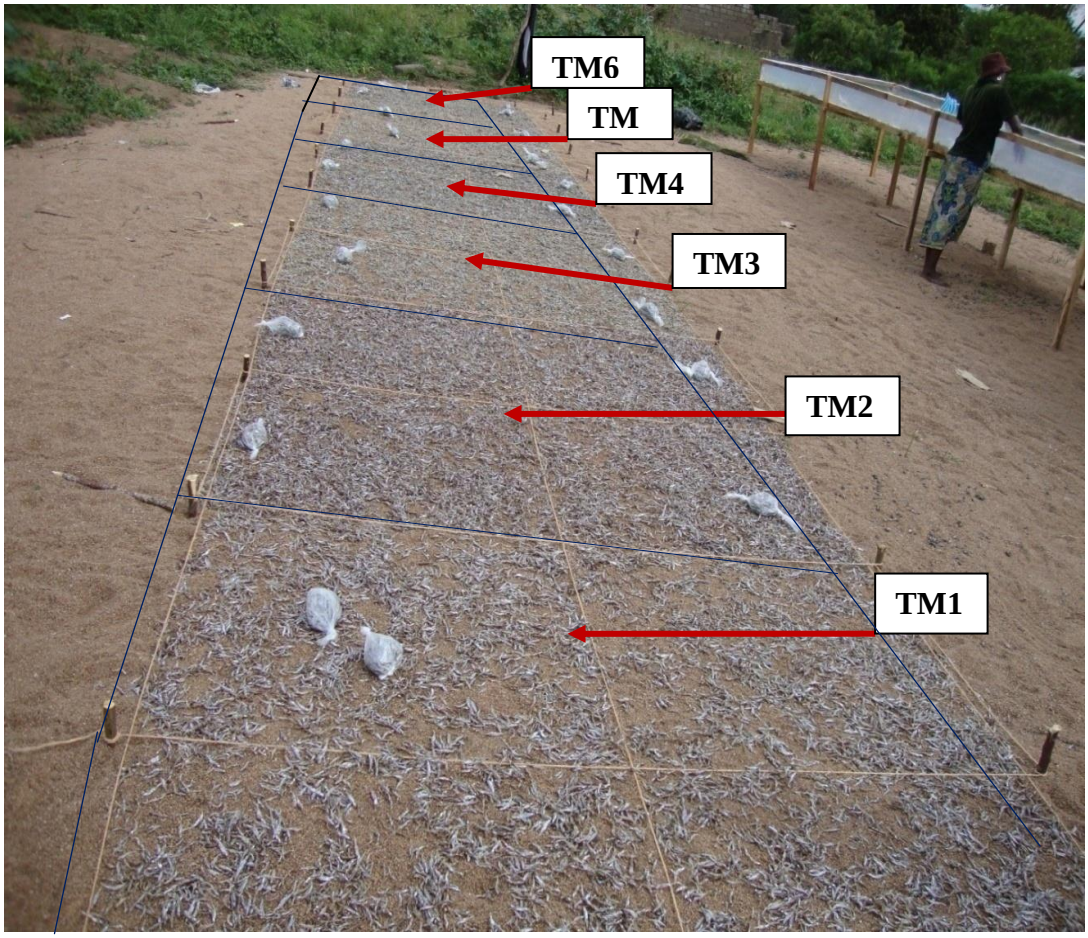

Plate 2: Sardines drying by traditional method with different levels of salt concentration and loading densities

TM= Traditional Method

TM1= Traditional 0% salt concentration and5 kg/m^2 loading density

TM2= Traditional 0% salt concentration and10 kg/m^2 loading density

TM3= Traditional 6% salt concentration and 5 kg/m^2 loading density

TM4= Traditional 6% salt concentration and10 kg/m^2 loading density

TM5= Traditional 10% salt concentration and5 kg/m^2 loading density

TM6= Traditional 10% salt concentration and10 kg/m^2 loading density

4.5.3 Effects of drying time on nutrients content of the sardines

There was a significant difference ($P< 0.05$) in overall mean moisture content between the sardines dried by traditional and improved methods. At time 0, the moisture content of fresh sardines was 74.5%. Table 10 shows that after drying for 36 h, moisture content in improved and traditional methods decreased from 74.5% to 15.33% and 16.43%, respectively. This elucidates that improved method is more effective in drying than the traditional method. The sardines' moisture content remained in non-aqueous material was insufficient to support bacterial or enzyme deterioration. According to Bellagha *et al*. (2007) the rates of change in moisture content of salted dried catfish fillets depend on drying time where the highest rates occurred during the initial stages of drying. Similarly, Akinneye (2007) found the final moisture contents of oven, sun and smoke salted dried fish to range from 9.79 to 16. 42%. Therefore, the moisture content (15.33%) attained in improved method is sufficiently enough for storage of sardines in ambient temperatures without spoilage (Kabahenda *et al*., 2009). If fish is not dried properly, moulds or bacteria can grow during storage and compromise the quality (Abowei and Tawar, 2011). Generally the quality of dried fish product is judged based on degree of drying, appearance and damage (Davies, 2009).

There was a significant difference in protein content ($P< 0.05$) between improved and traditional drying methods (Table 10). The protein content of fresh sardines was 64.9%; however, after drying for 36 h, it decreased to 59.05% and 57.79% in improved and traditional methods, respectively. The increase in drying time and loss of moisture content could lead to protein denaturation. The quantity of protein is variable and depends on the drying time of the fish (Dumay *et al.* 2006; Jonsson *et al.*, 2007; Chukwu 2009).

Table 10: Effect of drying time on nutrient contents (n=2)

Processing method	Time (hr)	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)
Fresh sardines	0	74.5	64.9	17.1	14.2	3.8
Improved	4	49.61^{b}	55.75^{m}	16.57^{a}	22.80^{e}	4.88^{e}
	8	40.48^{d}	58.14^{i}	15.77^{d}	21.73^{k}	4.36^{h}
	12	33.03^{h}	59.20^{h}	14.90^{i}	21.13^{l}	4.77^{f}
	16	33.40^{g}	58.07^{i}	16.05^{c}	21.97^{i}	3.93^{k}
	20	29.11^{j}	60.63^{b}	15.33^{f}	18.97^{o}	5.05^{d}
	24	23.09^{k}	59.77^{de}	16.23^{b}	19.82^{m}	4.18^{i}
	28	19.21^{m}	59.52^{k}	15.87^{d}	20.23^{l}	4.43^{gh}
	32	15.13^{q}	60.97^{a}	14.57^{k}	19.66^{n}	4.81^{ef}
	36	15.33^{q}	59.42^{g}	15.50^{e}	19.59^{n}	5.49^{b}
	Mean	28.71^{B}	59.05^{A}	15.64^{A}	20.66^{B}	4.65^{A}
Traditional	4	54.35^{a}	54.08^{n}	16.20^{b}	25.27^{a}	4.45^{g}
	8	45.24^{c}	54.18^{n}	15.30^{f}	24.73^{b}	5.78^{a}
	12	39.57^{e}	56.67^{l}	14.43^{l}	23.77^{c}	5.13^{c}
	16	35.84^{f}	57.88^{j}	15.15^{g}	23.28^{d}	3.68^{lm}
	20	30.52^{i}	58.17^{i}	15.02^{h}	22.40^{f}	4.42^{gh}
	24	22.19^{l}	59.72^{ef}	14.73^{j}	21.95^{i}	3.60^{m}
	28	18.70^{n}	59.92^{c}	14.00^{n}	22.37^{g}	3.72^{l}
	32	16.98^{o}	59.63^{f}	14.11^{m}	22.22^{h}	4.04^{j}
	36	16.43^{p}	59.83^{cd}	14.10^{m}	21.87^{j}	4.20^{i}
	Mean	31.09^{A}	57.79^{B}	14.78^{B}	23.09^{A}	4.34^{A}

