grocentre.is/ftp Final Project 2022

IMPROVEMENT OF NUTRITIVE QUALITY AND ACCEPTABILITY OF MAIZE SNACKS WITH CAPELIN (*Mallotus villosus*) FLOUR

Abubakary Saad Mbadjo
Fisheries Education and Training Agency (FETA) - The United Republic of Tanzania
PO Box 83, Mbegani Campus, Bagamoyo
mbegani@feta.ac.tz
mbadjossa@gmail.com

Supervisor(s):
Ólafur Reykdal: olafurr@matis.is
Óli Þór Hilmarsson: olithor@matis.is

ABSTRACT

The aim of this study was to increase utilisation of dried capelin powder through production of maize and fish snack products. Three sets of spices combinations at 3.5% of the recipe: ginger and garlic (GG), ginger and cardamom (GCM) and ginger and cinnamon (GCN) were used to mask the fish odour and flavour in produced snacks. A sample of 12.5 g/100g dried capelin powder without spices (WS) was used as control by trained and untrained panellists during sensory assessment of the snack products. The proximate compositions of the snacks containing 12.5 and 17.5g/100g of dried capelin powder were: Protein (10.3–14.2), total fat (4.0 – 4.6), Ash (3.3 – 3.8) and free fatty acid (8.1 – 12.1) g/100g. Furthermore, the acidity (pH), water content and water activity ranged from: (3.7 – 4.4), (2.0– 2.2) and (0.066 – 0.074) % respectively. Similarly, the peroxide value and total microbial count ranged from 12.9 – 24meq of PV/kg of fish oil and 40 – 80 CFU/g for the two formulations. There was significant difference ($P < 0.05$) in overall liking between snacks with spices (GCN) when compared with spices (GG) and control sample (WS). Moreover, a significant difference ($P < 0.05$) was found in organoleptic attributes between snacks with spices (GCM) and (GG). Furthermore, the increased concentration of dried capelin powder affects the texture attributes of snacks. A minimum force of 1,573(N) was required to break a control sample (WS) compared to average force of 1,924(N) of the same snacks with spices. As the concentration of dried capelin powder increased to 15 and 17.5g/100g, the force required to break the snacks was increased to 2,264 and 2,817(N) respectively. This suggests that different concentrations of dried capelin powder must be applied to produce snack products with convenient texture attributes to a wider range of target consumers (children, youth, adults, and older adults) on the market. Finally, the study has shown that with application of spices, there are possibilities to enrich maize with dried capelin powder to produce snack products with better nutrition and acceptable organoleptic attributes. This will align with increasing utilisation of underutilised fish species in the food supply chain. Consequently, this will contribute towards food security and health improvement.

Keywords: Dried capelin powder, maize-snacks, spices, proximates, sensory attributes.

This paper should be cited as:
Mbadjo, A.S. 2022. *Improvement of nutritive quality and acceptability of maize snacks with capelin (Mallotus villosus) flour.* GRÓ Fisheries Training Programme under the auspices of UNESCO, Iceland. Final project. https://www.grocentre.is/static/gro/publication/1727/document/Mbadjo21prf.pdf

CONTENTS

1 INTRODUCTION

1.1 State of fisheries

The United Republic of Tanzania is bestowed with a wide range of inland and inshore water occupying about 6.4% of the total land (FAO, 2016). Major freshwater bodies including Lake Victoria, Tanganyika and Nyasa (Malawi) lead inland fisheries production in the country. About 51%, 41% and 20% of water areas from the respective lakes are within a country territory while the remaining portion is shared with our neighbouring countries including Kenya, Uganda, DRC Congo, Burundi, Zambia and Malawi (FAO, 2007). In addition, there are about 63 dams, 4 small lakes (Ruaha, Manyara, Eyasi and Natron) and 6 rivers (Ruvuma, Ruaha, Kilombero, Malagarasi, Rufiji and Wami) which accommodate numerous chains of fishing and fisheries activities (FAO, 2016). Fresh water fisheries cover about fifty thousand square kilometres and have a significant contribution in fish production country wide (FAO, 2016).

The country has a coastline of 1,240km from Tanga to Mtwara regions, covering three islands and offshore water with a surface area about 17,900km^2. The economic exclusive zone (EEZ), which is a vital fishing ground for industrial commercial foreign fleet targeting highly valuable tuna and tuna like species, is 242,000km^2 with an estimated yield of 20,000 metric tonnes per year (URT, 2019) as indicated in Figure 1. About 340,000 metric tonnes of fish is landed in a year, of which 85% and 14% are from inland and marine, respectively. Only 1% of total fish produced is from the aquaculture sector (URT, 2019).

Figure 1. Tanzania marine and freshwater bodies (URT, 2015)

Despite of the total harvested catch in a year found to be 340,000 metric tonnes, the sector has a potential to increase production by 54% to reach it maximum potential. The distribution of the yield suggest that fresh water bodies could increase production to 86.3% compared to 13.7% of marine water (Kweka, Musa et al., 2006; Thomas, 2016).

Artisanal and commercial fishing are common fishing practices undertaken in inland and inshore water (URT, 2019). Technologically, artisanal fisheries use dugout and outrigger canoes equipped with traditional fishing gears targeting small pelagic fish. The commercial fisheries in the deep sea are conducted using a modern fishing vessels, well equipped with fishing gear (trawler) that target mainly large pelagic fish including tuna and tuna like species (January & Ngowi, 2010). Managerially, fisheries resources are governed by three regulatory authorities. The deep sea fishing authority (DSA) is responsible for commercial fisheries in exclusive economic zone, while the division of fisheries Zanzibar (DFZ) under the Ministry of blue economy responsible for inshore fisheries in Zanzibar Island (RGZ, 2010). Finally, the division of fisheries services (DFS) under the Ministry of Livestock and Fisheries is responsible for both inland and inshore water fisheries in Tanzania Mainland (URT, 2003).

Worldwide, fish is among the products which are highly consumed and traded to promote economies (Hasselberg, Aakre et al., 2020). In Tanzania, fisheries resources contribute about 1.7% of the nation gross domestic product (GDP). Generally, fish businesses generate revenue worth USD 1.04 billion annually. The business for live and ornament fish contributes to a good source of foreign income (URT, 2020). Furthermore, fish businesses offer direct and indirect employment opportunities to over 200,000 fishermen at a small-scale level (Onyango, 2017). Over 4 million men and women participate in various economic activities in the fish supply chain. These include processing and vending of fish at small and medium scale, net mending and boat repairing, as well as management of resources at community level (Kweka, Musa et al., 2006; January & Ngowi, 2010).Together with the tourism sector, recreational fisheries are gaining popularity along inshore water in Zanzibar Island and contribute directly to the economy of the local community by creating more skilled and unskilled employment opportunities which have an impact on individual livelihoods and the national economy at large (Kadagi, Wambiji et al., 2021).

Fisheries resources provide suitable and affordable protein to most poor and low-income people. In Tanzania, it contributes between 30 and 40% of animal protein in food supply chain (Kweka, Musa et al., 2006; Isaacs, 2016), which are required for the young and growing population (Kurien, 2004; Tacon & Metian, 2013). Similarly, proteins from fish are in high demand for pregnant and breastfeeding women as well as very young children to promote the growth and development of babies (Isaacs 2016). In addition, fish contains unsaturated fatty acids and a significant concentration of micronutrients including vitamins A, B1, B2 and D as well as a range of organic and inorganic minerals such as calcium, iron, zinc, selenium, and iodine, which are required for repairing and maintenance of body cells (Larsen, Eilertsen et al., 2011; Hasselberg, Aakre et al., 2020).

Figure 2, below, indicates the Tanzanian Mainland population whereby in 2020 the active group of young and adults aged (5 – 39) years and babies (0 – 4) years occupy 82.4% of the total population.

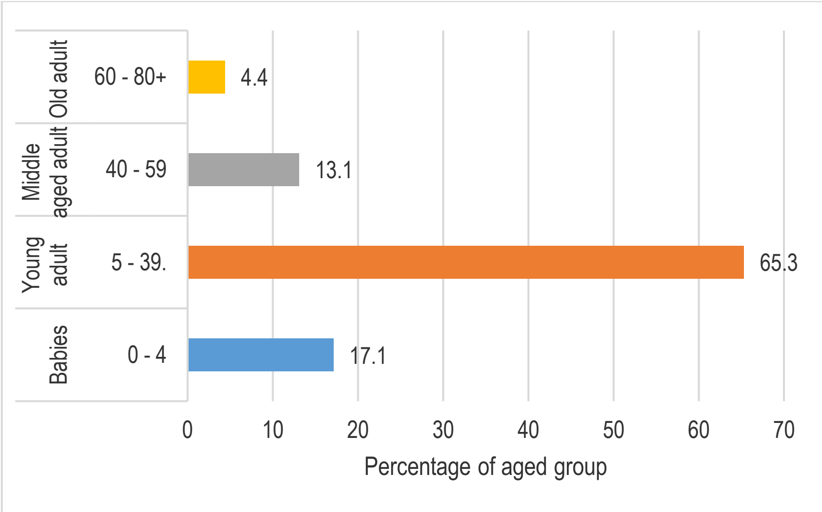

Figure 2. Tanzania Mainland population based on age group (URT, 2020).

From nutritional point of view, the population group under 40 years requires protein to promote growth. Also, the population of middle-aged and older adults (40-59) and (60–80^{+}), are about 17.5%, just above a quarter of the total population. Currently, the status of fish consumption for an individual Tanzanian is around 8kg a year, which is significantly less than the 20kg in a year for an individual at worldwide level (FAO, 2020).

In most developing countries, including Tanzania, a significant number of poor and low income earners live in rural areas near inland and inshore water bodies (Isaacs, 2016). This population is highly dependent on fisheries resources, specifically small pelagic fish like sardines, as animal protein sources to improve their health and wellbeing (Hasselberg, Aakre et al., 2020). Other animal protein sources including meat, milk and milk products from livestock subsector are highly accessible and consumed in communities involved in livestock keeping (Eik, Kifaro et al., 2008).

1.2 Rationale

Despite nutritional and socio-economic benefits associated with the fisheries sector, loss of resources after harvesting, particularlly small pelagic fish, remains a major challenge underpinning fish supply chain in Tanzania (Bille & Shemkai, 2006). Silver cyprinid *(Rastrineobola argentea)* is a vital fish species providing food, income, and livelihood to hundreds of thousands of Tanzanians. Over 200,000 metric tonnes of fish were harvested each year, but only 30% of the catch meet quality and safety requirements for human consumption (Kolding, van Zwieten et al., 2019). The quality and physical loss was estimated between 32 and 59% of the total fish landed while loss due to microbiological and market value was unquantifiable. Additionally, massive losses were experienced during the rainy season where efficiency of the sun drying is quite limited (Mgawe, 2009; Ibengwe & Kristófersson, 2012; Adeyeye, 2019).

Harvesting and handling practices of sardines in canoes impose physical impact to the bottom layer which lead to rupture the soft bellies and loose water, hence making the fish unsuitable for a fresh sale (Akande & Diei-Ouadi, 2010). Similarly, processing and preservation of sardines at landing sites is done using an open sun-drying technique whereby a large portion of sardines are exposed to the ground surface, covered with polythene sheet. In other occasions sacks, grasses, stones and raised platforms are also used to dry fish. However, unsatisfactory hygienic practices experienced in surrounding environment expose sardines to a range of physical and biological contaminants including dust, sand, insects, and animal infestations which undermine the quality and safety of produced sardines for human consumption (Mhongole & Mhina, 2012).

The dried sardines are stored in overloaded sacks with an average weight between 120 – 180kg. These sacks do not allow ventilation of air vital to prevent absorption and accumulation of moisture from the surrounding environment. Also, during distribution to various market channels, the dried sardines are broken into pieces and ultimately form a powder which undermines its market value (Akande & Diei-Ouadi, 2010). Therefore, the longer supply chain of sardines found to produce enormous post-harvest losses and waste of which large proportion of harvested catch utilized for non-food usage including production of animal feed and plant fertilizer (Kweka, Musa et al., 2006). Consequently, this limits availability of affordable nutritious fish protein required by large population of Tanzanian to improve their wellbeing and livelihood.

The demand for nutritious and affordable animal protein sources is increasing due to rapid increase in population across the world. In Tanzania, the population of vulnerable group of babies and young adults estimated to be 17.1% and 65.3% respectively which requires protein sources for their growth and wellbeing (URT, 2020). Between 95 and 98% of all landed sardines are preserved using a traditional open sun drying technique (Kweka, Musa et al. 2006; Mhongole and Mhina 2012), which produces enormous waste and post-harvest loss, hence limits availability of nutritious protein in the food supply chain.

