STUDY ON STRUCTURAL CHARACTERISTICS AND COMPOSITION OF TWO MARINE FISH SPECIES (*Dussumieria acuta, Sardinella fimbriata*) OF BANGLADESH

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Roll No. 0122/05

Registration No. 1127

Session: January-June 2022-2023

A thesis submitted in the total fulfillment of the requirements for the degree of Master of Science in fishing and Post Garvest Technology

Department of Fishing and Post-Harvest Technology,
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JULY 2023

Authorization page

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This is to certify that we have examined the above Masters thesis and have found that is complete and satisfactory in all respects, and that all revisions required by the thesis examination committee have been made

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JUNE 2023

ACKNOWLEDGEMENTS

First and foremost, thanks to Almighty God for His mercy and guidance for giving the strength to complete this thesis for the degree of Masters of Science in Department of Fishing and Post-Harvest Technology, Chattogram Veterinary and Animal Sciences University, Chattogram, Bangladesh.

The author wishes to express her sincere gratitude to her research supervisor, Dr. Mohammed Nurul Absar Khan, Professor, Department of Fishing and Post-Harvest Technology, Dean, Faculty of Fisheries, CVASU, Chattogram, for the continuous support and motivation of my M.S. study and research.

The author finds great pleasure in expressing her hearty appreciation and immense indebtedness to my co-supervisor, professor Dr. Md. Kamal, Treasurer, CVASU, who given the best help with his valuable suggestion, enthusiastic review and fruitful comments to carry out the research work systematically. For his patience, motivation, enthusiasm and immense knowledge, I feel proud to do a research work under his constructive, useful and effective supervisioion.

The author would like to express sincere grattitude to Dr. Md. Faisal, Associate Professor, Department of Fishing and Post-Harvest Technology, CVASU, Chattogram, for the continuous support and guidance of my M.S. study and research. The author also want to express grattitude to Tahsin Sultana, Assistant Professor, Department of Fishing and Post-Harvest Technology, CVASU

It is also a great pleasure for the author to express her cordial gratitude to our honorable and respected Vice-chancellor, Professor Dr. A.S.M Lutful Ahasan and Professor Dr. Mohammed Nurul Absar Khan, Dean, Faculty of Fisheries. CVASU for given me golden opportunity to work and study in this institution.

The author is humbly thankful to Prof. Dr. Zonaed Siddiki, Co-ordinator, Advanced Studies and Research (CASR), CVASU, for funding to complete my research work.

The author is forever indebted to her beloved parents and all family members for their blessing, tremendous sacrifice when it was most required and endless support with the strongest inspiration to achieve golden success.

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List of Abbreviation

Short form	Abbreviation
ANOVA	One-way Analysis of Variance
CVASU	Chittagong Veterinary and Animal Sciences University
DP	Dorsal Part
G	Gram
Mg	Miligram
%	Per Cent
Min	Minutes
L	Litre
°C	Degree Celcius
SD	Standard Deviation
VP	Ventral Part

ABSTRACT

Two marine fish species, *Dussumieria acuta* and *Sardinella fimbriata* were subjected to determine overall muscle structure, processing yields, nutritional composition and variation of nutritional composition with muscle type (dark, white and mixed), location (head, middle and tail) and with different cooking methods (boiling and frying). Gel forming ability of the fish muscle and comparison of their gel-forming with washed and unwashed muscle have been studied at various temperature . *Dussumieria acuta* had 3.86% dark and 96.2% white muscle, while *Sardinella fimbriata* had 7.87% dark and 92.32% white muscle. Analysis of nutritional composition of dark, white and mixed muscle showed that, white muscle possess higher moisture (72.12±1.17%, 73.29±0.91% in *Dussumieria acuta* and *Sardinella fimbriata*) and crude protein (24.75 ± 1.09% in *Dussumieria acuta* and 25.09 ±0.90% in *Sardinella fimbriata*) and dark muscle possess higher lipid content (2.21±0.17% and 2.23±0.44% both in *Dussumieria acuta* and *Sardinella fimbriata*). Comparison of nutritional composition of muscles from different parts of fish body showed that moisture percentage was significant in head muscle (73.56±1.87% and 73.58±1.08% in *Dussumieria acuta* and *Sardinella fimbriata*). Tail region had significant lipid content of 2.46 ±0.03% and 2.35±0.06% in *Dussumieria acuta* and *Sardinella fimbriata*, respectievly. In both fish moisture showed a declination with boiling and frying. Highest moisture loss was found in case of frying which is 56.46± 1.09% in *Dussumiera acuta* and 55.21±1.02% in *Sardinella fimbriata*. Highest crude protein percentage was found from boiled samples in both dry and wet weight basis (3.73±0 .18% and 3.30±0.35 % in *Dussumieria acuta* and *Sardinella fimbriata* respectively). Fried samples got highest lipid percentage, in frying which is 12.54±1.62% in *Dussumiera acuta* and 13.07±0.61% in *Sardinella fimbriata*. Significant ash content was found in fried sample (3.73±0.18% and 3.30±0.35 % in *Dussumieria acuta* and *Sardinella fimbriata*, respectively). The gel forming ability and the strength of both *Dussumiera acuta* and *Sardinella fimbriata* were investigated under different temperature conditions (40, 50 and 60^0 C) in water bath for a 120 minute. Highest breaking force was found at 50^0 C in both washed and unwashed fish muscle paste in both fish mince. Washing of mince results in better quality gels.

Keywords: Muscle Structure, Processing Yield, Dark and White Muscle, Proximate Composition, Cooking, Gel Forming Ability, Puncture Test, Folding Test

CHAPTER 1: INTRODUCTION

1.1 Background

Bangladesh is fortunate to have a variety of marine fishery. A window of opportunity to boost marine fisheries production has opened up with the recent enlargement of the nation's maritime region from its' bordering states India and Myanmar. (MoFA 2019). Bangladesh boasts an extensive marine expanse covering 118,813 square Kilometers, providing a thriving habitat for numerous ecologically valuable organisms, In Bangladesh, the vast marine water area of 118,813 square kilometers supports a wide variety of commercially significant animals, including 475 species of fish, 36 species of shrimp, 16 species of crab, and 165 species of seaweed, all of commercially significant. The tropical climate of this region, which has a high rainfall rate and a high potential for fisheries production, is a blessing for the country's coastal and marine habitats. As a result, Bangladesh's marine water body has been very productive and boasts one of the world's richest ecosystems (Hossain 2001, Islam 2003). In Bangladesh, the GDP of the nation is contributed by fishing, which accounts for 3.57% of the total and over 25% of the agricultural GDP. During the fiscal year 2020–2021 the total fisheries production was 4.621 million MT, and Bangladesh's marine fisheries resources contributed around 15% to that total. (DoF, 2022). Fish is a major source of animal protein and it also contains vitamins and minerals. The importance of fish as a source of high-quality protein in the human diet has long been acknowledged (Shahidi, 1994). As people become more aware of the value of consuming nutrient-dense meals, fish consumption is increasing due to its distinctive nutritional advantages (Shamsuzzaman et al., 2017).