Means within column superscripted by the letters of the same lower case are not significantly different at $P<0.05$. Similarly means superscripted by the same upper case letter are statistically similar at $P<0.05$.

Oyelese and Opatokun (2006) and Oparaku (2010) reported a decrease in protein of sardines after drying and suggested that protein nitrogen was lost during drying. Prolonged drying in ambient conditions facilitates fish spoilage due to autolysis, lipolysis and microbial action leading to lower protein content (Onyia *et al*., 2010). There was a significant difference in overall mean fat content ($P< 0.05$) between sardines dried by improved and traditional methods. The fat content in sardines decreased from 17.1% fresh sardines to overall mean of 15.64% and 14.78% in improved and traditional methods after 36 h of drying, respectively. In general it was observed that, fat content slightly decreased

as drying time increased for both methods. The decrease may be due to fat degradation by oxidation. According to Egbal *et al.* (2010) decrease in fat content in salt-dried fish is due to leaching out of some fat substances during processing. Previous studies FAO (2004), Akinneye (2007) and Kolakowska and Sikorski (2010) found that salted and sun-dried fish contain 10 – 26.42% fat.

The overall mean ash content of dried sardines differed significantly ($P < 0.05$) in sardines processed by improved and traditional methods with respect to drying time. The highest was in traditional (23.09%) and lowest in improved (20.66%) methods. But fresh sardines had 14.2% ash content, relatively lower than reported (14.4-19.6%) by Goddard *et al*. (2005). The higher value of ash content in traditional method could be attributed by heavy contamination with sands and other foreign materials due open sun drying on bare ground. The findings of improved method were relatively similar to previous findings of Bille and Shemkai (2006) who reported high ash content (18.66-19.29 %) in sun and smoke dried sardines.

There was no significant difference in overall mean carbohydrate content ($P> 0.05$) between sardines dried by improved and traditional methods. The carbohydrate content of sardines dried by traditional method was 4.34 and 4.65% for improved method. Total carbohydrates content in fish and shellfish flesh are relatively low (normally <0.5% fresh weight basis) (Anthony *et al*., 2000). However, this study indicated high carbohydrate content than in literature. This is due to the fact that there was no actual analysis of carbohydrate content in sardines was done but the content obtained only by subtraction method.

4.5.4 Effects of processing methods on microbiological quality of sardines

There was a significant difference ($P<0.05$) in microbiological content between fresh untreated sardines and sardines dried by improved method at different salt concentrations and loading densities (Table 11). However, no significant difference ($P>0.05$) in microbial contents for sardines dried by improved method at different salt concentrations and loading densities was observed. But a significant difference was observed between sardines dried by improved method at all treatments with those dried by traditional method at 0% salt concentration at 5 and 10 kg loading densities.

Table 11: Microbiological evaluation for sardines dried by improved and traditional methods (n=2)

Sample	Log CFU/g
Fresh sardines	6.08^{a}
IM1	4.16^{c}
IM2	5.02^{c}
IM3	3.95^{d}
IM4	4.24^{c}
IM5	3.75^{d}
IM6	4.9^{c}
TM1	5.83^{b}
TM2	6.13^{a}
TM3	4.24^{c}
TM4	4.35^{c}
TM5	4.36^{c}
TM6	5.32^{b}

Means with different superscript within the same column are significant different at $P<0.05$

Total microbial count in improved and traditional methods varied from 3.95-5.02 and 4. 24- 6.13 Log CFU/g, respectively. However, the microbial count for fresh sardines was 6. 08 Log CFU/g. Obodai *et al.* (2011) found that the mean microbial count for the salted smoked fish ranged from 4.79 to 6.52 Log CFU/g. In addition Jonsson *et al.* (2007) reported that outdoor and indoor dried fish showed values of 4 and 7 Log CFU/g, respectively. The highest microbial load (5.83 Log CFU/g) and (6.13 Log CFU/g) were

detected in 5 kg/m^2 and 10 kg/m^2 loading densities in traditional method at 0% salt concentration (Table 11).

This high microbial count was probably due to low salt content, high sardine's density per unit area and unhygienic processing conditions. However, the low microbial count in the improved method was due to preservative effect of high salt concentration. Salting of fish prevents the growth and proliferation of bacteria due to its bacteriostatic and bactericidal effects (Nguyen *et al*., 2007; Obodai *et al*., 2011). While high microbial load in fresh sardines could be attributed to high moisture content, poor handling and sanitation practices during fishing and transportation. Possible sources of high microbial counts in dried sardines are poor sanitary conditions during fishing, drying, storage and transportation (Bagge-Ravn *et al*., 2003; Abowei and Tawar, 2011).

In general, salted dried sardines showed low microbial load in both drying methods. The uncured fish in hot humid tropical climates are liable to deteriorate due to high moisture content and high relative humidity which favour multiplication of pathogens and spoilage microorganisms (Patterson and Ranjitha, 2009). Sablani *et al*. (2003) noted a decrease in total microbial count of sardines dried by open rack drier. According to ICMSF (1986), TBS (1988) and Huss (1994) fresh, frozen and cold smoked fish can be considered unacceptable when the total bacterial count is equal or greater than 7 Log CFU/g. Therefore microbial loads observed in the salted-dried sardines were within the acceptable limits in both improved and traditional methods.

4.5.5 Sensory evaluation

Results for sensory evaluation are presented in Table 12. There were no significant difference ($P>0.05$) in colour preference between sardines dried by improved method at

10% salt concentration with 5 and 10 kg/m^2 loading densities and traditional method at 0% salt concentration and 5 kg/m^2 loading density. Also no significant difference between improved and traditional methods at 6% salt concentration at 5 kg/m^2 loading density. Likewise, there were no significant difference in colour for commercial sardines from Lake Tanganyika and Lake Nyasa. However, a significant difference ($P<0.05$) in colour among sardines dried by improved method at 0% salt concentration with 5 and 10 kg/m^2 loading densities, 6% salt concentration with 10 kg/m^2 loading density, traditional method at 0, 6,10% salt concentrations at 10 kg/m^2 loading density and commercial sardines from the Indian Ocean. The highest colour score (4) was observed in improved method at 0% salt concentration and 5kg/m^2 loading density while the least score (2.96) was in sardines from the Indian Ocean (Table 12). The colour difference was due to the effect of browning reactions which could have taken place during drying or storage of sardines.