The need of reducing post-harvest loss of sardines is important for the nutrition of large populations of poor Tanzanians. This could be achieved through production of value-added products which are potential platforms that could maximise utilisation of whole fish loss in the food supply chain (Lopetcharat, Choi et al., 2001). The present study aims to increase utilisation of dried capelin powder into food formulations through developing a snack product with improved nutrition and acceptable organoleptic attributes through baking techniques.

Through development of nutritious ready-to-eat snack food products with stable shelf life and acceptable sensory attributes, large population of young and adults vulnerable to protein deficiency would have access to affordable fish protein sources. Consequently, utilisation of small pelagic fish resources could increase and the massive post-harvest loss in the food supply chain would be reduced. On a global scale, consumption of snack food products modified to improve nutritional value is increasingly popular due to their convenient, acceptable organoleptic attributes and shelf-life stability (Omwamba and Mahungu, 2014). To ensure that the fishy flavour and odour were reduced when the concentrations of dried capelin powder incorporated into the formulations, selection of natural spices and condiments including ginger, garlic, cardamom, and cinnamon was used to mask and manipulate the fishy odour.

1.3 Goal and objectives

The overall goal was to increase utilisation of small pelagic fish species including capelin (*Mallotus villosus*) and silver cyprinid (*Rastrineobola argentea*) for human food through production of snack food products using baking processing technique with combinations of natural spices capable of masking fish odour. The objective was to develop nutritious ready-to-eat snack products incorporated with dried capelin powder with acceptable sensory attributes to the consumer.

The study had the following specific objectives:

- Assess proximate composition of maize snack products
- Evaluate sensory attributes of maize snack products
- Analyse physical, chemical, and microbial quality of maize snack products

2 LITERATURE REVIEW

2.1 Available proteins resources

The silver cyprinid (*Rastrineobola argentea*) group of small pelagic fish (sardines) belong to the family cyprinidae, genus rastrineobola and species *R. argentea* (Wangechi & Kigano, 2016). Ecologically, they are found in freshwater bodies. They feed on zooplankton and have a maximum length of 9 cm (Nunan, Luomba et al., 2012). This fish species has a thin layer skin which lacks scales but poses mucus which makes it slippery, a defensive mechanism for the fish (Wangechi Kigano 2016). The sardine is among of the vital fisheries resources that fulfil both domestic uses where it offers nutritious food, income, and employment opportunities to the community surrounding the lake and large population in East African nations (Njiru, Kazungu et al., 2008).

Sardines are also a commercial fisheries resource in Tanzania targeting the most rewarding regional market in Eastern and Southern Africa where the demand for affordable animal protein sources is extremely high especially for nations experiencing political instability (Yongo, Keizire et al., 2005; Mukasa, 2013). In Tanzania, about 340,000 metric tonnes of fish are harvested in a year (Kulwijila, Masanyiwa et al., 2012) of which sardines (*Rastrineobola argentea*) occupy between 71 - 72% of the total landed catch (Chaula, Laswai et al., 2019; Mkunda, Chachage et al., 2019).

2.2 Traditional processing methods

Sun drying is the most common preservation method in tropical countries including Tanzania which uses it preserve between 95 and 98% of all sardines (Kweka, Musa et al., 2006; Mhongole & Mhina, 2012). The climatic condition within the country is associated with a relative humidity between 50 to 85% for morning and afternoon respectively, while the temperature is between 20 and 30^{0}C in a typical sunny day. These conditions facilitate the removal of substantial amount of water in fish during the drying process (Shang, 2020). On some occasions, the use of table salt at lower concentration between 1 to 3% enhanced the efficiency of the sun drying process whereby sufficient amount of moisture from fish can be reduced within a shorter period of time (Mbunda, Arason et al., 2013).

The open sun drying method is an inexpensive preservation technique (Reynolds, 1993), yet the quality and safety of the resulting product is not assured. In most cases, the ground surface is covered with either a plastic sheet, grasses, stones, or raised racks or other platforms are used to dry fish at landing sites in Tanzania (Mbunda, Arason et al., 2013). During the drying process, sardines are subject to numerous physical and biological contaminants including dust, dirt, sand particles, insects, flies and other animals moving around the area where the drying process is undertaken (Thomas, 2016). Also, the efficiency of sun drying techniques are undermined on rainy and cloudy days where the intensity of sunlight is extremely low (Shang 2020). In the rainy season, the fish catches are abundant and the massive post-harvest fish losses are experienced due to insufficient drying of fish (Akande & Diei-Ouadi, 2010).

Likewise, energy from the sun is also used to dry fish in a solar tent drying method. Compared to open sun drying, the solar tent drier produces dried fish products with quality attributes and adhere to safety practices. However, initial investment cost, limitations in capacity and inefficiency drying performance during rainy season were some of the arguments raised by majority of small scale fish processors which undermine the use of solar tend drier to dry fish and fish related products (Shang, 2020; Yuwana & Sidebang, 2017).

2.3 Improved processing methods

Production of fish value added products is an alternative way to increase utilisation of small pelagic fish in the food supply chain. The use of whole fish in production of a value added products had been well explored in fish sauce and sausage products (Lopetcharat, Choi et al., 2001; Hjalmarsson, Park et al., 2007). Incorporation of fish into plant-based snack products from cereals, grains, and legumes found to improve both macro and micro nutrients of the products (Mosha & Bennink, 2004). However, the concentration of dried fish powder reported to have a limit for the product to be accepted as per consumer sensory perception. A maximum concentration of 10% dried fish powder incorporated into snack products was found to have better sensory attributes and was fairly well accepted by sensory panellists representing a population of the ultimate consumers (Ganesan, Rathnakumar et al., 2017).

Yet, the desire to incorporate more dried fish powder to produce nutritious product with acceptable sensory attributes is ongoing research area which could benefit Tanzania. Thus, to fulfil both nutritional goals and consumer preferences, the use of natural preservatives from a selection of spices and condiments including garlic, ginger, cinnamon and cardamon can be used to mask the fish flavour and odour in production of maize snack products incorporated with dried capelin powder. Consequently, increased utilisation of capelin and improved nutrition, wellbeing and livelihood of the populations vulnerable to protein deficiency.

2.4 Experiment with sardines

2.4.1 The effect of sardines on supplementary food

A study to improve the protein quality of a cereal based meal due to increased concentration of amino acid score by incorporating sardines into the formulation was conducted by Mosha (2004). About six meals containing the following ingredients: corn, beans, and sardines (CBSM), rice, beans, and sardines (RBSM), corn and beans (CBM), rice and beans (RBM), corn meal (CM) and bean meal (BM) were formulated and given to a selected group of undernourished Sprague-Dawley weanling rats. Findings from this study indicate that the formulated meal containing corn-beans-sardine composite (CBSM) and rice-bean-sardines composite (RBSM) showed a potential to support growth and rehabilitation of selected undernourished Sprague-Dawley weanling rats compared to other meal formulations which do not contain sardines which did not show acceptable growth.

Similarly, a study by Torun (2005), was conducted to compare the effect of incorporation of sardines into formulated ready-to-eat snacks containing beans and traditional grains particularly sorghum and rice using an extrusion processing technique. Two formulations of snack products containing ingredients including (1) sorghum, beans, and sardines (SBSM) and (2) rice, beans, and sardines (RBSM) were produced. The protein content of the formulated snacks increased by 83 and 92% respectively compared to the formulation which containing sorghum and beans as well as rice and beans. Thus, based on the above studies it can be argued that incorporation of the sardines into a food formulation increases both product nutritional profile as well as availability of affordable protein sources to supplement the diets of large populations of children, young and adult who require a reasonable proportion of protein to promote body growth.

2.4.2 The effect of sardines on animal weight gain

A study investigating the effect of meal containing dried sardines as main source of protein to the weight gain of 30 male sheep was conducted by Mahgoub (2005). The experimental diets containing 0, 50, 100 and 200g/kg of dried sardines were incorporated into 50g/kg of soybean meal as the main protein source. Each of the four diets were given to a group of sheep randomly selected for a duration of 63 days. The findings from this experiment revealed that an average growth rate of sheep was increased to 129, 150, 141 and 122 g/day in relation to respective levels of sardines (0, 50, 100 and 200g/kg) contained in the diet. A significant increase in weight was observed to be 150 and 141g/day for the sheep that were fed with diets containing 50 and 100g/kg of dried sardines. In addition, insignificant weight gains of 129 and 122g/day were found when sheep were fed with the diets containing 0 and 200g/kg of dried sardines.

Similarly, Louala (2011) reported on a study investigating the effect of increased weight gain due to intake of a diet containing sardines. A set of three diets containing: 20% highly purified sardine protein added into cholesterol-enriched diet, a casein diet containing cholesterol and a standard diet of casein as a control were produced. The three diet formulations were fed to six male Wistar rats weighing 80g for a period of 28 days. Findings from this experiment suggest that weight gaining of rats fed with the cholesterol-enriched diet containing 20% highly purified sardines protein increased to 173g compared with only 160g and 154g, respectively, for rats fed with the casein diet containing cholesterol and the standard diet of casein. Based on the above studies, it can be concluded that addition of sardines as supplemental protein source into animal formulated diets offers nutritional benefit which improved animal weight gain and hence, account on their market value.

3 METHODOLOGY

3.1 Material

The Icelandic male capelin (*Mallotus villosus*) with weight between 0.03 – 0.04 kg and 14 – 17 cm in length were packed into 5 blocks of 20kg each, frozen soon after unloading at a harbour in East Iceland. The capelin sample was supplied by Síldarvinnslan hf, located at Hafnarbraut 6, 740 Fjarðarbyggð, Iceland and transported by truck to Reykjavik. After arrival at Matis laboratory facilities, the sample was stored at -18 ^{0}C in a cold storage unit. Other ingredients were purchased from Katla ehf, Garri ehf and local supermarkets (Kronan, Bonus and Hagkaup) including maize, wheat, and potato flour, baking powder, table salt, refined sugar, sunflower oil, guar gums, ascorbic acid (E 300), food colour (E102) and a selection of spices (ginger, garlic, cardamom, and cinnamon) in a powdered form.

3.2 Experimental design

3.2.1 Initial experiment

A pre-trial experiment was conducted in the last two weeks of December 2021 whereby, the frozen Icelandic male capelin stored at -18 ^{0}C was thawed at chilling temperature between 0 -

4^0C for 48 hours. Preparation of dried capelin powder (protein concentrate) followed procedure described in a study by Abraha (2018), with slight modification as indicated in Figure 3. The capelin was dressed by removing the gut, head, and tail. A brine solution 2% (w/v) was prepared and the prepared capelin was soaked for 30 minutes. The capelin was removed and allowed to drip in a perforated tray for 5 minutes. The capelin was then vacuum packed into a plastic bag and stored in a chilled room at temperature range 0 – 4 ^{0}C until required for use.

Steaming of the capelin was done using a Rational Self Cooking Centre, Model SCC WE 101 at 101 ^{0}C for 15 minutes and allowed to cool for 10 minutes. Thereafter, the capelin was mashed with a spoon to form a mince which was pressed with a cotton cloth about five times to release a mixture of fats and liquid. Drying of the pressed mince was done through dehydration technique at temperature 70 ^{0}C for 12 hours using a Stockli Dehydrator Non – Timer model until the mince was well dried. Finally, the dried capelin mince was ground into small powdered particles using a grinder Model HR. 1393/90/AJ, then sieved using laboratory sieve 1mm to get a fine dried capelin powder which was stored in vacuum plastic bags waiting for intended use.

3.2.2 Product formulation

Development of maize snack products incorporated with capelin dried powder at pre-trial experiment followed the procedure from a study by Mosha (2004) with a modification to align with the baking processing technique applied in the present study. The concentration of dried capelin powder added into the formulation was increased from 12.5 to 15 and 17.5 g/100g, with adjusted concentration of corn and potato flour, while other ingredients including salt, sugar, antioxidant, bicarbonates, and guar gums were maintained at constant levels. The concentration of spice recipe was 3.5% containing spices combinations ginger and garlic, ginger, and cardamom, as well as ginger and cinnamon for each formulation.

The aim of varying spices was to find a most preferred spice combination which could have an impact on masking the fish flavours and odour related to spoilage, rancidity and fishy flavour for each concentration of dried capelin powder as indicated in formulation Table 1. The ingredients in the formulations were mixed using a Hobart mixer Model K45SS at a rotating speed of 6 rpm between 10 and 15 minutes to form a soft dough which was moulded into a desired shape and baked at temperature 110 ^{0}C for 135 minutes using Dry heat Oven in Rational Self Cooking Centre. Finally, the snack products were allowed to cool, packed and stored in a plastic bag.