Among 475 marine fish species, about 100 species are commercially important. Preference of fish species is community specific and it remains constant over generations. Factors influencing behind the preference are flesh appearance of some species, presence of edible portion, numbers of unpalatable bones, palatability etc (Can et al., 2015). For example, Lobster receives a high ranking due its unique taste, the brilliant but fugitive coloration of some Snappers and Salmon made them ideal showpieces in a ceremonial meal. There are also some small fish species which are available year-round through artisanal fisheries but are regarded as low valued in fresh market. *Dussumieria acuta* and *Sardinella fimbriata* are two common marine fish pelagic species found mainly in indo-pacific region and are found through

artisanal fisheries all year round in Bangladesh water (Hata et al., 2020; Valenciennes, 1847). Fish meat is a complicated material both structurally and rheologicallly, similar to many other meals. The visual and audible textural features, the qualities and concentrations of the structural components of the tissue, their intricate arrangement in the muscle, are what determine how the muscle tissue behaves and feels in the mouth (Am, 2001). The species, age and size of the fish within the species, and nutritional status all have an impact on the texture of fish muscle. Glycolysis, rigor mortis and the subsequent contraction of the muscle that frequently results in separation of muscle segments (gaping), temperature profile during storage, cooking temperature, pH, and the presence of NaCl are post mortem factors that affect texture (Dunajski, 1980).

Marine fishes possess two distinct types of myotomal muscle fibres, red and white. Skeletal muscles come in a vast variety of forms, dimensions, anatomical placements, and physiological uses. They have a composite look due to the presence of connective, adipose, vascular, and neurological tissues in addition to muscle fibers (Bone, 1966; Greer-Walker, 1970; Walker & Pull, 1973). Fish quality selection for processing is of interest to many stakeholders in different ways. Not every fish species is equally suited to processing various items. Depending on how they intend to use the items, producers, processors, distributors, and consumers all have different quality standards. For producing any value added products from fish, it is important to have knowledge on muscle structure and their biochemical composition.

Any product's proximate composition provides a preliminary understanding of its nutritional characteristics. For consumers, producers, and scientists from a variety of perspectives, the study of the moisture, protein, fat, and ash contents of fish is very significant. Such a study not only helps to understand the nutritional worth of fish but also how to process and preserve it more effectively and regular assessment of the physiological condition of fish from fisheries point of view (Begum et al., 2012, Cui and Wotton, 1988). The chemical composition of fish serves as valuable resource for nutritionists in pinpointing readily available sources of high protein, low fat sustenance for human consumption. Additionally food scientists utilize this information to craft high protein food that not only offer rich nutritional content which provide a substantial source of energy unit. In contemporary times, a sound understanding of the approximate composition of fish is progressively gaining

significance and finding practical applications in a diverse range of profound fields. (Foran et al., 2005; Mozaffarian et al., 2003; Mohamed et al., 2010). It would also aid the processing technologists to characterise the optimum processing and storage conditions so that the quality of fish could be preserved up to the maximum possible extent.

Meat and fishes are significant components of the diets of people in many nations around the world. There are hundreds, if not thousands, of items that attest to the culinary talents that have been created to use these raw resources as food (Rodger & Wilding, 1990). The nutritive value of fish can be altered by processing or cooking methods. (Shahidi, 1994). Processing techniques assures the keeping quality of fishes throughout the year. Conventionally fish is eaten only after cooking application. Cooking improves digestibility and palatability, nutrient digestion and bioavailability in the gastrointestinal tract. The hygienic quality of food is improved by cooking (boiling, baking, roasting, frying, and grilling) (Ruxton et al., 2004). It assures safe eating by eradication of harmful microbes and parasites. Being one of the earliest methods of food preparation frying enhances food's sensory quality by creating scent compounds, appealing colours, crusts, and textures. There are a variety of traditional fish-cooking techniques that vary between nations and even within the same nation. The nutritional value of fish can be impacted by different cooking techniques, according to earlier studies (Gall et al., 1983).

Gelled comminuted fish products are gaining importance day by day due to changed attitudes of consumers specially those are made from previously under-utilized fish species. The advance of technology have eased deboning of fish meat which opens up the possibility of using several underused fish species as sources of protein. Despite the fact that fresh and marine fish are both used in processed meat items (Martin, 1972). Surimi or gel is a semi-purified concentrate of myofibrillar protein from deboned fish muscle, cleaned, and dewatered into minced fish flesh. Salt makes a viscous solution when it is combined with fish or meat muscle. The solution transforms into an elastic gel with heating and results in flexibility of muscle pastes (Poon et al., 1981). Washing is required to get rid of unwanted elements such colors and other water-soluble compounds, primarily sarcoplasmic proteins and lipids. Myofibrillar proteins, which are the main element in the production of three-dimensional gel structure and responsible for the gel-forming ability of surimi, are

concentrated when sarcoplasmic proteins are removed. Depending on the type of fish, how fresh it is, the type of washing machine, and the desired level of surimi quality, different amounts of water and the number of washing cycles will be used (Hall and Ahmad, 1997). Numerous studies are required to identify the species dependent variability and to maximize the utilization of raw materials (Stone and Stanely, 1992).

1.2 Significance of the Study

Most of the marine fish species of Bangladesh have not yet undergone a comprehensive study on musculature, nutritional composition and its variation with muscle types and different parts of fish body and with cooking application. Suitability of most of the fish muscle as an ingredient of value added product have not also been investigated. For the people of Bangladesh, marine fishes constitute a significant source of nutrition, and comprehension of their proximate composition is essential for dietary planning, food preparation, and nutritional analysis. Muscle structure is a unique feature for each species of fish. Presence, distribution and amount of two distinctive type of muscle fibre (red and white) creates a notable change in fish preference of people. Muscle structure, the ratio of dark and white muscle and their distribution was observed in this study. Knowing the processing yields of these marine fish species is crucial for efficient processing and exploitation of these fish species for various value-added products. Different stakeholders have different interest in choosing fish quality for processing. All the fish species are not equally suitable for processing different products. This study looked at the processing yields of whole muscle, white and black muscle, carcasses, and intestine sections. Fish muscle characteristics, processing yields and muscle properties influence the quality of products. From this information processors can take decision on feasibility of a certain fish species to be used as an ingredient of value added products. Low valued underutilized fish species, which have low economic value in fresh market, are most suitable candidate to be used as an ingredient in value added product preparation. This experiment aims at determining the suitability of both fishes for this purpose. Thus, gel forming ability and the comparison of gel forming ability between unwashed and washed fish muscle of both fishes have been studied.

1.3 Objectives

- To evaluate the muscle myotomal structure and muscle yield of *Dussumieria acuta* and *Sardinella fimbriata*
- To evaluate proximate composition of different muscle types and different body parts of these two species.
- To evaluate and compare the gel forming ability of fish muscle paste of these two fish species in washed and unwashed conditions.

CHAPTER 2: REVIEW OF LITERATURE

2.1Classification and Common Characteristics of Fish

2.1.1 *Dussumieria acuta* (Rainbow Sardine)

Local name: Nailla

Common name: Rainbow Sardine

Scientific name: *Dussumieria acuta*

Common characteristics: *Dussumieria acuta* is a marine fish from Clupeiformes order and Dussumieriidae family. Dorsal spines (total): 5; Dorsal soft rays (total): 7-9; Anal spines: 3; Anal soft rays: 8 - 9. Body stout, cylindrical in cross-section, slightly compressed; head broad and flattened. Well-developed adipose eyelid covering most of pupil. Upper lip thin and without papillae, armed with 1-6 rows of fine teeth; hind end of upper jaw reaching a vertical line from anterior eye margin; maxillary pad not visible below corner of mouth when closed; origin of 1st dorsal fin nearer to snout tip than to caudal-fin base; anterior parts and bases of 2nd dorsal and anal fins with a moderately dense coverage of scales; pectoral axillary process; 14-15 scale rows between origins of dorsal and pelvic fins.