There was no significant difference in taste ($P>0.05$) between for 5 kg/m^2 loading density sardines dried by improved and traditional methods at 0 and 10% salt concentrations respectively, with sardines from Lake Tanganyika (Table 12). Also sardines dried by improved method at 6% salt concentration with 5 and 10 kg/m^2 loading densities showed no significant difference ($P>0.05$) in taste with those from the Indian Ocean and Lake Nyasa. However, a significant difference was observed in sardines dried by improved method at 10% salt concentration with10 kg/m^2 loading density, traditional at 0% salt concentration with 5 and 10 kg/m^2 loading densities and sardines from Lake Victoria ($P<0.05$).

Table 12: Sensory attributes of sardines dried by improved method, traditional method and those from other fishing area of Tanzania (n=30)

Sample	Colour	Taste	Smell	texture	General acceptability
IM1	4.00^{a}	3.23^{abc}	3.76^{a}	3.66^{ab}	3.76^{a}
IM2	3.76^{abc}	3.03^{bcd}	3.36^{abcd}	3.46^{abcd}	3.46^{abc}
IM3	3.56^{abcdef}	3.56^{ab}	3.30^{abcd}	3.66^{ab}	3.63^{ab}
IM4	3.60^{abcde}	3.63^{ab}	3.43^{abc}	3.59^{ab}	3.46^{abc}
IM5	3.66^{abcd}	3.63^{ab}	3.30^{abcd}	3.63^{ab}	3.73^{a}
IM6	3.66^{abcd}	3.80^{a}	3.43^{abc}	3.76^{a}	3.73^{a}
TM1	3.70^{abcd}	2.83^{cd}	3.26^{abcd}	3.33^{abcd}	3.13^{bcd}
TM2	3.06^{def}	2.16^{e}	2.40^{e}	2.96^{cd}	2.60^{d}
TM3	3.40^{abcdef}	3.63^{ab}	3.36^{abcd}	3.53^{abcd}	3.46^{abc}
TM4	3.33^{bcdef}	3.03^{bcd}	3.23^{abcd}	3.33^{abcd}	3.20^{abc}
TM5	3.26^{cdef}	3.23^{abc}	2.83^{de}	3.16^{abcd}	3.10^{bcd}
TM6	3.00^{ef}	3.10^{bcd}	3.18^{bc}	3.06^{bcd}	3.36^{abc}
Indian Ocean	2.96^{f}	3.63^{ab}	3.13^{bcd}	3.43^{abcd}	3.56^{abc}
Lake Tanganyika	3.96^{ab}	3.40^{abc}	3.56^{ab}	3.50^{abcd}	3.66^{ab}
Lake Nyasa	3.96^{ab}	3.53^{ab}	3.76^{a}	3.10^{bcd}	3.53^{abc}
Lake Victoria	3.26^{cdef}	2.56^{de}	2.90^{cde}	2.90^{d}	3.00^{cd}

Means with different superscript within the same column are significant different at $P<0.05$. Values shown are the mean scores of 30 panelists.

Sensory scores;

5 – Like very much

4 – Like slightly

3 – Neither like nor dislike (cut off point)

2 – Dislike slightly

1 – Dislike very much

A mean score of 3and above was used as the acceptable limit.

The highest taste score (3.80) was observed in improved method at 10% salt concentration and 10 kg/m^2 loading density and the lowest (2.16) in traditional methods at 0% salt concentration and 10 kg/m^2 loading density. The high taste score could be due

to salt concentration and good drying method which prevents contamination with extraneous materials that could influence the taste of product.

There was a significant difference in smell between sardines dried by traditional method at 0 and 10% salt concentration and 5 and 10 kg/m^2 loading densities and Sardines from Indian Ocean and Lake Victoria. However, Sardines dried by improved method at 0% salt concentration and 5 kg/m^2 loading density showed no significant difference ($P>0.05$) in smell compared to those from Lake Nyasa. Sardines dried by improved method at 0% salt concentration and those from Lake Nyasa had highest smell score (3.76) and the least (2.4) was in traditional method at 0% salt concentration and 10 kg/m^2 loading densities. The low score with respect to smell in traditional method was probably due to decomposition of fat and protein compound in sardines and the resulting off flavours. Salt contributes to development of aroma and control autolysis in fish muscle (Nketsia-Tabiri and Sefa-Dedeh, 2000).

With regards to texture, there was no significant difference ($P>0.05$) for sardines dried by improved method at 5 kg/m^2 loading density and 0, 6 and 10 % salt concentrations. Also no significant difference was observed in improved at 0% salt concentration with 10 kg/m^2 loading density, traditional at 0 and 6% salt concentrations with 5 kg/m^2 loading density. There was a significant difference ($P<0.05$) in sardines dried by improved method at 10% salt concentration with 10 kg/m^2 loading density, traditional method with 10 kg/m^2 at 0 and 10 % salt concentrations, Lake Nyasa and Lake Victoria sardines (Table 12). The most preferred texture by panelists was in improved method (3.76) at 10% salt concentration with 10kg/m^2 loading density and least (2.90) was for commercial sardines from Lake Victoria. Nooralabettu (2011) reported that artificial dried fish treated

with 20% salt was rated best in terms of its appealing texture. Fish salted in pure sodium chloride may be soft, tender and yellow-brownish in colour (Jonsson *et al.*, 2007).

The organoleptic properties of sardines dried by the improved and traditional methods at 6% salt concentration and 5 and 10 kg/m^2 loading densities and those from Lake Tanganyika, Lake Nyasa and Indian Ocean were acceptable according to the panellist's evaluation. The least accepted sardines were those dried by traditional method at 0% salt concentration with 10 kg/m^2 loading density and sardines from Lake Victoria. The low acceptable scores could most likely be attributed to the high loading density, presence of sands and unhygienic handling practices during drying. In improved method, the normal silvery colour of sardines was changed to an attractive brownish colour which increased the appeal and acceptability. Salted sardines were highly preferred than unsalted. This was due to the fact that salt improves taste, palatability and flavour, and acts as a preservative or curing agent of different foods (Erdilal *et al*., 2010).

In terms of smell and texture salted sardines were preferred by panellists since application of salt can retard the activities of spoilage microorganisms and other chemical reactions which would contribute to off flavour and undesirable textural changes (Burkepile *et al.*, 2006). Both sardines from Lake Tanganyika and Lake Nyasa compared well to that processed by improved method in almost all sensory attributes than those from Lake Victoria, Indian Ocean and traditional drying method.