Table 1. Formulation of maize snack products incorporated with dried capelin powder.

Ingredients (g /100 g)	Treatment			
	Control	1	2	3
Capelin dried powder	12.5	12.5	15	17.5
Corn flour	52	52	51	49
Potato flour	30	26.5	25	24.5
Salt	1.5	1.5	1.5	1.5
Refined sugar	1.5	1.5	1.5	1.5
Ascorbic acid (E 300)	0.5	0.5	0.5	0.5
Ginger	0	2	2	2

Spice selection	0	1.5	1.5	1.5
Guar gums (E412)	1.5	1.5	1.5	1.5
Bicarbonate	0.5	0.5	0.5	0.5
Total	**100**	**100**	**100**	**100**
Water (ml)	70	70	70	70
Sunflower oil (ml)	2.5	2.5	2.5	2.5
Tartrazine solution (E102) (ml)	1	1	1	1

Note: Spice selection include garlic, cardamon and cinnamon (1.5 g/100g) for each spice

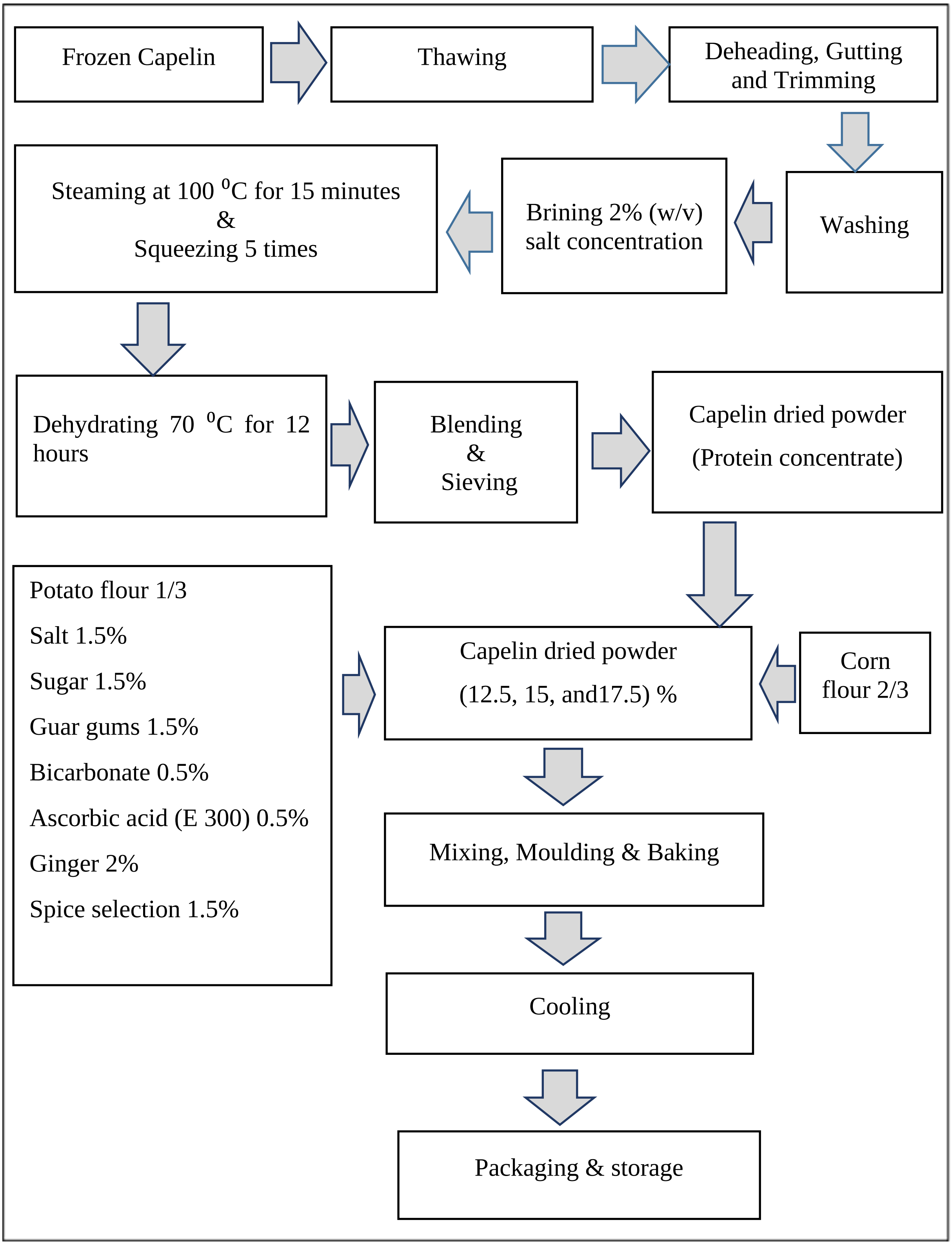

Figure 3. Flow chart of production of maize snacks incorporated with dried capelin powder and spices (garlic, cardamom and cinnamon) g/100g as adopted and modified from study by Abraha (2018)

3.2.3 Main experiment

Production of the maize snack products incorporated with capelin powder was done in experimental kitchen at Matis, by following the procedures described from the initial experiment. Ten treatments of maize snack formulations were produced including a control sample with 12.5g/100g of dried capelin powder without spices (WS). Other treatments contained 12.5, 15 and 17.5 g/100g of dried capelin powder with three different set of spices: ginger and garlic (GG), ginger and cinnamon (GCN) as well as ginger and cardamom (GCM).

The generic descriptive analysis (GDA) sensory evaluation method as per Heymann and Lawless (2013) was used to describe the odour and flavour attributes of the formulated maize snack products. A group of eight trained panellists were used to evaluate the spoilage, rancid as well as fishy flavour and odour using a scale range from 0 – 100, at the lowest concentration of capelin powder used in maize snack formulations at food sensory laboratory at Matis. Furthermore, a consumer survey (affective sensory taste method) using 10 untrained panellists from a multicultural group (GRÓ fellows from Africa, Asia, the Pacific, and Central America) screened and ranked the maize snack products attributes (appearance, colour, smell, texture and flavour) and overall liking at all concentrations of dried capelin powder using a nine-point hedonic scale.

The analysis of the total viable count, proximate and physical-chemical analysis were done at microbiological and chemical laboratory at Matis. The setup of the main experimental design is summarized in Figure 4 bellow.

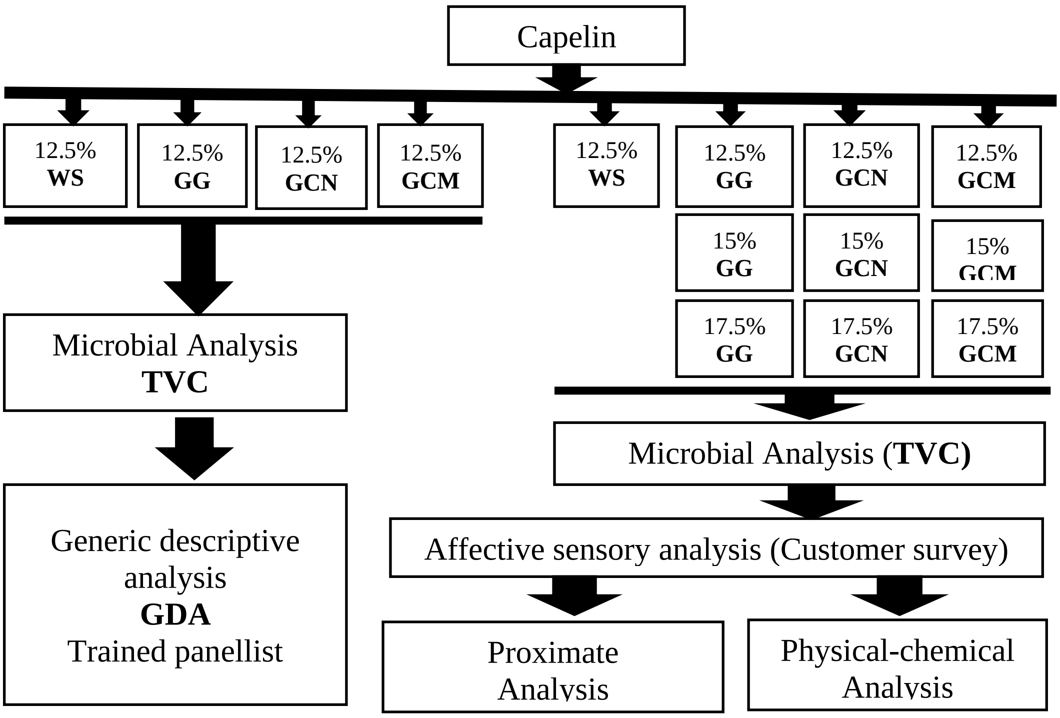

Figure 4. Flow chart demonstrating the production set up and measurement plan of maize snack products.

Physical-chemical and microbial analysis

The physical-chemical and microbial analysis of maize snack products incorporated with dried capelin powder was carried out at the chemistry laboratory at Matis. Sample preparation prior to analysis was carried out at the same laboratory. The production of control and three different batches of snack products for chemical analysis was completed in triplicate. A representative sample from each batch was selected randomly, ground and mixed mechanically to ensure the homogeneity of the selected sample.

3.2.4 Protein

The Kjedahl method was used to determine the percentage level of protein present in maize snacks incorporated with dried capelin powder. The sample was digested in sulphuric acid in presence of $CuSO_4$ as catalyst and placed in distillation unit, 2400 Kjeltec Auto Sample System. The acid solution was made alkaline by using sodium hydroxide (NaOH) solution. The ammonia was distilled into boric acid which was then titrated with sulphuric acid (H_2SO_4) solution. The nitrogen content formed was multiplied by factor 6.25 to obtain protein content in (g/100g). *Ref. ISO 5983-1:2005 and ISO 5983-2:2009 and Application for Tecator AN 300.*

3.2.5 Total lipid

The total fat determination in each formulation of maize snacks incorporated with dried capelin flour was done as per AOCS official method Ba-3-38, 2017. A ground sample was used in fat extraction with aid of petroleum ether as extraction solvent at boiling temperature between 40 – 60 ^{0}C, using Soxtherm Automatic System. Percentage of total lipid was calculated by using following equation:

$$\% \text{ Total lipid} = \left(\frac{\text{Weight of dried extraction cup - Weight of empty extraction cup}}{\text{Weight of dry sample}} \right) \text{ x } 100$$

3.2.6 Water content

The levels of water content in each formulation of maize snack products incorporated with dried capelin powder was determine by a drying technique. A dried sample was weighed into pre-dried and cooled aluminium dishes, then dried in oven at temperature ranged 103 - 105 °C for 4 hours, until a constant weight was attained. Dried sample was cooled to room temperature in a desiccator, then reweighed to measure a loss of weight due to evaporation of water from the sample.

3.2.7 Water activity (aw)

An Aqua –Lab (Decagon devices) water activity meter was used to measure the levels of water activity in each formulation of maize snack products incorporated with dried capelin powder. About 1g of ground dried maize snack products sample was weighed into plastic capsule and inserted into water activity meter for analysis. The equipment was calibrated with water prior to analysis of the maize snacks sample.

3.2.8 Ash

The ash content in each formulation of maize snack products incorporated with dried capelin powder was determined by a dry heating technique. A dried sample was weighed into pre-dried and cooled crucibles. A hot plate was used to heat the sample in crucibles until the sample became thoroughly charred, then was turned to ash at 550 °C for 3 hours in muffle furnace. Percentage ash was calculated by the following equation:

$$\% \text{ Ash} = \left(\frac{\text{Ash weight} - \text{Crucible weight}}{\text{Weight of sample}} \times 100\right)$$

3.2.9 Acidity (pH)

An Orion star A 111 pH meter was used to measure the pH in each formulation of maize snack products incorporated with dried capelin powder. About 1g of ground sample was dissolved in 10ml of deionized water to form a solution. The sample was mixed well for five minutes to form a homogeneous solution. Then an electrode was submerged into a homogeneous solution of ground powder of maize snacks incorporated with dried capelin flour until it produced a stable reading.

3.2.10 Free fatty acid (FFA)

The free fatty acid content of the maize snack products was determined using a titration method. About 10g (W) of the maize snacks were placed into a 250ml Erlenmeyer flask. About 100 ml of 2-propoanl was placed into another 250ml Erlenmeyer flask and 2 drops of phenolphthalein indicator was added. The mixture was titrated with base solution (NaOH) with volume between 0.05 to 0.06 ml until it becomes violet. The violet mixture was added into a 250ml Erlenmeyer flask containing 10g (W) of the maize snack products, mixed carefully to obtain a clear solution and a magnetic bar was added to facilitate mixing.