2.1.2 *Sardinella fimbriata* (Fringe scale sardine)

Local name: Takiya/ jatrik

Common name: Fringe scale sardine

Scientific name: *Sardinella fimbriata*

Common characteristics: *Sardinella fimbriata* is a marine fish from Clupeiformes order and Dorosodontidae family. It has dorsal spines (total): 0; Dorsal soft rays (total): 13-21; Anal spines: 0; Anal soft rays: 12 - 23. Body somewhat compressed but variable; total number of scutes 29 to 33. Vertical striae on scales not meeting at center, hind part of scales with a few perforations and (in Indian Ocean specimens) somewhat produced posteriorly. A dark spot at dorsal fin origin.

2.2 Fish Muscle Structure

According to Love et al. (1972), the fish organism is very simple compared to the body of higher animals, which has about 300 muscles. The ratio of dark to light muscle fluctuates according to the fish's activity. Up to 48% of the body weight of pelagic fish, or species that swim more or less continually, such as Herring and Mackerel, maybe made up of black muscle (Love, 1970). Demersal fish, or those that feed on the bottom and only sometimes move, have relatively little black muscle. The majority of fish meat is made up of a few lengthy sheets of muscles that run from the head to the tail on both sides of the body. A distinctive metameric structure that is relatively uncommon in mammalian tissues can be found in these muscles. Transverse connective tissue sheets (myocommata) divide the muscles into segments (myotomes) whose numbers match those of the vertebrae. The sheets of connective tissue in between the myotomes curve in a complicated way in the cross section. The form of the myotomes varies depending on where they are located within the muscle and is unique to each species of fish. The fundamental components of the musculature, the muscle cells (or muscle fibers), extend between two neighboring myocommata, roughly parallel to the long axis of the muscle. Even in the muscles of some fish, the fibers are quite short and do not extend beyond a dozen or so millimeters. Fish muscle fibers have an overall configuration that resembles cross-striated mammalian muscles. The supporting network of connective tissue throughout the muscle is more uniformly distributed in fish meat. The content varies in different species depending on the musculature and myotome distribution.

Dunajski et al. (1980) studied fish muscle morphology and chemical components and differences of red and ordinary meat. Connective tissues mainly disintegrates with heating and is used mainly for muscle texture and quality testing. Fishes have low amount of connective tissue and thus unsuitable for most of these experiments but when using the thin blade shear/ compression cell, the best results are obtained. The majority of the methods used to evaluate the instrumental texture of red meats are not entirely appropriate for evaluating the characteristics of fish muscles. In fish, the heat denaturation of collagen results in a complete loss of the connective tissue's binding abilities. The forces of attraction between the myofibrils and the fibers weaken to the point that heating causes the muscles to easily disintegrate, with the muscle fibers remaining the only resilient components in cooked fish meat. The narrow bladed

Kramer shear-compression cell is an effective tool for determining the rheological properties of these muscle fibers.

Kiessling et al. (2006) reported that, white muscle fibers remain tightly packed with myofibrils. White muscle fibers are larger than dark muscle. They also observed the position and distribution of dark and white muscle, the dark muscle is mostly found beneath the skin in caudal region of body. 9:1 distribution of white and dark muscle is a common feature in most of the marine fishes.

Blaxter et al. (1971) conducted a study on different groups of fishes based on their habitat such inshore fishes, mesopelagic fishes and deep-sea fishes. Fishes that live in deep water have more moisture content in their body and are sluggish in character. The deep-sea fish (Macrouridae and Chimaeridae) are a distinct family with small hearts, low hemoglobin levels. According to them, active fishes have higher ratio of trunk musculature and red muscles.

Chaijan et al. (2004) reported that, fast-oxidative (pink) fibers are another kind found in some species, and they are similar to red and white fibers in both form and function (Johnston, 1981). The meat's dark color results from the high myoglobin content, which gives it a reddish brown hue. According to Hiratsuka et al. (2011), headless skipjack tuna comprise 13–16% black muscle, which enables this species of fish to swim quickly for longer stretches of time without becoming exhausted. According to Suzuki et al. (1986), the amount of lipid in white meat might differ depending on the species and the time of harvest. Dark muscle, which contains more lipid, is therefore more susceptible to lipid oxidation than white muscle (Shahidi and Spurvy, 1996).

Listrat et al. (2016) conducted a study to examine the characteristics of these numerous muscle parts and how they relate to the technological, dietary, and sensory characteristics of meat and flesh from diverse livestock and fish species. In order to determine the appearance, color, tenderness, juiciness, flavor, and technological value of meat and flesh, various factors must be taken into consideration, including the contractile and metabolic types, size and number of muscle fibers, content, composition, and distribution of connective tissue, as well as the content and lipid composition of intramuscular fat. The biochemical and structural properties of muscle fibers, intramuscular connective tissue, and intramuscular fat appear to play independent roles. This suggests that the characteristics of these different muscle

components can be independently modified by genetics or environmental factors to improve production efficiency and meat/flesh quality.

2.3 Processing Yield Determination

Rustad et al. (2011) conducted a research work on Utilization options for marine by-products. They reported that, Depending on the post-harvest or industrial preparation processes, by-products from the fish business can make up as much as 75% of the catch. The ratio of food fish to byproducts varies depending on the size and species of fishing fish, the season, and the zone. Value adding offer an alternative to low-profit uses like mince, fish meal, and silage. Example of by product fractions are fish blood, marine lipids, omega-3 fatty acids, fish protein fractions, and bioactive components with nutraceutical potential, such as antioxidants and bioactive peptides etc. Future market potential must be taken into account, as well as the regulatory situation.

Villamil et al. (2017) reported that, bones can account for percentages of 9%–15% of whole fish, while the head comprises 9%–12%, viscera 12%–18%, skin 1%–3%, and scales 5% on wet weight basis. fish waste specifically viscera, hold considerable agro-industrial potential as sources of industrial protein and hydrolysates. These have the potential to make substantial contribution to various industries including agriculture, cosmetics, pharmaceuticals, food, and nutraceuticals. These contributions are achieved through a detailed examination of their production process, chemical composition, and the significant functional and bioactive properties they possess.

In some regions of the world, the head is also consumed as food, but most often it is lost during dressing losses. The leftover parts, including the head, fins, skin, and scales, can be fed to chickens (Choi and Regestein, 2000).

2.4 Proximate Composition:

2.4.1 **Proximate composition of dark and white muscle:** Liu et al. (2014), conducted an examination of the basic differences in the muscle of ordinary and dark skipjack tuna (Katsuwonus pelamis). Numerous elements, including as species, growth stage, season, and catch location, might affect the skipjack tuna's proximate composition. Both light and dark muscle were primarily made up of crude protein,

proving that skipjack tuna is a good source of amino acids. Both samples of normal and dark muscle did not substantially differ in terms of ash content ($p>0.05$) between both muscle types. The moisture, crude protein, and fat contents between light and dark muscle were significantly different ($p<0.05$). Compared to dark muscle, ordinary muscle had a higher crude protein concentration.