According to Bille and Shemkai (2006) salted sardines were highly accepted than spiced and smoke –dried sardines. The use of wire mesh racks or trays for drying purposes improves the acceptability and quality of sardines since the product is free from contamination with sands and filth particles (Bille and Shemkai, 2006; Ssebisubi, 2011).

Salting and drying methods reduce and control the enzyme actions which break down compounds and resulting into changes in flavour, texture and appearance of the fish (Alcicek and Atar, 2010).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The overall objective of this study was to assess the influence of post-harvest handling practices of sardines from Lake Victoria, a case study in Musoma and its effect on the quality and sensory attributes of the end product. It was found that poor handling practices of sardines from Lake Victoria negatively affect quality and sensory attributes and contribute to significant post harvest losses. The sardine value chain is associated with poor fishing practices, inadequate sanitation programme, insufficient drying, poor storage, and packaging and distribution facilities. Lack of detergents and disinfectants accompanied by use of contaminated water from the Lake to clean fishing gears and processing equipment, result into inadequate cleaning and product contamination.

Drying sardines by improved method lead to adequate drying and high quality products (in terms of nutrients retention, microbial load and sensory characteristics) compared to traditional methods. Also, improved method had higher drying rates and shorter drying time. Salting of sardines before processing enhances the drying rates and prevents the growth and proliferation of microorganisms. Sardines dried by improved method were highly acceptable by consumers than sardines dried by traditional method and commercially available sardines from Lakes Nyasa, Tanganyika and Victoria. Also, poor packaging of sardines contribute to poor quality and post harvest losses, hence, proper packaging is required to ensure quality and consumer appeal.

Therefore, the improved drying method developed in this study is highly recommended to fish processors to ensure quality of final products and reduction of postharvest losses.

5.2 Recommendations

Implement Good Manufacturing Practices (GMP) and Good Hygiene Practice (GHP) along the sardine supply chain to ensure quality and safer product. Training of fishers and processors in food hygiene should be a priority.

Proper control of raw materials/develop supplier specifications to prevent variability of quality of the final product. Chill or refrigerate fish soon after being caught and maintain the cold chain to prevent fish spoilage.

Packaging of processed sardines should be done in airtight containers to reduce contamination and moisture uptake.

An intensive and continuous fishers and processors awareness raising and sensitization on employing improved drying method are highly needed. By using improved method, good quality dried sardines product is achieved in short drying time as compared to conventional method.

Improved method with 6% salt concentration and 5kg/m^2 loading density is recommended as the best drying technique as it yield quality products with high nutrient retention and good sensory attributes regarding to this study.

Lastly, I recommend further studies to analyze the presence of moulds, dioxin and heavy metals in improved and salt-dried sardines; and increase of loading densities to establish the optimum loading density for drying sardines.

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APPENDICES

Appendix 1: Questionnaire for sardine fishermen

A: Background information

1. District: ……..….

2. Division: ……

3. Ward: …….

4. Name of the respondent: …….....

5. Age of the respondent: ……..

6. Name of the interviewer: ……..…..

7. Date of interview: ……..…….

8. Questionnaire no: ……..…….……

B: Fishermen information

B1. What is your age? (Circle the appropriate answer).
1. Below 18 years
2. 18-30 years
3. 31-50 years
4. 51-60years
5. Above 60 years

B2. What is your sex? (Circle the appropriate answer).
1. Male
2. Female

B3. Marital status (Circle the appropriate answer).
1. Single
2. Married
3. Separated
4. Living with partner
5. Divorced
6. Widowed

B4. Education level (Circle the appropriate answer).
1. None formal education
2. Primary school education

3. Secondary school education
4. Post secondary education (specify)

C. Sardine fishing practice

C1. What types of fishing gears do you use? List them,
(1)…… (2)…… (3)…… (4)……
(5)…… (6)…….. (7)…..... (8)……....
(9)…… (10)…… (11)…… (12)……..

C2. How did you acquire the fishing gears?
1. Inherited
2. Bought
3. Hired
4. Partnership with the owner

C3. If 2 in C2 how much did you pay? .....

C4. If 3 in C2 how much did you pay (per day, week or month)? ……..

C5. If 4in C2 what kind of partnership is it? Please explain ……...…
…….

C6. What kinds of materials do fishing gears are made of? List
1. …….....
2. …….....
3. …….....
4. …….....

C7.Is there any cleaning procedures for the fishing gears? (Circle the appropriate answer)
1. Yes
2. No

C8.If yes how many times do you clean your fishing gears per month? (Circle the appropriate answer)
1. Daily
2. Weekly
3. Every fortnights
4. Monthly
5. Others (specify)……

C9. Do you use any cleansing agent during cleaning of your fishing gears?
1. Yes
2. No

C10. If yes, what type of cleaning agents do you use? (List by priority. 1 being most used).
1. ……..
2. ……..
3. ……..
4. ……....

C11.How long does fishing last (hrs) in a single night? (Circle the appropriate answer)

1. Two hours
2. Four hours
3. Six hours
4. Eight hours
5. Ten hours
6. Twelve hours

C12. How long does it take (hrs) from the time sardines are caught until when they are off-loaded at the landing site?

1. ……
2. ……
3. ……
4. ……
5. ……

D. Sardine storage practices

D1. When is the harvested sardine stored? (Cycle the appropriate answer)

1. Immediately after harvest
2. Three hours after harvest
3. Six hours after harvest
4. Nine hours after harvest
5. Twelve hours after harvest

D2. At what condition do you store the sardine after fishing? (Cycle the appropriate answer)

1. At ambient temperature
2. Chilling temperature
3. Frozen temperature

D3. Where are the sardine kept after arriving at the shore? (Cycle the appropriate answer)

1. Plastic basin
2. Metal basin
3. Woven basket
4. Polyethylene sheet
5. On the ground

D4. What storage methods do you use? List

1. ……
2. ……
3. ……
4. ……

D5. Do you store other products in the store, together with sardine? No….Yes…

D6. If yes, what are these other products?

1. ……
2. ……
3. ……
4. ……

E. Storage problems

E1. Do you experience storage problems? Yes…. No….

Storage problems (in order of importance)

S/No	Problem (E2)	Storage time before occurrence(days/weeks/ months) (E3)	Solution (E4)

E5.What do you do in case of spoiled sardine in your store?

1. Discard the spoiled sardine……
2. Mix with fresh sardine……
3. Sold as animal feeds……...

E6. What is the average amount of sardine catch per day? Give in terms of kilograms……..

E7. What average amount is spoiled before storage per day? Give in terms of kilograms……..

E8. What is the average amount get spoiled after storage per day? Give in terms of kilograms……..

F. Transportation of sardines

F1. How do you transport your sardine after harvesting?

1. By boats……...
2. By canoe……..
3. Others (specify)……

F2. Is the vehicle used to transport sardine provided with cooling facilities?

1. Yes
2. No

F3. How long does it take to transport sardine to the landing site? ..... hours.