Finally, the mixture was titrated with base solution (NaOH) at a concentration of 0.1N until the mixture turned pink for at least 30 second. The volume (mL) of titrants consumed was recorded. The free fatty acid content was calculated using the following equation:

$$\% \text{ FFA} = \left(\frac{V \times C \times 282}{1{,}000 \times W}\right) \times 100$$

Whereby: V = Is the volume (mL) of titrants utilized
C= Is the calibrated concentration of NaOH ethanol solution
W= Is the weight (g) of the maize snack product
282= Is the molar mass (*g/mol*) of Oleic acid

3.2.11 Total oxidation value (Totox)

The total oxidation value was determined by the combined measurements of the peroxide value (PV) and Anisidine value (AnV). Fat was extracted from the maize snack products using Blight & Dyer method. The fat was treated with peroxide which oxidizes Fe2+ ions to form Fe3+ ions which was grouped and form a red complex. The colorimetric intensity of the red complex was measured at 505 nm by using CDR FoodLab instrument / reagent kit. The results obtained were expressed as meq O2/Kg and was proportional to the concentration of peroxides in maize snack products sample.

Moreover, the addition of p-anisidine which react with the aldehydes and ketones derived from secondary oxidation of fat, was used to predict the total oxidation of fat. The anisidine value (AnV) was measured by the variation in the absorbance at 366nm by using CDR FoodLab instrument / reagent kit. Finally, the total oxidation value of extracted fat was calculated using the following equation: Total oxidation value (Totox) = 2 × PV + AnV.

3.2.12 Colour detection

A Minolta Chroma Meter CR – 400 (Minolta Osaka, Japan) using the CIE Lab system was used to measure the intensity of colour on each formulation of maize snack products incorporated with dried capelin powder. The assessment of snacks colour was based on the coordinate (L*, a* and b*) whereby; L* represent lightness from black (0) and white (100), a* represent redness from red (+a) and green (–a) while b* represent yellowness from yellow (+b) and blue (–b). The white tile Lab Colour Standard was used to calibrate the equipment prior colour measurement of the snacks sample.

3.2.13 Total viable count

The aerobic plate count was determined by preparing a dilution series of the sample material according to general microbiological principles, followed by pour plating into petri dishes containing plate count agar (CPA). The samples were incubated under aerobic conditions at 30.0 ± 1.0 °C for 72 ± 6 hours.

The number of viable aerobic microorganisms per gram of sample was calculated from the number of colonies counted on selected plates and by multiplying the number of colonies obtained by the dilution factor.

3.2.14 Texture analysis

A stable micro system texture analyser was used to analyse the texture attributes of maize snack products incorporated with dried capelin powder. A round probe with test speed 2 mm/sec, pre and post-test speed of 1 mm/sec and 2 mm/sec respectively was inserted to break the snack samples at 3mm. The compression taste mode, of the texture analyser was used to measure the force in grams at a maximum peak value required to break the snacks.

3.3 Sensory analysis

The sensory evaluation was undertaken at the food sensory laboratory at Matis by a group of trained panellists. A group of eight trained panellists, were used to evaluate the spoilage, rancid as well as fishy flavour and odour using a scale 0 – 100, at the lowest intensity of capelin powder used in maize snack formulations at food sensory laboratory at Matis. Furthermore, a consumer survey to assess the sensory attributes (appearance, colour, smell, texture, and flavour) as well as overall liking of the maize snack products incorporated with dried capelin powder at increasing concentration, was done using affective sensory taste method whereby, ten untrained panellists from multicultural group were able to screen and ranked the products attributes by using a nine-point hedonic scale.

To avoid bias of the sensory taste, the sample of maize snacks incorporated with dried capelin powder, disposable containers each labelled with random three-digit codes, containing about 10g of sample were presented to the panellists in a random order. The nine-point hedonic scale was used by panellists to rank the snacks according to their preference whereby a rank of 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike, 5 = neither like nor dislike, 6 = like, 7 = like moderately, 8 = like very much and 9 = like extremely.

Clean water in a disposable cup was provided to panellists to cleanse the palate of residue particles after each test to avoid overlapping of attributes during evaluation.

3.4 Data analysis

All data were gathered in triplicate and used to generate descriptive statistics. The analysis of the generated descriptive statistics from sensory assessment was done using a Microsoft Excel-equipped statistical tool. The Student *t*-Test two sample assuming equal variance was used to compare sensory attributes of the snack product from consumer survey related to variation between groups in each treatment. Similarly, the results of water activity, acidity, proximate values, and physical-chemical were analysed using Student *t*-Test two sample assuming equal variance. The significance difference in mean was reported at a significance level $(P < 0.05)$. Furthermore, analysis of variance (ANOVA), was used to compare odour and flavour of produced maize snack products based on (fishy, spoilage and rancidity) from trained panellists.

4 RESULTS AND DISCUSSIONS

4.1 Sensory assessment

4.1.1 Flavour / Odour

The effect of increasing the concentration of dried capelin powder from 12.5, 15 and 17.5 g/100g into the snack formulation with spice combinations was investigated. About 10 untrained panellists were used to compare the three treatments with control sample based on overall liking and preference on appearance, colour, smell, texture, and flavour attributes of the snacks using a nine-point hedonic scale. The results obtained are presented in Figure 5.

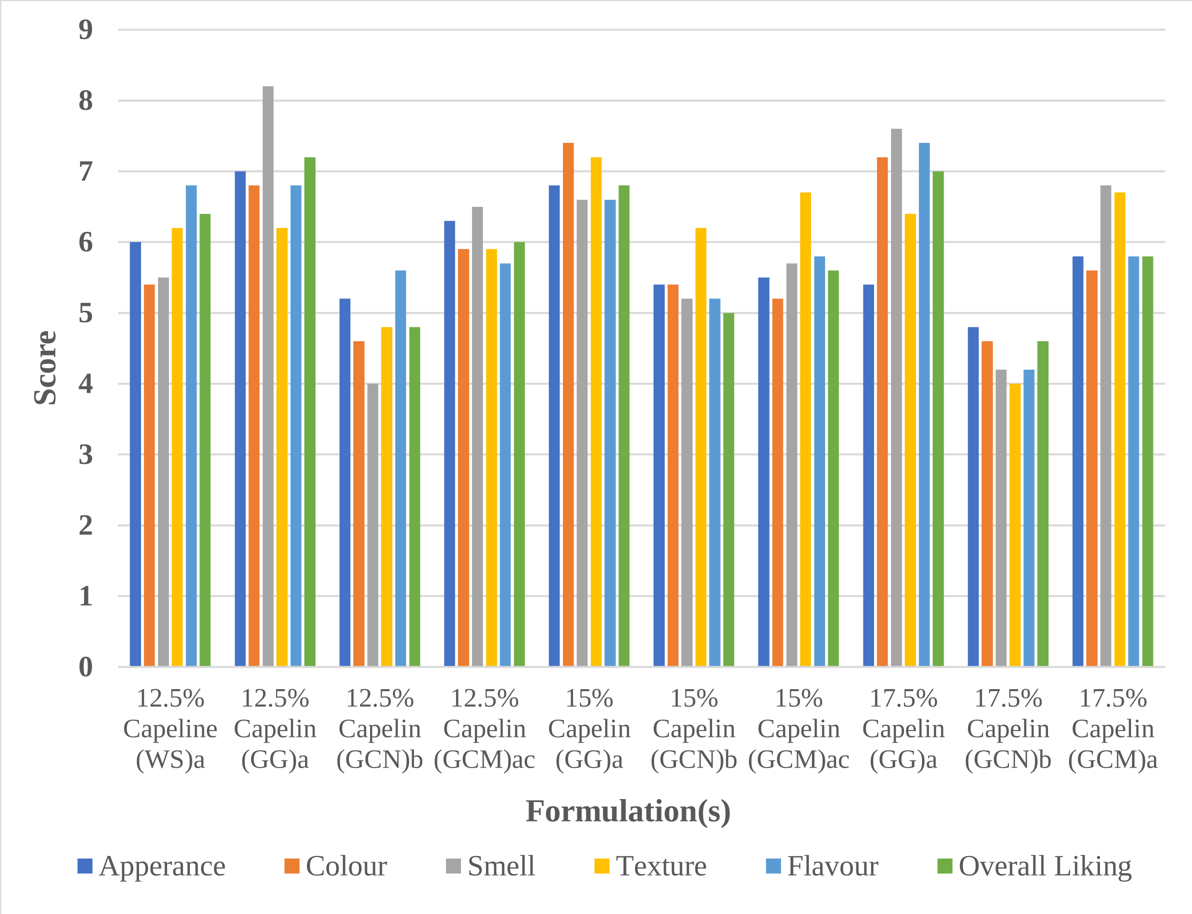

Figure 5. Customer survey on overall liking and preference of sensory attributes of maize snacks at increasing concentration of dried capelin powder). Different letters indicate significant difference at a significance level *($P < 0.05$)*.

The maize snack formulations containing dried capelin powder 12.5, 15 and 17.5 g /100g and spice combination of ginger and garlic (GG), were highly accepted by the panellists on overall liking with mean score of 7. Compared to the mean score of 6.2, 5.8 and 4.8 from control sample without spices (WS) and spice combination (GCM) and (GCN) respectively.

Furthermore, sensory attributes of the maize snacks with spices (GG) including appearance, colour, smell, texture, and flavour from similar formulations were ranked with mean score 6.4, 7.1, 7.5, 6.6 and 6.9 respectively. There was no significant difference *($P > 0.05$)* between the control sample containing dried capelin powder 12.5g/100g without spices (WS) and the formulations containing 12.5, 15 and 17.5g/100g dried capelin powder with spices (GG).

Similarly, the maize snack formulations containing 12.5, 15 and 17.5 g/100g of dried capelin powder and spice combination of ginger and cardamoms (GCM), were ranked second highest by panellists with mean score of 5.8 in overall liking. The appearance, colour, smell, texture, and flavour attributes were ranked with mean score 5.9, 5.6, 6.3, 6.4 and 5.8 respectively. In comparison to control sample containing dried capelin powder 12.5g/100g (WS), there was no significant difference (*($P > 0.05$)* observed with all three formulations containing spice (GCM). However, when the snack formulations containing dried capelin powder 12.5 and 15 g/100 with spice (GCM) compared with similar formulation containing spices (GG), there was significant difference *($P < 0.05$)*. Moreover, as the concentration of dried capelin powder, increased to 17.5 g/100g of the maize snack formulations, both spice combinations (GCM) and

(GG), were found to have no significant difference *($P > 0.05$)* in overall liking and other sensory attributes of the maize snack products.

Application of the spice combination of ginger and cinnamon (GCN) was observed to have lower preference to panellists at all concentrations of dried capelin powder incorporated into a maize snack formulation. The mean score of overall liking were ranked 4.8 while appearance, colour, smell, texture, and flavour attributes were ranked 5.1, 4.9, 4.5,5 and 5 respectively. The difference was found to be significant *($P < 0.05$)* when these formulations were compared to control sample containing dried capelin powder 12.5 g/100g (WS) and similar formulations with dried capelin powder 12.5, 15, 17.5 g/100g with spices (GG). Moreover, there was no significant difference *($P > 0.05$)* found when the spices combination (GCN) and (GCM) were used in formulations of maize snacks with an increasing concentration of dried capelin powder.

In food industry, the sensory attributes of a product play a crucial role towards customer choice, preference and acceptance of the product (Samuel, Ayoola et al., 2006; Calanche, Beltran et al., 2020). In the present study, incorporation of spices combination (GG) was found to improve both flavour and smell attributes of the maize snack products compared to (GCM) and (GCN) spice combinations.

As the concentration of dried capelin powder increased from 12.5, 15 and 17.5 g/100g, the mean score of flavour were ranked 6.8, 6.6 and 7.4 for spices combination (GG) compared to 6 of the control (WS). Similarly, the mean score of smell were ranked 8.2, 6.6 and 7.6 higher compared to 5.5 of the control (WS).

Thus, it can be argued that combination of spices in formulation of maize snack products improves the sensory attributes of the snacks including flavour and smell which accounts for its preference and acceptability to customer (Gupta, Sinha et al., 2012). The squeezing effect of steamed capelin to reduce fish oil as per study of Abraha (2018), as well as application of spices to mask the fishy odour and smell was an area of interest for the present study. The result from generic descriptive analysis (GDA), conducted by 8 trained panellists using a scale (0 – 100) on the fishy spoilage, rancid, flavour and odour attributes are demonstrated in Figure 6.