Mai and Kinsella, (1979) studied lipid composition of dark and white muscle from White Sucker (*Catostomus commersoni*) Compared to white muscle, dark muscle had a higher total lipid content (6.2% vs. 1.4%), which was primarily made up of triglycerides and phospholipids. The average lipid content of the white and dark muscles of the sucker is 1.4% and 6.2%, respectively. According to Bone (1964), white fish muscles frequently contain three to four times as much lipid as dark muscles. Lipid content is frequently higher in dark muscle. Sardine dark muscle has a 4.8 times higher lipid content than mackerel muscle. According to Sikorski et al. (1994), dark muscles had 2–5 times more lipids than white muscles and were especially high in chromoproteins.

The white and dark muscles of little tuna (*Euthynnus affinis*) were examined for their chemical content, fatty acid profile, texture, color, and freshness was studied by Kannaiyan et al. (2019). However, common muscle had less crude lipid content. When compared to black muscle, which had a moisture content of 74.85±0.10%, white muscle had a moisture content of 75.52±0.13%. Protein concentrations in white and dark muscle were higher, at 23.12 and 23.15 respectively. According to them, dark muscle had greater levels of histamine, tri-methylamine, total volatile base nitrogen, in textural profile analyses. Dark muscle had a better overall nutritional quality than white muscle.

2.4.2 Proximate composition of different parts of fish body: Tufan et al. (2013) studied the proximate chemical composition and fatty acid profile variations in different body parts Thornback Ray (Raja clavata). Tail region have more protein content (20.9±0.8%) than main body (19.9±0.8%), lipid content found in higher amount in middle part or main body than tail region but highest lipid value is found in liver 39.7 ± 2.0%. Tail region have lower moisture content and in terms mineral there were no significant difference.

In an effort to figure out the change that was occurring to the fish muscle, Stansby (1962) examined the salmon's pink muscles from the neck, center, and tail regions. In the neck to tail region, the level of moisture increased considerably by between 75.0% and 77.0%, according to the study. From the neck to the tail, however, there was a rise in the amount of fat content, going from 2.6% to 4.8%. The variation in protein and ash percentages was not as high, ranging from 18.8% to 19.9% and 1.1% to 1.2%, respectively. Nevertheless, such findings could not be applicable to all fish species.

The proximate components, fatty acid composition, and content of the dorsal and ventral fillet parts (dp and vp, respectively) of European sea bass (*Dicentrarchus labrax*), Gilthead Sea Bream (*Sparus aurata*), and Rainbow Trout (*Oncorhynchus mykiss*) were examined by Testi et al. (2006). Even though these changes were not equally significant for all of the nutrients taken into account, striking compositional differences between the dorsal and ventral fillet regions of farmed European Sea Bass, Gilthead Sea Bream, and Rainbow Trout appeared. When it came to proximate and fatty acid content, Sea Bass appeared to be the species among the three that was most impacted by dorso-ventral variations.

2.4.3 Proximate composition of cooked fishes: In 2008, Turkkan conducted a study investigating the impact of different cooking methods, namely frying, baking, and microwave cooking, on the proximate composition and fatty acid composition of seabass (*Dicentrarchus labrax*). Protein content exhibited significant alteration for all types of cooking methods. Fat content of fried samples was also found to be significantly different when compared with other cooking methods. Fat content of fried samples was also found to be notably significant when compared with the outcomes of other cooking methods. Upon comparing the raw and cooked fish, the findings revealed that cooking had a substantial impact on both the proximate composition and fatty acid compositions.

Two marine fish (*Sardinella* sp., *Dentex* sp.) and a freshwater fish (*Oreochromis* sp.) were studied to see how different processing techniques (cooking, frying, and smoking) affected their chemical makeup by Steiner-Asiedu in 1991. Protein content of fresh fishes were largely steady during cooking and smoking but significantly decreased during frying. Due to dilution by the frying oil, the fried fish has a decreased protein content. According to Stansby & Olcott (1963), the fish are

classified as low oil-high protein for flat sardines and medium oil-high protein for sea bream and tilapia. Processing raised the fat level, and the fried samples showed the biggest rise.

Puwastien in 1999 conducted a research on proximate composition of raw and cooked freshwater and marine fish in Thailand. Common household cooking methods had been used such as: steaming, boiling, frying and roasting. Roasting and frying showed a noticeable increase in the fat content of cooked items with values ranging from 7–23 g/100g, conversely boiling and steaming did not lead to a change in the fat percentage of the cooked fish which remained within the range of 0 to15g/100g.

Tokur in 2007 carried out a research on how different cooking method effect on proximate composition and fatty acids of rainbow trout (*Oncorhynchus mykiss*). Frying, oven-baking, barbecuing, and smoking have been applied. All cooking techniques had a substantial impact on the nearby compositions. Cooking methods significantly changed the proximate composition. All of the cooking techniques resulted in a rise in the lipid content and a fall in the moisture content. On a dry-weight basis, it was discovered that samples that had been smoked and grilled had less protein than samples that had been fried or baked in the oven.

Gokoglu in 2004 analyzed the effect of cooking types (frying, boiling, baking, grilling, microwave cooking) on proximate composition and mineral contents of rainbow trout (*Oncorhynchus mykiss*). For all cooking techniques, it was discovered that there were considerable changes in the moisture, protein, and ash levels. The increase of fat content is significant for only fried samples.

In 2008, Eroosi and Ozeren conducted a study examining the impact of various cooking methods on the mineral and vitamin contents of African catfish. In cooked African catfish, the proximate composition, mineral, and vitamin contents (A, E, B1, B2, niacin, and B6) were examined. Different cooking methods (baking, grilling, microwaving, and frying) were employed. All cooked fish had higher protein and ash concentrations. Only the fried fillets exhibited an increase in fat content. Cooked fish has less moisture. Cooking techniques had an impact on mineral levels, with the exception of Cu All cooked fish had higher vitamin E levels, despite the fact that the vitamin A content in both grilled and fried fish increased significantly. Fish that has been cooked significantly has less vitamin B1 in it (Alipour et al., 2010).

Effects of cooking methods on the proximate composition of Black Sea Anchovy, *Engraulis encrasicolus*, was studied by Kocatepe in 2010. The results showed that cooking techniques had a significant impact on the proximate composition when raw and cooked fish were compared. Fried anchovies had the highest water loss measurement (49.55%). After cooking, fat content increased considerably but moisture content in all treatments (grilled, baked, fried, and microwaved) decreased (Kocatepe et al., 2011). A declination of moisture content and increase of other nutrients is a common feature. In grilling opearation highest protein , calory and lowest fat was reported.

Ghelichpour in 2011, evaluated the proximate composition and protein solubility in processed mullet fillets. Grilling, frying and steaming were used as processing application. All cooked fish had higher protein and ash concentrations. The most noticeable changes in proximate composition were an increase in fat content and a decrease in moisture content. The amount of fat in fillets did not change substantially after steaming, but it did after frying and grilling (P 0.05).

A study was carried out by Abraha et al., 2018 to review the effects of processing methods on nutritional vaue and physico-chemical composition. According to the study, on the basis of wet matter, cooking of Sardine fillets results in reduction of moisture value, significant rise of protein, fat and ash content.