F4. Do you experience any sardine spoilage during transportation?

1. Yes
2. No

F5. What amount is spoiled during transportation? ……..kg

F6. What is the total capacity of the vehicle? ……...kg

Thank you for your contribution

Appendix 2: Questionnaire for sardine processors

A: Background information

1. District: ……..
2. Division: ……
3. Ward: ……..…
4. Name of the respondent …….....
5. Age of the respondent ……..….
6. Name of the interviewer ……...….
7. Date of interview……...…
8. Questionnaire no……....…

B: Processor's information

B1. What is your age? (Circle the appropriate answer).

1. Below 18 years
2. 18 – 30 years
3. 31 - 50 years
4. 51 – 60 years
5. Above 60 years

B2. What is your sex? (Circle the appropriate answer).

1. Male
2. Female

B3. Marital status (Circle the appropriate answer).

1. Single
2. Married
3. Separated
4. Living with partner
5. Divorced
6. Widowed

B4. Education level (Circle the appropriate answer).

1. None formal education
2. Primary school education
3. Secondary school education
4. Post secondary school education (specify)……

C. Sardines processing practice

C1. Where do you get the sardine?

1. ……
2. ……
3. ……
4. ……

C2. Do you store sardine before processing?

1. Yes
2. No

C3. If yes, at what temperature do you store your sardine before processing?
1. At ambient temperature
2. Chilling temperature
3. Frozen temperature

C4 .For how long do you store your sardine before processing?
1. Less than hour
2. 2-4 hours
3. 5-8 hours
4. 9-12 hours
5. Other (specify)……..

C5. What methods do you use for sardine processing?
1. ……..
2. ……..
3. ……..
4. ……..

C6. Do you use salt in your processing method?
1. Yes
2. No

C7. If yes, how do you apply it?
1. Dry salting
2. Brining

C8.What is the concentration of salt do you apply (kg salt per kg of fish)? ……..

C9. How long do you process your sardines?
1. One day
2. Two days
3. Three days
4. Four days
5. More than four days (specify)……..……....…

C10. How do you ensure that your product is adequately dried?
……

C11. What amount of sardine do you process per day? ……kg

C12. What amount gets spoiled during the processing period? ……kg

C13. What are the possible sources of spoilage?
1. Insects
2. Birds
3. Moulds
4. Microorganisms
5. Others (specify)……

C14.Have you attended any training on fish processing?

1. Yes
2. No

C15. If yes, what level did you attain?

……
……

C16.What is your suggestion(s) to improve the future training?

……
……

C17. Do government fishery officers visit you to provide advice on fish processing?

1. Yes
2. No

C18. If yes, how many times do they visit you per month?

1. Once
2. Twice
3. Once every week
4. Other (specify)……

C19. What are the problems associated with sardine processing?

1. ……
2. ……
3. ……
4. ……

C20. Do you pack your product?

1. Yes
2. No

C21. If yes, what packaging material do you use?

1. ……
2. ……
3. ……
4. ……

C22. Where do you sell your sardines?

1. Production site
2. Local market
3. Hawking
4. Tender
5. Town market
6. Other (specify)……...…

C23. Do you find difficulties in selling your sardine product?

1. Yes
2. No

C24. If yes why?

1. Market is very far from processing area
2. Lack of transport facilities
3. Few customers
4. Low demand
5. Brokers offer low prices

C25. Which factors determine the price of sardine?

1. Quality of product
2. Preferences
3. Demand at market place
4. I don’t know

C26. What kind of transport do you use to carry sardine to the market?

1. Own vehicle
2. Hired bicycle
3. Public transport
4. Hired vehicle

Thank you for your contribution

Appendix 3: Questionnaire for fishery officers

A: Background information

A1. District: …….
A2. Name of the respondent: …….
A3. Name of the interviewer …… Date of interview ……
A4. Questionnaire no……..

B. Extension services provision

B1. What fields are you experienced in?

1. ……
2. ……
3. ……

B2. How many years are you in this field? …….....

B3. What type of extension services are you offering to the fishermen?

1. ……
2. ……
3. ……
4. ……

B4. What type of extension services are you offering to the sardine processor?

1. ……
2. ……

B5. How many fishermen do you encounter per month in offering extension services? .....

B6. How many sardines' processors do you encounter per month in offering extensionservices? .....

B7. How does fishing and processing contribute to sardines value added products?
.....
.....

B8. Do you encounter difficulties when performing your extension services?

1. Yes
2. No

B9.If yes what are they, please mention them in a scale form, 1 being the most serious and 5 being the least;

1. ……
2. ……

B10. What are your suggestions to eliminate such difficulties?