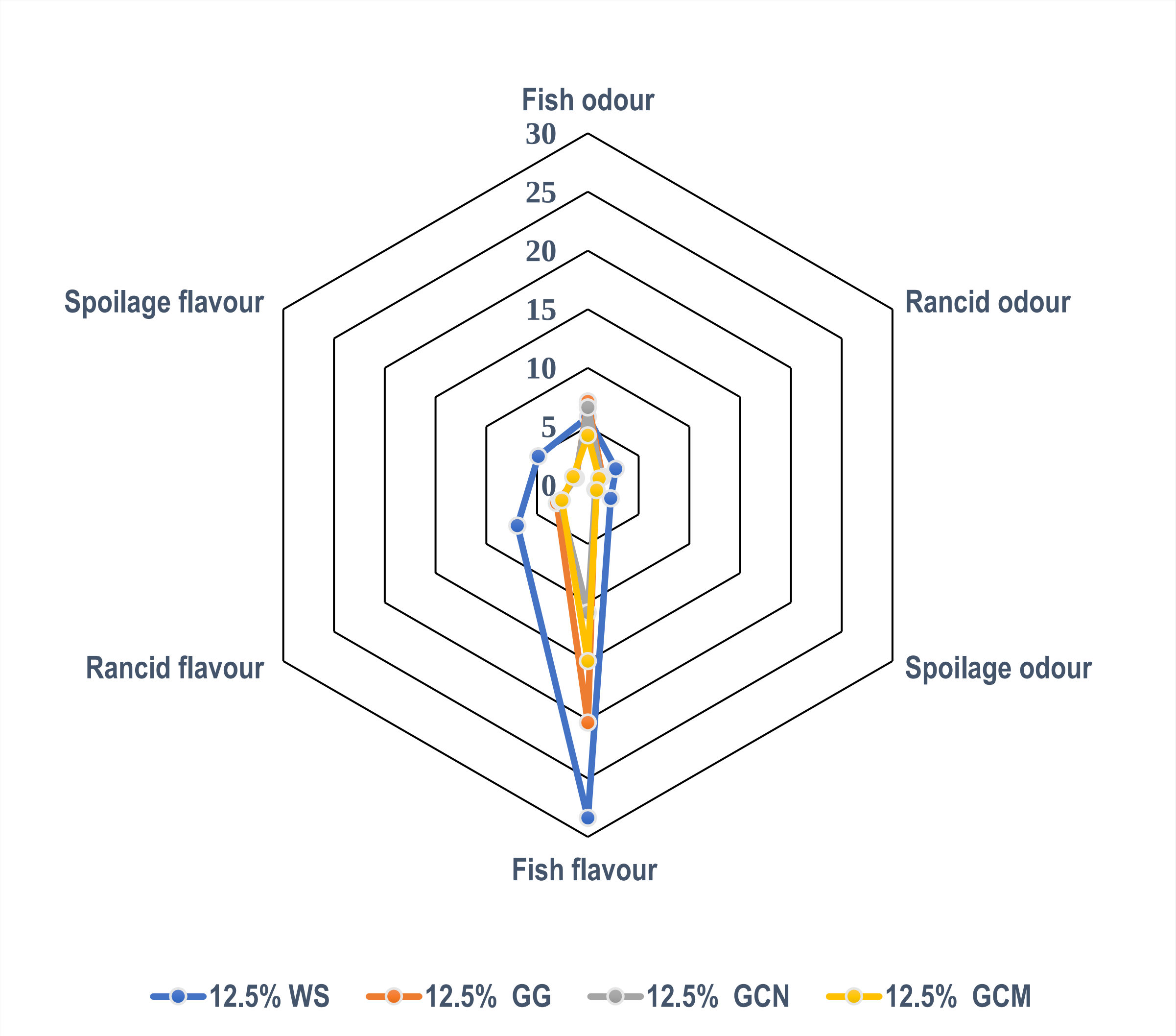

Figure 6. Assessment of trained panellists on flavour and odour attributes of maize snack products at lower concentration of dried capelin powder.

The control sample containing dried capelin powder 12.5 g/100g without spices (WS) was ranked higher in flavour attributes compared to similar concentration of dried capelin powder used in formulation containing spices. The panellists ranked the mean score of fishy, rancid and spoilage flavour in control sample 28.4, 6.9 and 4.9 respectively. Also, the rancid and spoilage odour of the control sample was ranked slightly higher with mean score 2.8 and 2.3 compared to formulations containing spices. There was no significant difference ($P > 0.05$) found between the control and all formulations containing spices.

The modified squeezing technique of the steamed capelin with cotton cloth to reduce fish oil applied in present study reduced and masked the fishy odour and flavour as reported in a study of Abraha (2018). Moreover, application of spices in food formulation such as combination ginger and cardamoms (GCM) was found to improve flavour (Senthil & Bhat, 2011), and was capable of effectively masking fishy odour and flavour at lower concentration of dried capelin powder 12.5g/100g of the snack formulations. In this study, the mean score of fishy odour and flavour of maize snacks containing spice combinations (GCM) was ranked 4.3 and 15 which is lower compared to 5.8 and 28.4 of the control sample. Likewise, the mean scores of 4.3 and 15 for fish odour and flavour for the maize snacks containing spice combinations (GCM) was lower than mean scores of 6.6 and 10.9 as well as 7.1 and 20.3 of the maize snacks containing spice combinations (GCN) and (GG) respectively.

4.1.2 Colour attributes

The colour attributes of a food product influence the customer perception of flavour and preference towards a product (Lee, Lee et al., 2013; Scotter, 2015). In the present study, the maize snacks with spice combination (GG), was ranked slightly higher in colour attribute with mean scores of 6.8, 7.4 and 7.2 as the concentration of dried capelin powder increased. The mean score of colour attribute from snacks containing spice combinations (GCM) and (GCN) were ranked between 4.6 and 5.9 at all concentration of dried capelin powder used in formulations. There were non-significant differences ($P > 0.05$) found in colour attribute of snacks between the control sample with mean score of 5.4 and all formulations containing spices.

The spices in a dried powder form tend to have a natural colour which is likely to be reflected when added into food formulations. Figure 7 indicates the original colour of the spices used in this study which was changed due to addition of 1ml of tartrazine (E102), intended to improve the appearance of the product. Scotter (2015) reported the use of food colouring to mask natural colour variations of the food as well as improve food attractiveness and visual appealing to consumer.

The highest mean score of 7 on the snacks appearance was ranked by panellists to formulation containing dried capelin powder 12.5 g/100g spice combination (GG). However, as the concentration of dried capelin powder increased in formulations, the appearance of snacks was ranked lower in all spice formulations with mean scores between 6.4 and 4.6 compared to control sample 12.5 g/100g (WS) with mean score of 6.

Dried capelin powder 17.5 g/100g in a dough from left to right (1). Cardamom (2). Cinnamon and (3) Garlic

Dried capelin powder 17.5 g/100g in a dough after addition of 1ml (E102) from left to right (1). Cardamom (2). Cinnamon and (3) Garlic

Cardamom

Cinnamon

Garlic

Figure 7. Photographs of the appearance of maize snacks dough with natural spice colour, artificial food colour and its final products.

4.2 Physical results

4.2.1 Colour measurement

The colour determination was studied at different concentrations of dried capelin powder used in maize snack formulations. The lightness and redness (L* and a*) values increased with increased concentration of dried capelin powder, while the yellowness (b*) value decreased, as indicated in Table 2. At the lowest concentration of dried capelin powder (12.5 g/100) the yellowness colour (b*) value of snacks from spice combinations (GCM), (GCN) and (GG) were higher with mean scores of 39.1, 34.4 and 41.6 respectively, compared to control sample with mean score of 14.2.

The increased yellowness (b*) value is linked to Maillard reaction occurring due to heating effect (Chakraborty, Sahoo et al., 2020), whereby the reduced sugar and free amino acids from fish react to form a complex which browns with addition of fish protein to snack formulations (Mohammed, Babiker et al., 2016; Abraha, Mahmud et al., 2018; Leiva-Valenzuela, Quilaqueo et al., 2018). Apart from that, the low levels of water content and baking temperature between 100 and 110 ^{0}C can stimulate the browning reaction of the maize snack products (Kawai, Hando et al., 2016; Leiva-Valenzuela, Quilaqueo et al., 2018).

Additionally, as the concentration of dried capelin powder increased to 15 g/100g, the yellowness (b*) value of the snacks decreased to a mean score of 6.8, 5.1 and 10.5 for the spices combination (GCM), (GCN) and (GG) respectively. The results are in line with previous studies which report about diminishing of the intensity of luminosity and yellowness colour due to increased effect of fish in formulation (Sawant, Thakor et al., 2012; Chakraborty, Sahoo et al., 2020). However, in this study the decreased patterns of yellowness (b*) value were not clear as the intensity of dried capelin powder increased to 17.5 g/100g.

The mean score of yellowness colour (b*) value were 9.1, 7.4 and 14.6 for the spices combination (GCM), (GCN) and (GG) respectively were higher than the mean score of 6.8, 5.1 and 10.5 when the concentration of dried capelin powder 15 g/100g was used in snacks formulation.

Table 2. Measurement of colour attribute of maize snack products with increased intensity of dried capelin powder in different spice formulation

Colour value	12.5 g/ 100g				15 g/ 100g			17.5 g/ 100g		
	WS	GCM	GCN	GG	GCM	GCN	GG	GCM	GCN	GG
L*	99.4	65.9	62.5	71.8	99.3	91.0	97.8	99.1	96.2	98.7
a *	-7.0	-5.4	-1.8	-6.4	-1.0	2.8	-3.1	-1.6	2.4	-3.9
b*	14.2	39.1	34.4	41.6	6.8	5.1	10.5	9.1	7.6	14.6

4.2.2 Texture

Assessment of breaking strength of the maize snacks from the selected spices formulation were studied and results are demonstrated in Figure 8.

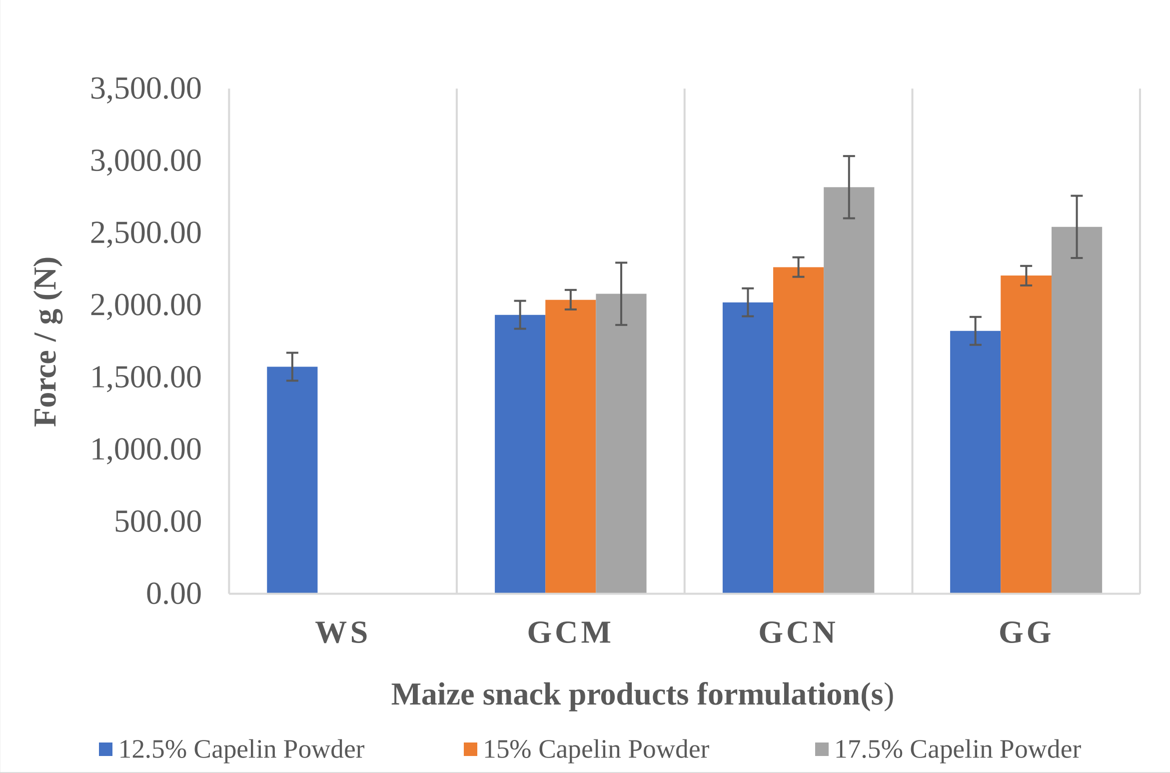

Figure 8. Texture attributes of the maize snack products with increased concentration of dried capelin powder

The minimum force 1,573N was required to break the control sample with dried capelin powder 12.5 g/100g (WS). Application of spices into snack formulations were observed to increase the hardness textural attribute of the snacks. The mean value of force 1,821, 1,933 and 2,019N from spice formulation (GG), (GCM) and (GCN) respectively, were required to break the snacks with similar concentration of dried capelin powder as control sample.