2.5. Gel Forming Ability of Fish Muscle Paste

Ability to form gel from muscle depends largely on the presence and performance attributes of different protein fractions (Rodger & Wilding, 1990). According to Stone and Stanely (1992), presence aggregation and interaction of myosin molecule is mainly involved in gelation and it is species specific. Two steps are involved in protein gelation. One is thermal denaturation of proein and the other is aggregation of denatured protein. Heating temperature is the major factor contributing to gelation. Protein species, concentration, pH, and the ionic environment are other elements influencing the gel quality. (Ferry, 1948, Shimizu et al., 1986). Myofibrillar protein myosin is the main substitute for gel formation in both fish and other animals. The factors influencing the formation of protein gels, encompass a range of determinants including species variation, and the interplay between muscle proteins like actin and myosin. These proteins interact not only with each other but also with constituents

such as fat, gelatin, starch, hydrocolloids, specific protein sources like soy and whey, and non-protein additives like phosphates and acidifiers. Additionally, pH levels, ionic strength, heating rates (or lack thereof), protein oxidation, the application of transglutaminase, and the use of high hydrostatic pressure all play crucial roles in this process.

A gradual increase of temperature in the heating process can facilitate the formation of more favourable protein-proten interaction, resulting in the development of a more robust and well-structured three dimensional gels. Temperature play a significant role in influencing the gelation properties as noted by Shimizu in 1981. According to the findings of Ishioroshi and colleagues in 1979, the optimal temperature range for inducing gelation in myosin at a pH of 6 was identified to be between 60 and 70°C.

2.5.1 Effect of temperature on gel forming ability: According to Stone and Stanely (1992), heating temperature is the major factor contributing to gelation. A research was carried out by Hossain et al. (2004) to investigate the effect of washing solution, washing period and salt concentration on gelling ability of Silver Carp (*Hypophthalmichthys molitrix*) and Pangas (*Pangasius hypophthalmus*). Both Silver carp and Pangas mince were washed with 0, 0.05, 0.1, 0.15, and 0.2% NaCl for 5, 10 and 15 minutes. Regardless of the heating schedule, adding 3% NaCl to the fish minces in grinding exhibited the maximum gel strength. 50°C was discovered to be the ideal setup temperature for achieving the highest gel strength. A two-step heating technique (heating at 50°C for 120 minutes, then 80°C for 30 minutes) produced better gelling results than a single-step heating process (heating at 50°C for two hours).

A research was conducted by Nowsad et al. (1999) on the effects of heating and washing on the gelling properties of tropical Major Carp muscle (Rohu, katla, Mrigel and silver Carp). Between 40 and 50 °C, gel strength was at its peak, and between 60 and 70° C, gel disintegration took place. The gel strength of the two-step heated gels was higher. The texture and color of the gels were significantly enhanced after just one wash with the mince. The second wash of the minces had no discernible effect on texture or color.

Common carp (Cyprinus carpio) muscles' ability to create gel was examined by Ganesh et al. (2006) in relation to freezing and frozen storage. According to a big strain test (gel strength of 1027 g/cm) and dynamic viscoelastic behavior, fresh carp meat demonstrated good gel-forming capacity. The good gelling properties of common carp meat make it suitable for use in items made from fish mince, such as fish sausage and kamaboko, which are heated.

MI Hossain, (2005) carried out a research on Influence of ice storage on gel forming ability of ice stored Queen Fish (*Chorinemus lysan*). Puncture test, teeth cutting test and folding test were done for testing gel strength. Both washed and unwashed mince produced maximum gel strength at incubation temperature of 50^0 C. The gel strength of both unwashed and washed meat paste gradually decreased over the course of the storage period, and washed meat paste demonstrated higher gel forming ability than unwashed meat paste.

Nowsad et al. (2000) investigated several characteristics and the gel-forming capacity of the mince of 11 underused marine species. These species were among them: Bombay Duck, Silver Belly, Sea Catfish, Silver Jewfish, Jewelled Shad, Queenfish, Spanish Mackerel, Hardtail, Indian Tuna, Tripletail, and False Conger Eel. A portion of the mince, which was prepared from fillet, undergone two washings in cold, 5°C water that contained 0.1% NaCl. We ground the mince, both washed and unwashed, with 3% NaCl. Muscle paste was put into plastic tubes. In one phase, the tubes were heated to 25, 30, 35, 40, 50, 60, 70, and 80° C for 60, 120, and 180 minutes. Sensory, piercing, folding, and expressible moisture tests were performed on the gel. Two-step heating considerably enhanced the gel strength when compared to one-step heating. Except for Bombay duck, all of the gels improved in texture and color following washing.

2.5.2 Effect of washing: Hall and Ahmad, 1997 reported that, the step washing created a significant difference in breaking force. Washed mince gel is superior to unwashed mince gel. Sarcoplasmic proteins, pigment and other water soluble substances are eliminated through washing and thus myofibrillar protein can be concentrated and produce better quality gel (Hall and Ahmad, 1997). Hossain et al. (2004) found surimi from washed mince is superior to unwashed mince in terms of gel forming ability. Washing necessarily removes water soluble substances (mainly Sarcoplasmic protein), fat and pigment type undesirable materials. Myofibrillar

protein can be concentrated due to removal of Sarcoplasmic protein. Thus it can form better three dimensional gel structure which finally results in superior gel strength or gel forming ability.

According to Kim et al. (1996) in surimi created from complete muscle, washing off is crucial for the gel's strengthening and enhancement in color. Surimi's color can be improved by lengthening the washing process and adding more water. Horse mackerel mince's color could be improved by ozonized water after a brief washing period (Chen et al., 1997).

Chaizan et al., 2004 conducted a research on gelling properties of muscles from Sardine (*Sardinella gibbosa*) and Mackerel (*Rastrelliger kanagurta*). They investigated effect of washing on extractible myoglobin content of resulting gels. The color, expressible drip, and textural characteristics of the sardine and mackerel mince gels were significantly impacted by the washing media. In comparison to unwashed and water-washed mince, the breaking force of directly heated and washed gels made from both sardine and mackerel mince was higher. Additionally, washing led to an improvement in whiteness and a decrease in expressible moisture. Sardine surimi generally shown greater gel-forming and whiteness than mackerel surimi. Three kinds of fish were used to make excellent gels when NaCl is added. Excellent to good quality gels can be made from fish muscle, depending on the species, if the chopped tissue was rinsed before the gel was formed. In the absence of NaCl, red hake, cod, and flounder all generated excellent, good, and fair gels, as determined by fold scores of 5, 4, and 3, respectively (Suwansakornkul, 1993).

2.5.3 Factors affecting gel-forming ability of fishes: Two steps are involved in protein gelation. One is thermal denaturation of protein and the other is aggregation of denatured protein. Protein species, concentration, pH, and the ionic environment are other elements influencing the gel's character. Presence aggregation and interaction of myosin molecule is mainly involved in gelation and it is species specific. (Ferry, 1948). A study was conducted by Sun and Holley (2011) to understand factors affecting the gel formation by myofibrillar proteins in muscle foods. This report compiles information on factors that affect the formation of protein gels, looking at different muscle types and fiber types, species influences, and interactions between the MPs actin and myosin as well as with fat, gelatin, starch, hydrocolloids, some proteins like soy and whey, and non-protein additives like phosphates and acidifiers,

as well as the use of transglutaminase and other enzymes. Functionally Myosin by itself produces gel. The optimal conditions for gel formation by MPs are pH 6, 0.6 M of ionic strength, and 60 to 70 °C. The characteristics of the resulting gel are significantly influenced by the heating rate as well.