1. ……
2. ……
3. ……

Thank you for your contribution

Appendix 4: Raw data for sardine's proximate composition

Sample	Tm (h)	MC (%)	Pr (%)	Fat (%)	Ash (%)	CHO (%)	Tm (h)	MC (%)	Pr (%)	Fat (%)	Ash (%)	CHO (%)
FS	0	74.5	64.9	17.1	14.2	3.8						
RM1	4	58.0	56.8	17.6	21.2	4.4	8	45.1	60.0	17.2	17.5	5.4
RM2		61.0	58.1	17.5	19.2	5.2		44.2	65.8	17.0	13.2	4.0
RM3		38.0	55.6	17.5	22.7	4.2		31.3	56.1	16.6	23.7	3.6
RM4		38.0	55.6	17.5	22.7	4.2		42.0	54.9	15.4	24.0	5.8
RM5		50.3	57.9	15.9	24.1	2.1		35.6	57.4	13.5	24.6	4.5
RM6		44.0	52.6	15.8	26.5	5.1		44.7	54.7	15.0	27.4	2.9
TM1		60.2	52.3	17.1	25.9	4.7		52.3	55.4	15.5	23.1	6.4
TM2		64.5	58.3	17.3	21.3	3.1		47.0	57.6	16.7	20.4	5.3
TM3		43.1	53.9	16.2	23.5	6.4		40.1	52.3	15.0	27.0	7.2
TM4		45.9	54.6	16.2	24.3	4.9		42.5	50.8	16.0	27.4	5.8
TM5		64.5	54.2	15.1	26.8	3.9		44.6	55.1	12.8	27.3	4.8
TM6		47.9	51.2	15.3	29.8	3.7		45.0	53.9	16.2	24.7	5.2
RM1	12	26.0	66.1	16.3	13.7	3.9	16	33.1	61.9	17.3	15.4	5.4
RM2		40.3	62.9	14.3	15.6	7.2		38.7	64.2	16.5	16.2	3.1
RM3		28.6	58.0	15.6	21.5	4.9		27.0	59.8	13.7	23.0	3.5
RM4		39.0	54.9	14.6	25.3	5.2		34.4	53.3	17.3	23.8	5.6
RM5		25.6	57.0	14.8	25.4	2.8		34.4	56.2	16.6	25.9	1.4
RM6		42.7	56.3	13.8	25.3	4.6		32.8	53.0	14.9	27.5	4.6
TM1		43.4	58.6	14.6	21.7	5.1		45.6	62.9	17.6	15.3	4.2
TM2		35.3	58.8	17.0	18.1	6.1		22.1	59.6	17.6	19.6	3.2
TM3		38.0	58.3	15.3	22.8	3.6		35.0	58.9	13.2	23.5	4.4
TM4		39.5	55.4	12.1	25.9	6.6		36.8	54.8	14.5	25.2	5.5
TM5		39.6	54.1	13.6	26.9	5.4		38.0	56.9	14.3	27.2	1.6
TM6		41.7	54.8	14.0	27.2	4.0		37.6	54.2	13.7	28.9	3.2
RM1	20	30.9	63.7	17.1	14.7	4.5	24	18.3	63.4	17.2	13.7	5.7
RM2		20.3	62.4	17.2	14.0	6.4		20.8	61.7	18.0	16.9	3.4
RM3		24.6	60.7	16.3	17.1	5.9		23.1	61.4	16.9	16.6	5.1
RM4		30.8	57.1	16.4	21.9	4.6		24.8	57.6	15.0	22.9	4.5
RM5		31.5	58.1	13.3	24.6	4.0		24.1	55.8	16.5	24.1	3.6
RM6		32.6	61.8	11.7	21.6	4.9		24.8	58.7	13.8	24.7	2.8
TM1		32.6	60.8	16.3	16.8	6.1		18.1	62.1	14.7	17.3	5.9
TM2		22.1	60.7	15.7	18.1	5.5		21.6	58.8	18.3	19.9	3.0
TM3		32.4	60.1	14.8	21.9	3.2		24.3	60.8	16.1	19.7	3.4
TM4		31.3	56.7	13.2	23.7	6.4		22.1	59.8	14.3	22.9	3.0
TM5		32.9	55.3	15.6	27.0	2.1		26.3	58.1	12.0	26.4	3.5
TM6		31.8	55.4	14.5	26.9	3.2		20.9	58.7	13.0	25.5	2.8
RM1	28	15.9	64.2	17.9	13.4	4.5	32	10.0	62.8	17.0	15.3	4.9
RM2		19.7	63.6	17.7	13.6	5.2		17.3	65.7	15.2	15.0	4.1
RM3		19.1	58.1	17.6	20.6	3.7		13.3	61.4	16.4	17.0	5.2
RM4		21.5	55.7	16.6	24.4	3.3		18.6	57.9	12.9	21.8	7.5
RM5		19.4	56.7	13.6	24.0	5.7		16.9	57.5	13.3	23.8	5.4
RM6		19.7	58.8	11.5	25.5	4.2		14.7	60.5	12.6	25.1	1.8

TM1		16.9	61.5	15.3	19.5	3.7		13.2	60.9	16.2	18.0	4.9
TM2		19.1	63.4	14.9	15.6	6.1		16.8	63.8	14.1	19.0	3.1
TM3		20.8	60.1	15.1	21.3	3.5		19.6	61.6	13.7	20.4	4.3
TM4		16.8	58.1	12.4	24.2	5.3		15.0	56.4	14.3	23.9	5.4
TM5		18.7	56.7	14.3	26.8	2.2		17.2	57.2	13.6	25.7	3.5
TM6		20.0	59.7	12.0	26.8	1.5		20.1	57.9	12.8	26.3	3.1
RM1	36	10.4	63.9	16.9	13.5	5.7						
RM2		15.2	62.6	17.0	13.2	7.2						
RM3		14.0	58.0	16.8	20.3	4.9						
RM4		17.4	59.0	15.5	20.4	5.1						
RM5		17.4	59.0	15.5	20.4	5.1						
RM6		18.6	56.4	13.3	25.7	4.7						
TM1		15.2	64.1	16.5	16.7	2.7						
TM2		12.5	62.9	13.4	17.0	5.6						
TM3		16.4	59.3	14.1	22.9	3.7						
TM4		17.3	59.0	14.8	22.1	4.1						
TM5		18.0	56.7	13.8	25.8	3.7						
TM6		19.2	57.0	12.0	26.7	4.3						

FS = Fresh sardines
MC = Moisture content
Pr = Protein content
CHO = Carbohydrate content
Tm = Drying time

Appendix 5: Data for sardines' microbiological examination after 36 hours drying time and fresh sample

Sample	CFU/g
Fresh sardines	1 190 000
RM1	14 500
RM2	104 000
RM3	8 960
RM4	17 500
RM5	5 250
RM6	79 500
TM1	677 000
TM2	1360 000
TM3	17 200
TM4	22 300
TM5	22 700
TM6	211 000

Appendix 6: Sensory Evaluation Form

Name ……. Sex ……. Age …….……....
Time …… Date…….
Please look at and taste each of the eight (3-digits) coded samples. Indicate how much you like or dislike each sample by checking the appropriate sample attribute and indicate your preference (5 to 1) in the column against each attribute by putting the appropriate number. Please wash your mouth with provided water after every sample test and spit at the sink to avoid the "carry-over" effect.

Key:

5 – Like very much
4 – Like slightly
3 – Neither like nor dislike
2 – Dislike slightly
1 – Dislike very much

Sample attribute	Sample code							
Colour								
Taste								
Smell								
Texture								
General acceptability								

Comments …….

Appendix 7: Raw data for sensory evaluation

S. code	Pan	Sensory attributes						Pan	Sensory attributes				
		Co.	Ta	Sm	Te	Ac			Co.	Ta	Sm	Te	Ac
RM1	1	3	4	3	3	3		2	4	4	2	4	4
RM2		2	3	3	2	3			4	3	3	3	3
RM3		3	2	4	3	3			3	2	3	2	2
RM4		3	3	3	3	3			3	3	3	3	3
RM5		1	4	2	2	2			3	3	2	3	3
RM6		2	1	4	3	3			4	2	4	4	4
TM1		1	3	1	4	2			5	5	5	4	5
TM2		4	2	5	4	4			3	3	2	3	3
TM3		4	3	4	4	3			3	4	4	3	4
TM4		3	2	3	5	3			4	3	4	4	4
TM5		3	4	4	3	4			4	4	4	4	4
TM6		3	3	2	2	2			4	3	4	4	3
Indian Ocean		5	2	4	5	4			4	2	4	4	4
L. Tanganyika		3	5	2	4	4			4	5	5	5	5
L. Nyasa		4	4	4	3	4			1	1	1	1	1
L. Victoria		3	2	2	3	4			4	2	2	2	3
RM1	3	4	5	4	4	4		4	4	5	3	4	4
RM2		3	4	2	3	3			3	4	2	3	3
RM3		5	2	3	3	3			5	5	4	5	5
RM4		3	1	1	2	2			4	5	4	3	5
RM5		3	3	3	3	3			3	3	2	1	3
RM6		4	3	4	2	3			4	1	2	1	2
TM1		4	5	3	4	5			5	2	3	3	4
TM2		4	5	4	5	5			4	3	4	2	3
TM3		5	4	4	4	4			3	4	2	4	3
TM4		5	4	3	4	2			1	2	2	2	2
TM5		5	3	4	4	4			1	2	2	3	2
TM6		5	3	2	3	3			1	1	1	1	1
Indian Ocean		5	4	4	4	4			2	1	2	1	2
L. Tanganyika		4	3	4	4	4			1	3	4	1	4
L. Nyasa		5	5	4	4	4			4	1	1	1	1
L. Victoria		4	4	4	3	4			4	2	2	2	2
RM1	5	4	5	4	4	3		6	4	4	3	4	4
RM2		4	2	4	4	3			4	4	4	4	5
RM3		4	3	4	4	3			5	2	3	4	4
RM4		4	4	4	4	3			4	5	3	5	4
RM5		1	2	3	2	3			4	4	3	4	4
RM6		4	2	4	4	3			5	2	5	4	4
TM1		4	5	4	5	5			3	5	2	4	4
TM2		5	4	4	5	5			3	3	4	4	3