As the concentration of dried capelin powder increased to 15 and 17.5 g/100g, the texture was harder and force between 2,264 and 2,817N was required to break the snacks. The result aligns with study by Nurul (2009), which observed increased hardness of fish cracker due to increased proportion of fish flour. Similarly, Leiva et al. (2018), reported an increased firmness texture attributes of biscuit due to increased and decreased effect of protein and moisture contents respectively. In general, the maize snack products with 15 and 17.5 g/100g of dried capelin powder could be suitable and acceptable to active group of youth and adult while children and older adults could require maize snacks with concentration of dried capelin 12.5 g/100g which were observed to have a soft texture.

The result from the consumer survey indicated that texture attributes of snacks from spice combinations (GG) and (GCM) with concentration of 15 and 17.5 g/100g of dried capelin powder were liked and ranked higher with mean scores between 6 and 7.2 closer to 6.2 of the control sample. Moreover, other spice combinations were ranked slightly lower than the control sample while non-significant ($P > 0.05$) difference was found in texture attributes between each treatment.

4.3 Proximate results

4.3.1 Water content

Application of hot air in baking cereal snacks can provide products with moisture content below 5% (Leiva-Valenzuela, Quilaqueo et al., 2018). The low levels of water content contribute positively towards the dryness and crunchy texture attributes which are vital to ensure the quality and shelf-life stability of baked cereal-based snack products (Cook & Johnson 2009; Rico, González-Paramás et al., 2020).

In the present study the levels of water (Table 3) were found to be 1.8 and 2.0 g/100g for the formulations containing dried capelin powder at concentration of 15 and 12.5 g/100g respectively. However, as the concentration of capelin powder increased to 17.5 g/100g the levels of water content also increased to 2.2 g/100g. The results were in harmony with a study by Abraha (2018), which reported a decrease moisture content to 1.96% as dried fish powder added into the biscuit formulations. Additionally, increased concentration of dried capelin powder into the maize snack formulations were observed to have a non-significant difference ($P > 0.05$) in water contents.

Table 3.Water activity, acidity (pH) and proximates in maize snacks incorporated with dried capelin powder.

Level of capelin dried powder (g/100g)	Analysed parameters					
	Water activity *(aw)*	Acidity (pH) level	Water (g/100g)	Ash (g/100g)	Protein (g/100g)	Total fat (g/100g)
12.5	0.066 ± 0.0	3.7 ± 0.01	2.0	3.3	10.3	4.0
15.0	0.070 ± 0.03	3.7 ± 0.06	1.8	3.5	12.4	3.5
17.5	0.074 ± 0.01	4.4 ± 0.04	2.2	3.8	14.2	4.6

The results are means ± standard deviation of triplicate analysis of two lots (n=3).

Akhade et al. (2016) and Immaculate et al. (2012) reported that the ability to reduce the water contents in fish to a lower proportion depended on the efficiency of drying method applied. The baking technique applied produce sufficient heat energy to dry and reduce the water contents of the maize snack products. Furthermore, the dried capelin powder contained the bound water remained after the drying process. Thus, an attempt to increase concentration of dried capelin powder into the snack formulations will correspondingly increase the moisture contents in produced maize snack products.

Moreover, increased levels of water content in maize snack products can be linked with the presence of hydrophilic groups surrounding the protein structure. Zayas (1997) reported the hydrophilic group have ability to interact and react with charged particles such as water to form a hydrogen bond that bind and retain water within food matrix. As the concentration of protein increases, the more hydrophilic group become available and sufficient water content can be absorbed and retained which lead to increase in moisture contents of the maize snack products.

In addition, the proportion of potato flour, sugar and salts used in formulation account to the lower level of water contents. The starch from potato was reported to have 20% moisture content and have water binding capacities (Belitz, Grosch et al., 2008). The potato and corn flour at ratio of (1:2) respectively were the main ingredients of the snacks produced. Such ratio of potato flour and other dried ingredients would likely increase the water binding capacity which lead to a product with lower levels of moisture content in produced maize snack products.

4.3.2 Water activity (aw)

Stability of food products depends on the level of water activity (Chirife, Zamora et al., 2006). In general the snack food based products are dried to water activity <0.7, hence categorized as low water activity food (Gurtler, Doyle et al., 2014).

The results revealed very low levels of water activity with mean scores of (6.6, 7 and 7.4)x10^{-2} for the maize snack products containing 12.5, 15 and 17.5 g/100g of dried capelin powder respectively. The results were in line with microbiological safety aspects of food products which inhibit both enzymatic activity, growth and survival of spoilage and pathogenic microorganisms particularly *Zygosaccharomyces rouxii* (yeast), *Xeromyces bisporus* (fungi) and osmophilic yeasts that could tolerate at < 0.6 water activity level (Brown, 1976; Abramovič, Jamnik et al., 2008; Cook & Johnson, 2009).

Bauchat et al. (2013), reported that the lower level of water activity in dried food was associated with heating effect, dryness of raw material, and level of solutes added to the food formulations. In this study about 3% of the ingredients were salt and sugar while 97% of the remaining ingredients were in form of dried powder. The formulations that were subjected to dry heat treatment (110 ^{0}C for 135 minutes) produced a dried maize snack product with lower water activity with a slightly increasing effect as the concentration of fish increased (Fontana, 2000).

Labuza *et al* (1985), observed a decrease of water activity of salt solutions when they were under heat treatments. Similarly Jay (1996), reported the use of humectants, particular salt and sugar, to reduce water activity while maintaining the moistness texture of the dough. Also, the use of guar gums as water binding agents and spices were observed to decrease the amount of free water in produced maize snack products. Furthermore, a study by Chakraborty et al. (2020) reported the strong relationship between water content and water activity of a product. Thus, it can be argued that the observed water content (2.0 ± 0.12), (1.8 ± 0.11) and (2.2 ± 0.1) contributed to low level of water activity of the produced maize snack products. The increased concentration of dried capelin powder in the formulations were found to have non-significant effect ($P > 0.05$) on water activity of the produced maize snack products.

4.3.3 Acidity (pH)

The acidity (pH) levels of the formulated maize snack products was studied and results revealed that the mean scores of the acidity level were (3.7 ± 0.01) and (3.7 ± 0.06) for the formulations containing 12.5 and 15 g/100g of dried capelin powder. A slight increase of the acidity (pH) level to 4.4 ± 0.04 was observed as the concentration of dried capelin powder increased to 17.5 g/100g of the snack formulations. The results were slightly lower compared to acidity level between 5.4 and 7.5 found to wider range of cereals base baked products (Cook & Johnson, 2009).

Since the acidity (pH) levels of the formulated maize snack products were < 4.5, it is considered weakly acidic, capable of inhibiting enzymatic and microbial activity and hence prolonging the shelf life stability of snack products (Guiné, 2018). Moreover, the increased concentration of dried capelin powder in the maize snack formulations were observed to have non-significant difference ($P > 0.05$) in acidity (pH) levels of the produced maize snack products.

4.3.4 Ash

The level of ash contents in produced maize snack products were observed to increase with increased concentration of dried capelin powder. About 3.3, 3.5 and 3.8 g/100g of the mineral contents were observed when 12.5, 15 and 17.5 g/100g of dried capelin powder incorporated into the formulation. All formulations of the maize snacks were found to be not significantly different ($P > 0.05$) in ash contents. The ash contents are strongly associated with mineral compositions (Udensi, Odom et al., 2012). The increased levels of ash content in produced maize snacks due to increased concentration of dried capelin powder indicates the availability of the wider range of minerals which could offer better nutrients to the targeted populations.

The results for ash were in harmony with findings from a study by Masha et al. (2000) which reported increased ash content of 3.9% when dried powdered sardines and millets were incorporated into a nutritious snack products. Similarly, increased ash content from 3.99 to 5.94% were reported when dried fish was added into fish crackers (Huda, Leng et al., 2010). However, the findings above were lower compared to (21 ± 0.09) and (23 ± 0.1) % of ash content in dried capelin powder (Aberoumand, 2011). Hence, it can be argued that as the concentration of dried fish utilised in food snack formulations increased, the levels of ash contents also increased which enrich the snacks with minerals contents and promote better nutrition to consumer (King, 2002; Nurul, Boni et al., 2009).

4.3.5 Protein

Addition of dried capelin powder increased the protein content of the maize snack products. The protein profile of the snack products was 10.3, 12.4 and 14.2 for the formulations containing 12.5, 15 and 17.5 g/100g concentration of dried capelin powder respectively. The difference in protein contents of the maize snack products was not significant ($P > 0.05$) as the concentration of dried capelin powder increased into the snack formulations.

Aberoumand (2011) reported the presence of 69.6 ± 0.01 and 71.1 ± 0.02 % protein in dried capelin powder. This proportion of protein content made fish to be a vital ingredient for production of nutritious ready-to-eat snack food based products (Chakraborty, Sahoo et al., 2020). The results of protein content were closer to 11.85, 10.21 9.8 and 9.21% protein content reported when dried fish powder from tuna, sardines, tilapia and salmon respectively, were incorporated to produce extruded snack products at 9% level of fish powder (Goes, Souza et al., 2015). However, the results were extremely low compared to 28% protein content of the extruded snacks formulated containing 30% level of dried blanched lizard fish powder (Ganesan, Rathnakumar et al., 2017). Thus, it can be argued that the increased concentration of fish dried powder into food snack formulations have positive effects on the protein contents. Also, additional of fish powder improved the nutritional profile of the produced cereal based snack products (Chakraborty, Sahoo et al., 2020).

4.3.6 Total fat

The total fat contents of the maize snacks ranged from 4.0 to 4.6 g/100g for the snack formulations containing 12.5 and 17.5 g/100g of dried capelin powder. The difference in total fat content was not significant ($P > 0.05$) with increased concentration of dried capelin powder in the maize snack formulations. The results of total fat were lower compared to 11.6 ± 0.04 and 12.2 ± 0.27% of the dried capelin powder (Aberoumand, 2011). The decrease of total fat contents in produced maize snack products associated with the use of fish which were removed head and visceral which contain a large proportion of fat. Overall, the fish muscles, head and visceral contain a large proportion of fat (Orlova, Rudneva et al., 2010; Rai, Swapna et al., 2012; Secci & Parisi, 2016). Thus, the removal of guts and head from the capelin fish used in present study could account on the lower level of the fat content in produced maize snack products.

Similarly, the effect of squeezing the steamed capelin five times using cotton cloth in the present study was observed to reduce the levels of fat contents in fish muscles which could also account for the lower fat contents of the produced maize snack products. Interestingly, there was a slightly lower level of fat 3.5 g/100g observed when 15 g/100g of dried capelin powder used in formulations compared to 4.0 g/100g at lower concentration 12.5 g/100g of dried capelin powder. Huda et al. (2010) reported that the contribution of the fat content into the products highly depends on the concentration of fat in part of fish or material used in product formulation. Based on that, it is likely that the portion of dried capelin powder taken into this formulation had slightly less fat content compared to the portions taken into other formulations.

4.4 Chemical and microbial results

The chemical and microbial data of the maize snacks were studied, and the results are summarised in Table 4.

Table 4. The chemical and microbial data of the maize snack products with increased concentration of dried capelin powder

Level of capelin dried powder (g/100g)	Analysed parameters				
	Free fatty acid of the oil (g/100g)	Anisidine Value	Peroxide Value meq of PV/kg of fish oil	Totox (meq/kg)	Total viable count (CFU/g)
12.5	12.14	14.2	24	62.2	80
15.0	8.92	12.5	9.7	31.9	10
17.5	8.12	4.4	12.9	30.2	40

4.4.1 Free fatty acid

Fish is a potential source of lipids containing fatty acids which have a multiple nutritional and health benefits to humans (Chow, 2007; Rubio-Rodríguez, Sara et al., 2012). Incorporation of fatty acid into the diet was linked with normal growth and development of cell and tissue as well as moderate disease risk including diabetes and hypertension (Bell, Henderson et al., 2002; Singh, Majumdar et al., 2014).