Ability to form gel from muscle depends largely on the presence and performance attributes of different protein fractions (Rodger & Wilding, 1990, Saeki et al., 1995). Factors influencing gel-forming ability were examined by Suzuki and Watabe in 1986. The ability to create gels is also influenced by other factors, including high lipid content, protein instability in the muscle, the presence of sarcoplasmic proteins, and a high ratio of dark to white muscle fibers. Making surimi from non-fresh fish is impossible, even with the use of effective processing techniques, due to the muscle's high fat content, which hinders the ability to gel. Scott et al., 1988, as well as Holmquist et al., 1984, reported on the change in gel quality caused by variations in moisture content level. Luo et al. (2014) reported that, dark muscle has a poorer gel-forming capacity than regular muscle. This appears to be the result of variations in the two muscles' myosin's heat stability and unfolding properties. According to Ishioroshi et al. (1979), the ideal temperature for the heat-induced gelation of myosin at pH 6 was between 60 and 70° C.A slow heating rate may allow more favorable protein–protein interactions to occur, producing a stronger, better-ordered 3-dimensional gel. Temperature is one of the major factors that influence gelation property.

2.5.4 Effect of ice storage on gel forming ability: Hossain et al. (2005) conducted an experiment to see how ice storage affected the queen fish (*Chorinemus lysan*)'s ability to form gels, the solubility of myofibrillar proteins, and the activity of the Ca 2+ -ATPase. They discovered that 50°C was the optimal incubation temperature for both washed and unwashed mince to produce the most breaking force. Both unwashed and cleaned meat paste's gel strength steadily decreased over the course of storage. Sabina (2009) investigated the relationship between gel strength and ice storage in the example of pangas (*Pangasius hypothalmus*), and she found that the ability of Pangas to produce gel reduced as storage time increased. In his research, the breaking force was initially measured at 669.33 (0.67g) and lowered to 205 (0.88g) after one step of heating, while after two steps of heating, the breaking force was initially measured at 1005.67 (3.93g) and decreased to 480.23 (0.88g) after 16 days of ice storage. Tiwo et al. (2018) investigated how ice storage affected the rheological and textural

characteristics of proteins from *Cyprinus carpio* (Common Carp), a freshwater fish. After 15 days of ice storage, they discovered that the gel's potency had significantly decreased. After five days of ice storage, the gel strength values of the produced gels rapidly decreased. When made with 2.5% NaCl, the gels' initial gel strength values were 668, 285 and 818.

2.5.5 Gel Strength: The quality of the proteins present in the muscle is indicated by the ability of the meat to create a decent gel. Sardine meat's gel strength was 259.67 g-cm as evaluated by Rheotex in a research by Das et al. (2015); other marine species typically have gel strengths between 300 and 500 g-cm (Shamasundar et al. 1988). The specific responses of the proteins to applied forces encountered during preparation, processing, and storage determine the type and quality of gel that is produced.

2.5.6 Gel color: In contrast to unwashed mince, gels derived from the washed mince exhibited a greater degree of whiteness. Sardine gels have a frequently higher whiteness than Mackerel gels, according to Chaijan et al. (2004)

CHAPTER 3: MATERIALS AND METHOD

3.1 Collection of Samples

Two fish species, Rainbow Sardine *Dussumieria acuta* (average length 13.69 cm and weight 23.76 g) and Fringe scale sardine *Sardinella fimbriata* (average length 17.0 cm and weight 50.14) were collected in fresh condition direcly from fishermen of the day fishing boat in Teknaf. They were kept in an insulated box with ice immediately after being purchased in fresh condition, and they were then frozen at -20° C in a freezer right away. The samples were transported to the Fishing and Post-harvest Technology Laboratory of the Chattogram Veterinary and Animal Sciences University (CVASU) in frozen conditions in an insulated box. For the ensuing series of of subsequent experiments, the samples were divided into several sections. The fishes were cleaned well using cold potable water before being used in the experiment, and measurements of their length (in centimeter) and weight (in gram) were made for each experiment.

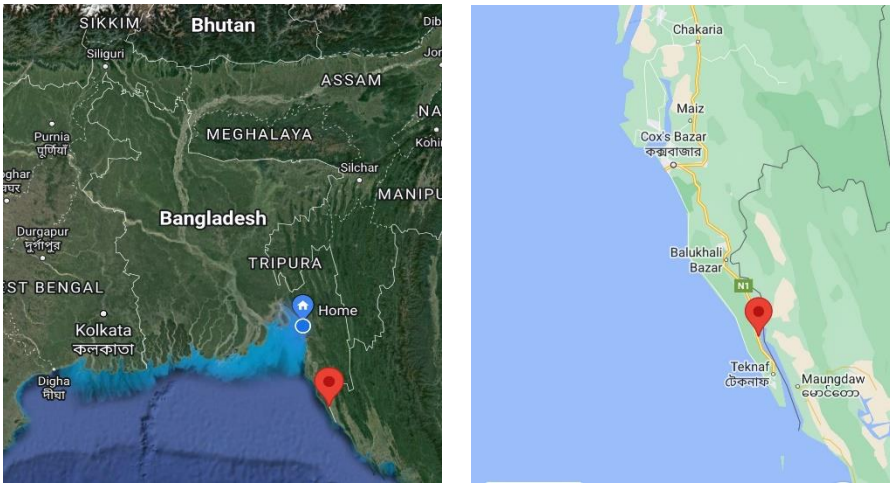


Figure 1: Location of Sample Collection

3.2 Identification of Common Characteristics of Fish

The fishes were carefully investigated to identify their genus and species after being completely washed in water. Important characteristics such as body form, number of fins, fin rays, and positions were noted and compared to the literature.

Plate 1: *Dussumieria acuta* (Rainbow Sardine)

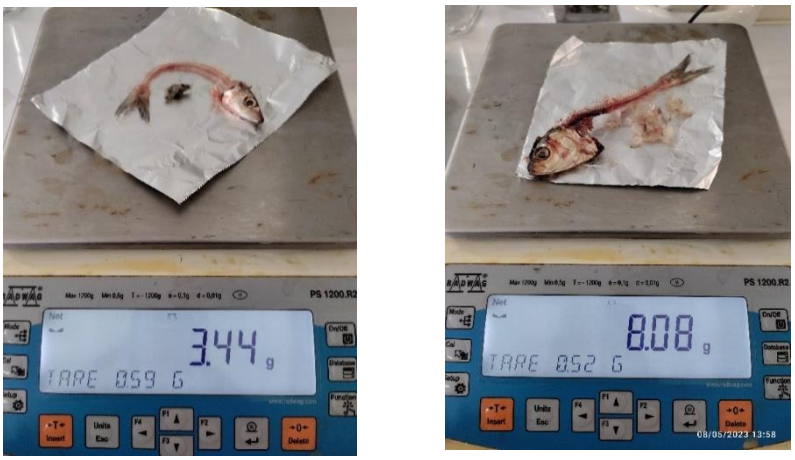
Plate 2: *Sardinella fimbiata* (Fringe Scale Sardine)

3.3 Observation of Myotomes (myomeres) Structure

The quantity of myotomes is a crucial factor in fish fillet identification. Myotome structure and their number in the fillets differ from species to species. Myomeres come in two varieties. One is made up of wide white muscle fibers, whereas the other is a narrow red myoglobin-containing fiber. For this experiment, five samples of each species were collected. The fish were thoroughly dressed and washed before being dissected and filleted from tail to head on both sides. Then, from the tail to the head area, W-like segments (myotomes) were counted. In order to examine the distribution of red and white muscles, fish were filleted. The areas of red and white muscles in each transverse section of the fish were then measured along the body. The muscle weight and proportion for a total area were calculated. Form, color and width of myotoms were observed. The distribution of red and white muscle was observed and area of red and white muscle in each transeverse section was measured.