TM3		4	4	3	3	3			4	3	4	2	4
TM4		2	2	2	3	3			3	3	3	4	3
TM5		3	3	3	3	3			2	3	4	3	4
TM6		4	2	2	3	3			3	2	3	3	2
Indian Ocean		4	3	3	2	3			4	4	4	3	4
L. Tanganyika		4	3	2	3	4			3	3	3	2	2
L. Nyasa		5	4	4	2	4			4	5	3	4	5
L. Victoria		2	2	3	2	2			3	3	4	3	3
RM1	7	5	5	5	5	5		8	4	4	4	3	4
RM2		5	5	4	5	5			4	2	3	2	3
RM3		5	5	5	5	5			4	3	3	3	3
RM4		5	5	5	5	5			4	4	3	3	3
RM5		5	5	5	5	5			4	4	4	3	4
RM6		5	2	5	5	4			4	3	3	3	3
TM1		2	5	5	5	4			2	2	2	3	2
TM2		4	1	5	5	3			4	3	2	2	2
TM3		3	4	4	4	3			4	3	4	4	4
TM4		3	3	3	3	3			4	4	3	3	4
TM5		3	3	3	3	3			3	3	3	4	3
TM6		4	2	2	2	2			3	1	2	2	2
Indian Ocean		5	1	3	3	3			2	3	1	1	1
L. Tanganyika		3	2	1	3	3			2	1	2	1	1
L. Nyasa		2	3	4	1	3			5	5	4	4	5
L. Victoria		2	2	3	2	2			2	2	1	1	2
RM1	9	3	4	4	3	4		10	5	4	4	4	4
RM2		3	2	1	3	4			5	4	4	5	5
RM3		4	2	3	4	3			5	2	4	4	4
RM4		2	2	2	3	3			3	4	2	2	3
RM5		2	4	3	3	3			3	2	2	2	2
RM6		5	4	5	4	3			5	2	4	4	5
TM1		3	5	2	4	5			1	2	2	2	2
TM2		4	4	5	3	4			3	3	3	3	2
TM3		3	5	4	3	5			4	4	4	5	4
TM4		3	4	4	3	3			5	3	4	4	3
TM5		3	5	4	3	4			4	4	3	4	3
TM6		4	2	4	3	3			4	2	2	3	2
Indian Ocean		4	4	4	3	3			4	3	3	3	3
L. Tanganyika		2	4	4	3	3			4	3	3	3	4
L. Nyasa		4	2	4	4	3			5	5	4	5	5
L. Victoria		3	2	4	4	3			4	2	2	2	2
RM1	11	2	4	3	4	4		12	4	3	4	4	3
RM2		2	1	4	4	3			4	3	4	3	4
RM3		2	2	3	4	4			5	4	4	3	4
RM4		3	4	3	4	4			4	3	4	4	4

RM5		4	2	3	4	2			5	4	3	4	4
RM6		2	2	3	4	2			4	4	4	3	5
TM1		2	4	2	4	4			2	2	1	1	1
TM2		5	4	4	4	5			5	2	5	2	5
TM3		4	4	4	4	4			5	4	3	5	4
TM4		3	4	4	4	2			4	4	4	5	3
TM5		4	3	4	4	3			5	5	5	5	5
TM6		2	2	4	4	2			3	3	3	5	3
Indian Ocean		4	2	4	4	2			4	4	5	5	4
L. Tanganyika		3	3	4	4	2			4	5	4	5	5
L. Nyasa		3	5	4	4	4			2	2	3	1	2
L. Victoria		2	4	4	4	3			3	2	3	3	3
RM1	13	5	5	4	5	5		14	5	5	3	5	5
RM2		5	5	3	5	5			5	5	3	5	5
RM3		5	4	2	5	5			5	5	3	5	5
RM4		5	5	2	5	5			5	5	4	5	5
RM5		5	5	1	5	5			4	5	4	5	4
RM6		5	4	2	5	5			5	5	4	5	5
TM1		4	5	3	5	5			4	5	5	5	5
TM2		3	4	4	5	5			5	5	5	5	5
TM3		5	4	4	4	4			2	2	2	3	2
TM4		5	5	4	2	3			2	3	3	2	2
TM5		3	3	4	3	3			3	4	4	2	4
TM6		2	2	2	2	2			3	5	5	4	3
Indian Ocean		4	4	4	5	5			5	1	3	5	4
L. Tanganyika		4	4	4	2	5			1	1	3	3	3
L. Nyasa		1	3	4	4	1			5	5	5	3	5
L. Victoria		4	4	4	3	4			2	2	1	2	2
RM1	15	2	2	4	2	2		16	3	5	4	3	3
RM2		2	2	4	2	2			3	5	4	4	4
RM3		4	2	4	2	2			4	4	5	4	2
RM4		2	4	4	4	4			3	5	4	4	4
RM5		2	2	5	4	2			3	5	4	3	3
RM6		4	4	5	4	4			4	4	4	5	4
TM1		2	4	2	4	4			3	5	5	3	4
TM2		5	5	5	5	5			5	5	5	5	5
TM3		4	3	4	4	4			4	4	4	3	4
TM4		4	2	3	3	3			5	5	4	4	5
TM5		4	4	3	3	3			4	4	4	2	4
TM6		2	2	1	2	3			5	1	3	4	4
Indian Ocean		3	4	3	4	4			4	3	4	2	3
L. Tanganyika		4	2	2	2	2			4	3	4	3	4
L. Nyasa		5	4	4	4	5			5	2	4	4	5