In the present study, the extracted oil from the produced maize snacks observed to have 12.14, 8.92 and 8.12 g/100g of free fatty acids contents with increased concentration of dried capelin powder into maize snack products formulations. The coefficient of multiple determination (R^2) was -0.95 which implies a negative relevance between increased intensity of dried capelin powder and the yield of the free fatty acid from the produced maize snack products. A study by Kuna et al. (2013) reported a decrease of fatty acids of fish mice from 2.4% to 0.1% for eicosapentaenoic acid (EPA) and 6.3% to 0.3% for docosahexaenoic acid (DHA) due to extrusion effect to of the corn snacks. Such proportional reduction of fatty acids was highly linked with the mixing effect of the fish mince with other ingredients in particular flours.

4.4.2 Total oxidation value (TOTOX)

Mourente et al. (2007) reported that the polyunsaturated fatty acids (PUFA) are among the essential fatty acids present in fish. The breakdown of PUFA under presence of high temperature, oxygen, light and metal compounds resulted in production of hydroperoxide, aldehydes and ketones (Rubio-Rodríguez, Sara et al., 2012).

The presence of hydroperoxide, acid value and thiobarbituric acid (TBA) were highly used as parameters to describe the total oxidation of oil. Similarly, presence of hydroperoxide it determined the extent at which the rancidity had developed in a produced product (Jensen & Risbo, 2007; Tiwari, Gunasekaran et al., 2011).

The results revealed considerable rancidity, > 20 meq of PV/kg of fish, to all snacks formulations. About 62.2, 31.9 and 30.2 meq/kg of the total oxidation value were found in the snack formulations containing 12.5, 15 and 17.5 g/100g of dried capelin powder respectively. High level of rancidity 62.2 meq/kg was found in the formulation containing 12.5 g/100g of dried capelin powder. This could be influenced by presence of 12.14 g/100g of free fatty acids of the oil which was broken down to produce hydroperoxide compounds with peroxide value 24 meq of PV/kg of fish oil. The observed level of peroxide value was above the range (10 – 20) meq of PV/kg of fish oil and it indicates a development of early oxidative rancidity (Haque, Kamruzzaman et al., 2013; Abraha, Samuel et al., 2017; Abraha, Mahmud et al., 2018).

The presence of higher level of polyunsaturated fatty acids content in fish muscles incorporated in corn flour to produce extruded corn fish snacks observed to have higher peroxide value which indicate presence of rancidity (Shahmohammadi, Bakar et al., 2016). Moreover, the peroxide value of 9.7 and 12.9 meq of PV/kg of fish oil for the maize snack formulations containing 15 and 17.5 g/100g of dried capelin powder. The results were within the range of acceptable limits, and it can be argued that the heating effect produced minimum lipid oxidation which resulted in a considerable oxidative rancidity (Shaviklo, Olafsdottir et al., 2011).

Moreover, the lower levels of moisture contents (less than 2-3%) and water activity just below and above optimum value (0.6) were observed to trigger the rate of lipid oxidation in most of dried food products (Jensen & Risbo, 2007). Correspondingly, the water activity < 0.3 was reported to offer protection to food products against non-enzymatic browning, lipid oxidation, enzymatic activity and microbial growth (Belitz, Grosch et al., 2008). The results indicate that both water activity and moisture contents of all formulations ranged from (0.066 ± 0.0) to (0.074 ± 0.01) and (1.8±0.11) to (2.2 ± 0.0) % respectively. The results were extremely low compared to moisture content (2 -3%) and water activity (0.3 -0.6) proposed from previous studies. Thus, it can be argued that there was a presence of considerable proportion of rancidity influenced by dryness effect at all concentration of dried capelin powder used in production of maize snack products.

4.4.3 Total viable count

The microbiological status of produced maize snack products was studied by assessing the total viable count (TVC) from all formulations. The results suggest that total number of microorganisms were 80, 10 and 40 (CFU/g) for the maize snack formulations containing dried capelin powder at concentration of 12.5, 15 and 17.5 g/100g respectively. Raja et al. (2014) reported a lower number of microbial count between 2.21 ± 0.29^{e} and 5.46 ± 0.04^{e} (log CFU/g) when fish meat incorporated with rice, corn, black gram and peanut flour to produce extruded fish curl at ambient temperature storage for the duration of 29 days after production.

Generally, dried food products are less vulnerable to microbial contamination (Rand, Pennington et al., 1991). The lower moisture content < 3% and water activity <0.3 observed in produced maize snack products undermine both the enzymatic and growth of spoilage and pathogenic microorganisms ensure shelf life stability of product (Jay, Loessner et al., 1996; Cook & Johnson, 2009). Likewise, the lower number of total viable count <100 (log CFU/g) in all levels of snack formulations indicates that the hygiene and sanitary practices were highly considered during the production process which assure the safety of the product. Pahor et al. (2012) reported adherence to good hygiene practice (GHP) and good manufacture practice (GMP) in food processing lines contributes to safety of produced products. Thus, it can be argued that the safety, taste and health aspects advocated by Secci et al (2016) were key aspects considered in production of maize snacks incorporated with dried capelin powder to attain the quality aspect of the snack products.

5 CONCLUSIONS

Production of maize and fish-based snack products is a platform that could increase utilisation of underutilised capelin fish in food supply chains. In the present study, the formulations of snack products with spices combination ginger and garlic (GG) were ranked slightly higher in smell, colour and flavour sensory attributes than control sample without spices (WS) and formulations with spices combination ginger and cardamoms (GCM), ginger and cinnamon (GCN). Overall, formulation with spices combination (GG) were highly accepted by consumers, however the texture and appearance at concentration 12.5 and 17.5 g/100 of dried capelin powder respectively, need to be improved to suit the preference of the target market.

In addition, the maize snack products were a good source of protein, ash, total fat and free fatty acids. As expected, the protein profile of the maize snack products was increased 10.3 and 14.2 g/100g, which is close to the protein level in wheat, due to increased concentration of dried capelin powder. These levels of protein are sufficient to offer better nutrition to vulnerable populations of children and active groups who require a reasonable proportion of dietary proteins to promote their growth. Finally, the optimum utilisation of underutilised fish resources will assure availability of quality and cost-effective nutritious proteins sources to the community. Consequently, this will contribute towards food security and health improvement.

REFERENCES

Aberoumand, A. (2011). Proximate composition for assay of quality of some fishes meals. *Annals Food Science and Technology* 12(1): 35-38.

Abraha, B., A. Mahmud, et al. (2018). Production of biscuit from Chinese sturgeon fish fillet powder (Acipeneser sinensis): A snack food for children. J*ournal of Aquatic Food Product Technology* 27(10): 1048-1062.

Abraha, B., A. Mahmud, et al. (2018). Production and quality evaluation of biscuit incorporated with fish fillet protein concentrate. *Journal of Nutrition* 8(6): 1000744.

Abraha, B., M. Samuel, et al. (2017). A comparative study on quality of dried anchovy (*Stelophorus heterolobus*) using open sun rack and solar tent drying methods. *Turkish Journal of Fisheries and Aquatic Sciences* 17(6): 1107-1115.

Abramovič, H., M. Jamnik, et al. (2008). Water activity and water content in Slovenian honeys. *Food Control* 19(11): 1086-1090.

Adeyeye, S. A. O. (2019). Smoking of fish: A critical review. J*ournal of Culinary Science & Technology* 17(6): 559-575.

Akande, B. and Y. Diei-Ouadi (2010). Post-harvest losses in small-scale fisheries. *Food and Agriculture Organization of the United Nations.*

Akhade, A., J. Koli, et al. (2016). Functional properties of fish protein concentrate extracted from ribbon fish, Lepturacanthus savala by different methods. *International Journal of Processing and Post Harvest Technology* 7(2): 1-9.

Belitz, H.-D., W. Grosch, et al. (2008). *Food Chemistry*. Springer Science & Business Media.

Bell, J. G., R. J. Henderson, et al. (2002). Substituting fish oil with crude palm oil in the diet of Atlantic salmon (*Salmo salar*) affects muscle, fatty acid composition, and hepatic fatty acid metabolism. *Journal of Nutrition* 132(2): 222-230.

Bille, P. G. and R. H. Shemkai (2006). Process development, nutrition and sensory characteristics of spiced-smoked and sun-dried dagaa (*Rastrineobola argentea*) from Lake Victoria, Tanzania. *African Journal of Food, Agriculture, Nutrition and Development* 6(2).

Brown, A. (1976). Microbial water stress. *Bacteriological Reviews* 40(4): 803-846.

Calanche, J. B., J. A. Beltran, et al. (2020). Aquaculture and sensometrics: the need to evaluate sensory attributes and the consumers' preferences. *Reviews in Aquaculture* 12(2): 805-821.

Chakraborty, P., S. Sahoo, et al. (2020). Marine lizardfish (*Harpadon nehereus*) meal concentrate in preparation of ready-to-eat protein and calcium rich extruded snacks. *Journal of Food Science and Technology* 57(1): 338-349.

Chaula, D., H. Laswai, et al. (2019). Fatty acid profiles and lipid oxidation status of sun dried, deep fried, and smoked sardine (*Rastrineobola argentea*) from Lake Victoria, Tanzania. *Journal of Aquatic Food Product Technology* 28(2): 165-176.

Chirife, J., M. C. Zamora, et al. (2006). The correlation between water activity and % moisture in honey: Fundamental aspects and application to Argentine honeys. *Journal of Food Engineering* 72(3): 287-292.

Chow, C. K. (2007). *Fatty acids in foods and their health implications*. CRC press.

Cook, F. K. and B. L. Johnson (2009). *Microbiological spoilage of cereal products. Compendium of the microbiological spoilage of foods and beverages*. Springer: 223-244.

Eik, L., G. Kifaro, et al. (2008). Productivity of goats and their contribution to household food security in high potential areas of East Africa: A case of Mgeta, Tanzania. *African Journal of Food, Agriculture, Nutrition and Development* 8(3): 278-290.

FAO (2007). FID/CP/URT. *National Fishery Sector Review. Country profile, United Republic of Tanzania.* Food and Agriculture Organisation of United Nation. FAO, Rome, Italy.

FAO (2016). AQUASTAT. *Country profile, United Republic of Tanzania.* Food and Agriculture Organisation of United Nation. FAO, Rome, Italy.

FAO (2020) *The State of World Fisheries and Aquaculture; Sustainability in Action*. United Nation Food and Agriculture Organization. Rome , Italy.

Fontana, A. J. (2000). Understanding the importance of water activity in food. *Cereal Foods World* 45(1): 7-10.

Ganesan, P., K. Rathnakumar, et al. (2017). Improvement of nutritional value of extruded snack product by incorporation of blanched dried fish powder from sardine and Lizard fish and selection by organoleptic evaluation. *Journal of Entomology and Zoology Studies* 5(6): 2552-2554.

Goes, E. S. d. R., M. L. R. d. Souza, et al. (2015). Extruded snacks with the addition of different fish meals. *Food Science and Technology* 35: 683-689.

Guiné, R. (2018). The drying of foods and its effect on the physical-chemical, sensorial and nutritional properties. *International Journal of Food Engineering* 2(4): 93-100.

Gupta, E., J. Sinha, et al. (2012). Utilization of dehydrated herbs in the formulation of value added snack “rice flakes mix”. *Journal of Food Processing Technology* S1-002. doi 10: 2157-7110.

Gurtler, J. B., M. P. Doyle, et al. (2014). *The microbiological safety of low water activity foods and spices*. Springer.

Haque, E., M. Kamruzzaman, et al. (2013). Assessment and comparison of quality of solar tunnel dried Bombay duck and silver pomfret with traditional sun dried samples. *International Journal of Nutrition and Food Sciences* 2(4): 187-195.

Hasselberg, A. E., I. Aakre, et al. (2020). Fish for food and nutrition security in Ghana: Challenges and opportunities. *Global Food Security* 26: 100380.

Heymann, H. and H. T. Lawless (2013). *Sensory evaluation of food: principles and practices*. Springer Science & Business Media.

Hjalmarsson, G. H., J. W. Park, et al. (2007). Seasonal effects on the physicochemical characteristics of fish sauce made from capelin (*Mallotus villosus*). *Food Chemistry* 103(2): 495-504.

Huda, N., A. L. Leng, et al. (2010). Chemical composition, color and linear expansion properties of Malaysian commercial fish cracker (keropok). *Asian Journal of Food and Agro-Industry* 3(05): 473-482.

Ibengwe, L. and D. M. Kristófersson (2012). Reducing post-harvest losses of the artisanal dagaa (*Rastrineobola argentea*) fishery in Lake Victoria Tanzania: A cost benefit analysis. *International Institute of Fisheries Economics and Trade*, Oregon State University.

Immaculate, J., P. Sinduja, et al. (2012). Biochemical and microbial qualities of S*ardinella fimbriata* sun dried in different methods. *International Food Research Journal* 19(4).