3.4 Processing Yield Determination

Ten individuals were selected randomly from each species for this experiment. At first individual body weight of fishes were taken. The fish were afterwards dressed, washed and fileted, and the muscle and carcass were completely separated. Carcass weight and total muscle weight were taken. Red and white muscle were also separated from whole muscle. The weight of red and white muscles was measured. Muscle percentage with body weight, dark muscle percentage with total muscle, white muscle percentage with total muscle were calculated.



(a) (b)

Plate 3: Carcass weight of (a) *Dussumieria acuta* and (b) *Sardinella fimbriata*

3.5. Preparation of Fish Samples for Biochemical Analysis

3.5.1 Preparation of sample based on muscle type: To prepare sample for proximate composition, frozen fishes were defrosted and then fishes were washed, deheaded, gutted and skimmed. Fish muscles were separated from fish body. For comparison of different muscles, dark, white, and mixed muscle were collected randomly from samples of each fish species.

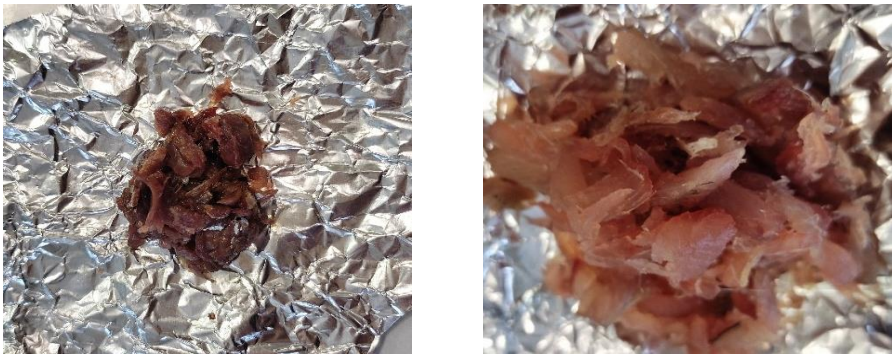


Plate 4 : Dark and white sample

3.5.2 Preparation of sample from different body parts: For comparison of composition of different parts of fish body, the samples were first defrosted. After that fishes were thoroughly dressed well and washed using potable water. Then the body of the fish samples were cut into three segments (head, middle and tail) and gutted. Muscles were taken from each part and subsequent analysis was conducted accordingly.

Plate 5: Three segmented part of fish

3.5.3 Preparation of Cooked Samples: The samples were boiled and fried to prepare them for analysis. In a typical cooking pot, boiling was done for 15 minutes at about 100°C. In soybean oil, fish samples were fried for 10 minutes in the pan at 150o C for the purpose of frying. To calculate cooking loss, the boiled and fried samples were weighed once more. A kitchen blender was used to quickly homogenize samples of raw or cooked fish fillets before they were examined to analyse their proximate composition.

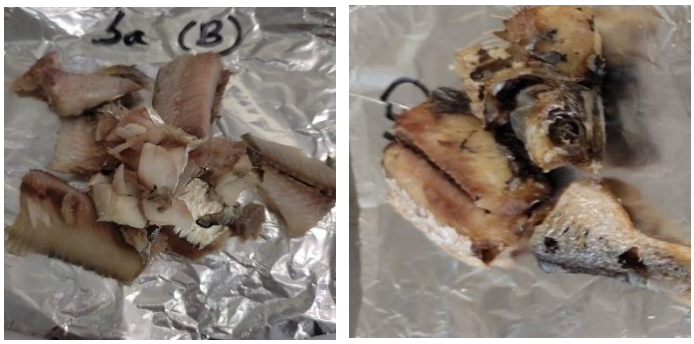


Plate 6: Boiled and fried fish

3.5.3.1 Cooking loss: Cooking loss was computed from the variations in the mass of pieces of Rainbow Sardine (*Dussumiera acuta)* and Fringe Scale Sardine (*Sardinella fimbriata)* before and after each cooking procedure (frying and boiling). Below is a calculation of cooking loss:

$$\text{Cooking Loss (\%)} = \frac{\text{Mass before cooking} - \text{Mass after cooking}}{\text{Mass before cooking}} \times 100$$

3.5.3.2 Sensory evaluation of cooked fishes: To evaluate sensory changes, a panel of 10 members was formed. The observed changes in muscle color, texture and smell in boiled and fried samples were recorded and compared with raw fish muscles. A form was given to the panel members to evaluate three categories in muscle color (white, light red and red)**,** three types of texture (firm, soft and burst) and three types of smell (strong, medium and low). Panelists put tick marking on different aspects based on their observations.

3.6 Biochemical Analysis

Moisture, ash, crude protein, crude fat, and crude fiber were studied following the standard methods accordance with the Association of Official Analytical Chemists' protocol (AOAC, 2016) with certain modifications. Triplicate samples were used for each treatments. Kjeldahl apparatus was used to assess the protein content, and a hot air oven was used to determine the moisture content. A Soxhlet Apparatus was used to determine the lipid content of fish samples. By measuring the inorganic residues, such as oxides, sulphates, silicates, and chlorides left behind in the dry muscle sample in a muffle furnace, the ash content of the samples was calculated. This analysis has been carried out in Nutrition and Processing Lab, Chattogram Veterinary and Animal Sciences University (CVASU).

3.6.1 Crude Protein : Crude protein content was investigate using the Micro Kjeldahl Apparatus. After placing 0.3 g of the samples in the digestion tube, 5 ml of concentrated H2SO4 and 4 g of catalyst were added. The digestion tube was then inserted into the digestion apparatus, where it was digested for 30 minutes. After proper digestion, the tubes are removed from the apparatus and left at room temperature for 30 minutes to cool. The digesting tube was then filled with 25 ml of distilled water. The tubes were then connected with distillation unit's where conical flask contained solution of 10 ml boric acid with mixed indicator. Under the pipe (white and black) of the distillation unit, 25 ml of NaOH and distilled water were put. Subsequently ammonia from the digestion samples released and trapped into the boric acid solution. After that, 0.2 N HCl was used to titrate the sample.

Total Nitrogen content was determined by the following formula:

$$\% \text{ of N} = \frac{ml\ of\ titrant \times Strength\ of\ HCl\ (0.2N) \times Equivalent\ of\ Nitrogen\ (0.014)}{Weight\ of\ sample} \times 100$$

The amount of crude protein was then calculated by the following formula:

% of Protein = % N × 5.85

Plate 7: Titrated protein sample

3.6.2 Lipid: A Soxhlet Apparatus was used to determine the lipid content of fish samples. A 2 g sample was put on thimble paper, which was then pulled up and positioned beneath a magnetic holder by a magnetic ring. To determine the weight, a sterilized empty beaker was marked and measured. The designated beaker was filled with 70 ml of diethyl ether, and the solvent-filled beaker was fitted beneath the condenser. The extraction beaker was then placed on the burner and heated to 100°C for 20 minutes before the thimbles were lowered into it. The thimbles were then

raised, the beakers cooled for 20 minutes, and the solvent was allowed to evaporate for 10-15 minutes. The extraction beakers were then placed in a hot air oven set at 105°C for 30 minutes before being allowed to cool in a desiccator. . Following that, the beaker's weight was determined.

$$\% \text{ of Lipid} = \frac{(Weight\ of\ lipid)}{Weight\ of\ sample} \times 100$$