L. Victoria		3	2	2	1	2			3	1	4	2	3
RM1	17	4	4	3	4	4		18	2	1	3	2	1
RM2		4	4	4	5	4			4	4	3	2	3
RM3		3	3	3	2	3			3	2	2	2	1
RM4		3	3	4	4	4			4	4	3	2	3
RM5		3	3	4	3	3			3	3	3	2	4
RM6		5	5	4	4	5			5	4	3	4	4
TM1		5	5	5	5	5			1	2	3	1	2
TM2		3	3	4	3	3			5	5	3	5	4
TM3		3	4	3	2	3			5	4	3	4	4
TM4		2	3	1	1	1			3	4	3	4	3
TM5		1	4	3	3	2			4	5	3	4	4
TM6		3	2	1	1	2			4	2	3	3	4
Indian Ocean		4	4	4	4	4			4	3	3	4	4
L. Tanganyika		1	1	1	1	1			3	4	3	2	3
L. Nyasa		5	5	5	5	4			4	2	3	4	2
L. Victoria		4	4	4	4	4			3	1	3	4	2
RM1	19	4	4	4	5	4		20	3	2	1	4	2
RM2		4	4	3	4	3			4	4	3	4	4
RM3		5	3	5	5	3			5	2	1	4	3
RM4		4	4	4	4	4			4	2	3	3	3
RM5		4	5	4	5	4			4	1	3	2	2
RM6		5	4	5	4	4			4	1	1	3	3
TM1		3	5	5	4	5			1	4	4	2	3
TM2		5	3	3	1	3			5	5	1	5	5
TM3		4	4	3	5	4			2	5	4	3	4
TM4		4	1	3	4	4			3	2	4	4	5
TM5		4	4	3	5	4			4	3	3	5	4
TM6		4	2	2	4	3			2	1	3	4	4
Indian Ocean		4	2	3	5	4			4	2	3	4	4
L. Tanganyika		3	4	4	4	4			3	4	2	5	4
L. Nyasa		5	3	5	2	4			4	3	2	1	4
L. Victoria		4	2	4	3	3			3	2	1	4	4
RM1	21	4	5	4	5	4		22	4	5	4	5	5
RM2		4	4	3	4	4			3	5	2	4	4
RM3		5	4	4	4	4			3	3	4	3	4
RM4		4	5	4	5	5			5	4	3	4	4
RM5		3	4	3	4	3			2	4	2	4	4
RM6		3	4	5	4	4			3	2	3	3	3
TM1		3	3	3	3	3			1	2	1	1	1
TM2		5	4	4	5	5			3	3	3	2	2
TM3		2	2	3	3	3			3	3	4	4	3
TM4		2	1	4	3	4			4	4	4	4	5

TM5		2	2	3	5	3			4	4	4	4	4
TM6		3	3	2	3	3			2	2	2	3	3
Indian Ocean		4	3	3	3	4			4	3	5	4	4
L. Tanganyika		1	3	3	3	3			3	3	3	3	3
L. Nyasa		5	5	4	3	5			5	4	5	5	5
L. Victoria		4	3	4	3	4			4	2	2	2	2
RM1	23	4	3	2	3	3		24	1	3	1	2	3
RM2		5	4	3	4	3			2	3	2	3	3
RM3		4	2	2	3	3			1	3	1	1	2
RM4		5	3	4	2	3			2	2	2	3	3
RM5		4	3	3	4	4			3	3	2	2	2
RM6		5	5	4	4	4			2	3	3	5	4
TM1		1	3	2	3	3			4	2	2	4	3
TM2		5	4	4	5	5			2	2	2	2	3
TM3		4	5	2	4	4			4	5	3	4	5
TM4		3	1	1	1	1			4	4	4	4	4
TM5		5	4	2	4	3			5	5	4	2	3
TM6		2	1	1	3	2			2	1	1	2	1
Indian Ocean		5	3	3	3	5			1	3	3	1	2
L. Tanganyika		5	5	4	5	5			4	2	4	2	3
L. Nyasa		4	3	5	2	1			5	2	5	2	4
L. Victoria		3	3	1	2	2			3	2	3	2	3
RM1	25	2	2	3	3	3		26	3	3	3	3	3
RM2		5	3	4	4	4			3	4	4	4	4
RM3		4	1	5	2	1			2	4	3	3	3
RM4		5	2	5	5	3			3	2	3	4	3
RM5		3	3	3	3	3			4	2	3	3	3
RM6		4	5	4	3	3			3	4	3	2	3
TM1		4	1	4	1	3			4	5	3	4	4
TM2		2	2	1	2	2			3	3	2	2	2
TM3		3	5	4	4	4			5	5	3	4	4
TM4		3	3	4	3	4			3	4	4	4	4
TM5		5	5	4	3	3			4	5	3	5	4
TM6		4	3	3	2	3			3	4	4	4	4
Indian Ocean		4	4	3	4	3			5	5	4	5	5
L. Tanganyika		3	3	3	2	3			3	5	4	5	5
L. Nyasa		5	5	5	4	4			5	5	5	5	5
L. Victoria		4	3	4	5	4			3	5	3	5	5
RM1	27	4	1	4	1	2		28	2	3	3	2	3
RM2		4	4	3	3	3			3	4	4	2	4
RM3		1	1	1	4	1			2	3	3	2	3
RM4		1	3	2	3	2			2	3	3	2	2
RM5		5	1	1	2	1			3	2	1	2	2

RM6		5	5	5	5	5			3	3	2	2	3
TM1		5	5	5	5	5			5	4	4	4	4
TM2		2	1	4	2	1			4	3	3	1	3
TM3		4	4	3	4	4			2	3	2	3	3
TM4		3	3	3	2	3			2	3	2	2	3
TM5		4	3	4	3	4			4	3	2	3	2
TM6		2	1	1	5	2			2	1	1	1	1
Indian Ocean		3	3	3	4	2			2	2	1	2	2
L. Tanganyika		3	2	2	3	3			3	4	3	3	2
L. Nyasa		1	2	1	2	2			5	4	4	5	3
L. Victoria		5	2	2	3	3			3	3	2	2	2
RM1	29	2	3	4	3	3		30	2	3	4	3	3
RM2		3	4	5	4	4			4	4	4	5	5
RM3		2	3	4	3	3			3	2	3	2	3
RM4		3	4	4	5	5			5	4	4	5	5
RM5		2	3	2	3	3			3	3	2	3	3
RM6		4	3	4	4	4			3	4	5	3	5
TM1		2	2	3	3	2			3	2	3	3	3
TM2		4	4	3	4	4			5	4	4	4	4
TM3		3	1	4	4	3			4	4	3	4	4
TM4		3	1	3	5	3			5	4	4	4	4
TM5		4	2	4	4	3			4	3	3	4	4
TM6		3	4	4	4	4			4	2	2	3	2
Indian Ocean		4	5	4	4	5			2	4	4	3	3
L. Tanganyika		3	1	3	3	3			2	2	4	3	4
L. Nyasa		4	4	3	1	3			2	3	4	3	3
L. Victoria		5	4	4	5	5			2	3	5	4	3

S. code = Sample code; Co = Colour; Ta = Taste; Sm = Smell; Te = Texture; Pan = Panellist; Ac =Acceptability