Isaacs, M. (2016). The humble sardine (small pelagics): fish as food or fodder. A*griculture & Food Security* 5(1): 1-14.

January, M. and H. P. Ngowi (2010). *Untangling the nets: The governance of Tanzania's marine fisheries*. South African Institute of International Affairs.

Jay, J. M., M. Loessner, et al. (1996). *Modern food microbiology*. Chapman Hall.

Jensen, P. N. and J. Risbo (2007). Oxidative stability of snack and cereal products in relation to moisture sorption. *Food Chemistry* 103(3): 717-724.

Kadagi, N. I., N. Wambiji, et al. (2021). Challenges and opportunities for sustainable development and management of marine recreational and sport fisheries in the Western Indian Ocean. *Marine Policy* 124: 104351.

Kawai, K., K. Hando, et al. (2016). Effect of stepwise baking on the structure, browning, texture, and in vitro starch digestibility of cookie. *Food Science and Technology* 66: 384-389.

King, M. A. (2002). Development and sensory acceptability of crackers made from the big-eye fish (*Brachydeuterus auritus*). *Food and Nutrition Bulletin* 23(3): 317-320.

Kolding, J., P. van Zwieten, et al. (2019). *Freshwater small pelagic fish and their fisheries in major African lakes and reservoirs in relation to food security and nutrition*. Rome: FAO.

Kulwijila, M., Z. S. Masanyiwa, et al. (2012). Impacts of Artisanal Fishing to the Livelihoods of Small Scale Fishing Communities in Lake Victoria in Ukerewe District, Tanzania. *International Journal of Research in Chemistry and Environment* 2(3): 75-83.

Kuna, A., N. L. Devi, et al. (2013). Utilization of fish powder in ready-to-eat extruded snacks. *Fishery Technology* 50: 245 - 250.

Kurien, J. (2004). Fish trade for the people. Toward understanding the relationship between international fish trade and food security. Rome: FAO.

Kweka, J., J. Musa, et al. (2006). The linkages between trade development and poverty reduction. *Economic and Social Research Foundation (ESRF)*.

Labuza, T., A. Kaanane, et al. (1985). Effect of temperature on the moisture sorption isotherms and water activity shift of two dehydrated foods. *Journal of Food Science* 50(2): 385-392.

Larsen, R., K.-E. Eilertsen, et al. (2011). Health benefits of marine foods and ingredients. *Biotechnology Advances* 29(5): 508-518.

Lee, S.-M., K.-T. Lee, et al. (2013). Origin of human colour preference for food. *Journal of Food Engineering* 119(3): 508-515.

Leiva-Valenzuela, G. A., M. Quilaqueo, et al. (2018). Effect of formulation and baking conditions on the structure and development of non-enzymatic browning in biscuit models using images. *Journal of Food Science and Technology* 55(4): 1234-1243.

Lopetcharat, K., Y. J. Choi, et al. (2001). Fish sauce products and manufacturing: a review. *Food Reviews International* 17(1): 65-88.

Louala, S., S. Hamza-Reguig, et al. (2011). Effects of highly purified sardine proteins on lipid peroxidation and reverse cholesterol transport in rats fed a cholesterol-rich diet. *Journal of Functional Foods* 3(4): 321-328.

Mahgoub, O., I. T. Kadim, et al. (2005). Evaluation of sun-dried sardines as a protein supplement for Omani sheep. *Animal Feed Science and Technology* 120(3-4): 245-257.

Mbunda, A. E., S. Arason, et al. (2013). The quality change in smoked and dried fresh water sardine (*Rastrineobola argentea*) and marine pelagic fish (capelin) as influenced by processing methods. *United Nations University Fisheries Training Programme*: Iceland.

Mgawe, Y. (2009). Post-harvest fish loss assessment on Lake Victoria sardine fishery in Tanzania (*Rastrineobola argentea*). *FAO Fisheries and Aquaculture Report* (904): 85-96.

Mhongole, O. J. and M. P. Mhina (2012). Value addition- hot smoked Lake Victoria sardine (*Rastrineobola argentea*) for human consumption. *International Institute of Fisheries Economics and Trade*.

Mkunda, J. J., B. Chachage, et al. (2019). Consumers' product knowledge and attitudes as determinants of buying intention of processed sardine product: case of Lake Victoria basin. *African Journal of Emerging Issues*.

Mohammed, A., E. Babiker, et al. (2016). Nutritional evaluation and sensory characteristics of biscuits flour supplemented with difference levels of whey protein concentrates. *Journal of Food Processing and Technology* 7(1).

Mosha, T. C. and M. R. Bennink (2004). Protein quality of drum-processed cereal–bean–sardine composite supplementary foods for preschool-age children. J*ournal of the Science of Food and Agriculture* 84(10): 1111-1118.

Mourente, G., J. G. Bell, et al. (2007). Does dietary tocopherol level affect fatty acid metabolism in fish? *Fish Physiology and Biochemistry* 33(3): 269-280.

Mukasa, C. T. K. (2013). Regional fish trade in Eastern and Southern Africa – products and markets: A fish trader's guide. *SmartFish*. Working Papers No.013.

Njiru, M., J. Kazungu, et al. (2008). An overview of the current status of Lake Victoria fishery: Opportunities, challenges and management strategies. *Lakes & Reservoirs: Research & Management* 13(1): 1-12.

Nunan, F., J. Luomba, et al. (2012). Finding space for participation: fisherfolk mobility and co-management of Lake Victoria fisheries. *Environmental Management* 50(2): 204-216.

Nurul, H., I. Boni, et al. (2009). The effect of different ratios of Dory fish to tapioca flour on the linear expansion, oil absorption, colour and hardness of fish crackers. *International Food Research Journal* 16(2): 159-165.

Omwamba, M. and S. M. Mahungu (2014). Development of a protein-rich ready-to-eat extruded snack from a composite blend of rice, sorghum and soybean flour. *Food and Nutrition Sciences*.

Onyango, P. (2017). *Socio-economic characteristics of the Lake Victoria Fisheries. Lake Victoria Fisheries Resources.* Springer: 161-184.

Orlova, E. L., G. B. Rudneva, et al. (2010). Climate impacts on feeding and condition of capelin (*Mallotus villosus*) in the Barent's Sea: evidence and mechanisms from a 30 year data set. *Aquatic Biology* 10(2): 105-118.

Pahor, Đ. and V. Podobnik (2012). Practical implementation of prerequisite programs to ensure food safety in bakeries: guidelines for use by sector guide for baking, Guide to good hygiene practice for bakeries and HACCP guide-practical implementation of the HACCP system for bakeries. Zbornik Radova 24. Znanstveno Stručno Edukativni Seminar DDD i ZUPP 2011: Korunić doo Zagreb.

Rai, A. K., H. Swapna, et al. (2012). Potential of seafood industry byproducts as sources of recoverable lipids: Fatty acid composition of meat and nonmeat component of selected Indian marine fishes. *Journal of Food Biochemistry* 36(4): 441-448.

Raja, W. H., S. Kumar, et al. (2014). Effect of ambient storage on the quality characteristics of aerobically packaged fish curls incorporated with different flours. *SpringerPlus* 3(1): 106.

Rand, W. M., J. A. Pennington, et al. (1991). *Compiling data for food composition data bases*. United Nations University Press. Tokyo, Japan:.

Reynolds, J. E. (1993). *Marketing and consumption of fish in eastern and southern Africa: selected country studies*. Rome: FAO.

RGZ. (2010). Fisheries Act. 7 of 2010. The Revolutionary Government of Zanzibar.

Rico, D., A. M. González-Paramás, et al. (2020). Baking optimization as a strategy to extend shelf-life through the enhanced quality and bioactive properties of pulse-based snacks. *Molecules* 25(16): 3716.

Rubio-Rodríguez, N., M. Sara, et al. (2012). Supercritical fluid extraction of fish oil from fish by-products: A comparison with other extraction methods. *Journal of Food Engineering* 109(2): 238-248.

Samuel, F., E. Ayoola, et al. (2006). Chemical analysis and consumer acceptability of tapioca fortified with soybeans. *International Journal of Applied Agricultural Research* 3(1): 1-5.

Sawant, A. A., N. J. Thakor, et al. (2012). Physical and sensory characteristics of ready-to-eat food prepared from finger millet based composite mixer by extrusion. *Agricultural Engineering International: CIGR Journal* 15(1): 100-105.

Scotter, M. J. (2015). *Colour additives for foods and beverages*. Elsevier.

Secci, G. and G. Parisi (2016). From farm to fork: lipid oxidation in fish products. A review. *Italian Journal of Animal Science* 15(1): 124-136.

Senthil, A. and K. Bhat (2011). Best estimated taste detection threshold for cardamom (*Elettaria cardamomum maton*) aroma in different media. *Journal of Sensory Studies* 26(1): 48-53.

Shahmohammadi, H., J. Bakar, et al. (2016). Studying the effects of fish muscle incorporation on storage stability of a novel corn-fish snack. *Journal of Food Quality* 39(1): 45-53.

Shang, C.-H. (2020). *Design for Sustainability: Fish Preservation in Tanzania*. Master Thesis. Delft University of Technology.

Shaviklo, G. R., A. Olafsdottir, et al. (2011). Quality characteristics and consumer acceptance of a high fish protein puffed corn-fish snack. *Journal of Food Science and Technology* 48(6): 668-676.

Singh, R. R., R. K. Majumdar, et al. (2014). Effect of process conditions on physico-chemical and sensory properties of fish-cereal-based extruded snack-like products. *Journal of Food Processing and Preservation* 38(1): 68-82.

Tacon, A. G. and M. Metian (2013). Fish matters: importance of aquatic foods in human nutrition and global food supply. *Reviews in Fisheries Science* 21(1): 22-38.

Thomas, N. (2016). *Evaluation of safety and quality of the Lake Victoria sardines along the value chain*. Sokoine University of Agriculture.

Tiwari, U., M. Gunasekaran, et al. (2011). Quality characteristic and shelf life studies of deep-fried snack prepared from rice brokens and legumes by-product. *Food and Bioprocess Technology* 4(7): 1172-1178.

Torun, B. (2005). Energy requirements of children and adolescents. *Public Health Nutrition* 8(7a): 968-993.

Udensi, E., T. Odom, et al. (2012). Production and evaluation of the nutritional quality of weaning food formulation from roasted millet and Mucuna cochinchinesis. *Sky Journal of Food Science* 1(1): 1-5.

URT (2003). Fisheries Act. No 22 of 2003. The Unied Republic of Tanzania.

URT (2015). Map of marine and fresh water bodies in Tanzania. Ministry of Land and Humman Settlement Development. United Republic of Tanzania.

URT (2019). Investment opportunities in the fisheries and aquaculture sub-sector, Tanzania. The Unite Republic of Tanzania, Investment Centre.

URT (2020). The Status of National Economy. Ministry of Finance and Planning. Dodoma, United Republic of Tanzania

Wangechi Kigano, S. (2016). Genetic diversity, population structure and morphological characterization of the silver cyprinid *Rastrineobola argentea* (Pellegrin) in Port Victoria, Mbita and Nyanza Gulf of Lake Victoria (Kenya). *JKUAT*.

Yongo, E., B. Keizire, et al. (2005). Socioeconomic impacts of trade. The state of the fisheries resources of Lake Victoria and their management. *Proceedings of the Regional Stakeholders' Conference, Secretariat, Jinja.*

Yuwana, Y. and B. Sidebang (2017). Performative improvement of solar-biomass hybrid dryer for fish drying. *IJASEIT* 7(6): 2251-2257.

Zayas, J. F. (1997). Functionality of proteins in food. Springer science & business media.

APPENDICES

Appendix 1. Sensory analysis of the maize snack products incorporated with dried capelin powder.

Sensory Evaluation Questionnaire

PRODUCT NAME: Maize and Fish based snacks product
NAME:..**NATIONALITY**...
GENDER:...**AGE:**..**DATE:**..........................

Please ensure you read all instruction before tasting samples and filling in this questionnaire

Please **observe and taste** the samples of maize snacks incorporated with dried capelin flour in the order presented and rate the sample attributes (*appearance, colour, smell, texture, flavour and overall liking*) according to your preference by writing their code (e.g. **396**) in the appropriate section of the table below.

Code:	**Sample attributes**					
Preference	Appearance	Colour	Smell	Texture	Flavour	Overall liking
Like extremely						
Like very much						
Like moderately						
Like						
Neither like or dislike						
Dislike						
Dislike moderately						
Dislike very much						
Dislike Extremely						

COMMENNT:..
....
....
....

End of sensory evaluation

Thank you for your participation