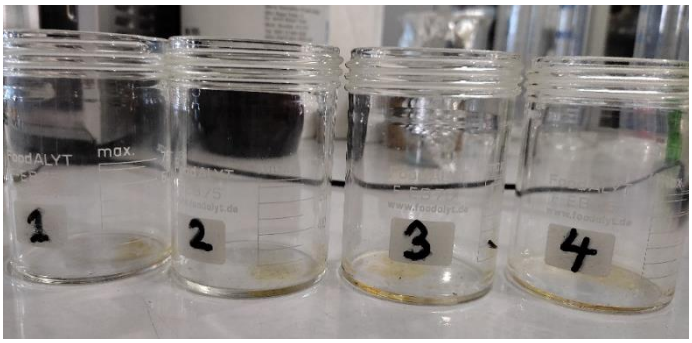


Plate 8: Extracted Lipid samples

3.6.3 Moisture: Weights of empty crucibles were taken and 3 grams of each sample were put to the previously weighted crucible that was empty. The crucibles were then held at a temperature of 105°C in a hot air oven for the whole of the following 12-hour day. After cooling down, the crucibles were taken out and put immediately in the desiccator. The crucibles were kept in the desicator until their weight could be measured.

Formula:

$$\% \text{ Moisture} = \frac{(weight\ of\ wet\ materials - weight\ of\ dry\ materials)}{(Weight\ of\ wet\ materials)} \times 100$$

Plate 8: Extracted moisture sample

3.6.4 Ash: After weighing the cleaned empty crucibles, 3 g of samples were then placed into each one of the crucibles. Sample-containing crucibles were held in the muffle furnace for five hours at a temperature of 550°C. After that, they were taken out and put into a desiccator immediately. After cooling, the weight of the crucibles were measured. Ash content was determined using the following formula:

$$\% \text{ Ash} = \frac{Ash\ Weight}{Sample\ Weight} \times 100$$

Plate 8: Extracted Ash samples

3.7 Gel Forming Ability of Fish Muscle

3.7.1 Organoleptic test: Freshness influences greatly on the gel-forming ability of fish. Therefore, before starting the experiment, the freshness of both fishes (*Dussumieria acuta, Sardinella fimbriata*) were assessed by determining organoleptic aspects. The protocol for determination of organoleptic quality was based on the determination of defect points. The aspects of which are given in table are according to Howgate et al., (1992) with slight modification. The evaluation aspects are according to the method of Howgate *et al.* with slight modification.

Gel forming ability of fish muscle gel have been studied by following the literature of Hossain *et al.* (2005).

3.7.2 Preparation of meat paste:

Fishes were decapitated and gutted and washed thoroughly with chilled water. Scales, skin, red muscle and belly flap and kidney tissue were removed. Fish muscle tissue is then deboned and minced. Bones and connective tissues were removed by sieving through a fine mesh sieve. Mince was washed for two times using chilled fresh water

containing 0.1% NaCl. Mince was stirred in four volumes of washing solution for 2 minutes and kept for settling for 10 minutes. Then dewatering was done through a bag made of cotton cloth. Washed and unwashed mince was grounded with 3% NaCl and 20% iced water by a mortar and pestle.

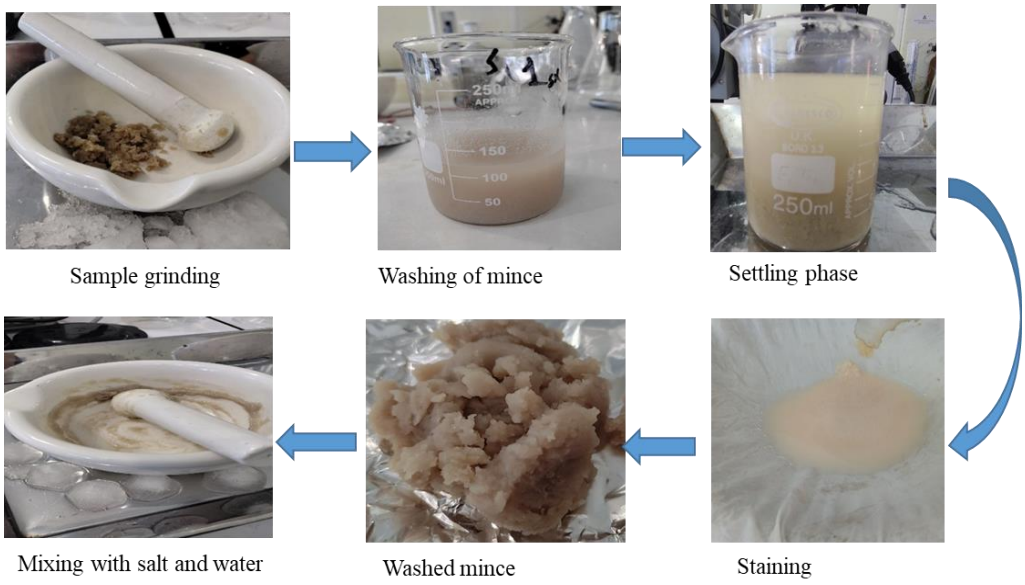


Figure 2: Preparation of meat paste

3.7.3 Preparation of Gel:

Salt grounded meat paste was stuffed into a heat stable PVC tube of 2 inch length. Both end of tube was sealed with polythene wrap and tightened. Then tubes were placed in water baths at temperature 40°C, 50°C and 60°C for 120 minute. Resulting gels were taken out from water bath and kept in ice for 60 minutes.

Figure 3: Preparation of gel

3.7.4 Measurement of gel strength: Resulting gels were subjected to puncture and folding test.

3.7.4.1 Puncture test: Resulting gels were cut into equal 2 cm pieces. Measuring of breaking force of gel was done by plunging with a spherical shaped plunger on the pan of electronic balance manually to quantify the breaking force. The plunger was metal based and its diameter was 5 mm. The force (g) needed to break the gel was recorded.

Plate 9 : Puncture test

3.7.4.2 Folding test: A spherical disc of 1 mm diameter gel was cut. It was placed on the index and middle finger tip and folded by thumb into half and quarter. Grading of gels were done using the scores presented in table 3.1.

The folding test result was assessed using the table of Poon et al., (1981)

Grade	Results on folding
AA	No crack visible when disc is folded into quarter
A	No crack when disc is folded into half but one or more cracks are visible when folded into quarter
B	One or more cracks are visible when folded into half
C	Breaks, but doesn't split into halves
D	Splits into halves when folded into half
O	Sample too soft to evaluate

Table no 3.1: Grade used in folding test of the gel

Plate 10: Folding test

3.8 Statistical Analysis

All of the experiments were conducted in triplicate. Using Microsoft Excel, the mean and standard error of the mean (SEM) were determined. Then a one-way analysis of variance (ANOVA) was performed on the data. For each treatment, descriptive statistics and a test for homogeneity of variance was conducted. With a 95% confidence level, Tukey HSD multiple comparison tests were used to analyze significant differences between treatments. The Statistical Package for Social Science (SPSS 8.0 for Windows, SPSS Inc., Chicago, IL) was used to conduct the statistical analysis.

CHAPTER 4: RESULTS

4.1 Myotome Structure and Muscle Yield

4.1.1 Myotome structure: The muscle structure of *Dussumieria acuta* and *Sardinella fimbriata* are shown in **plate 12 and plate 13** respectively. Fish possess a segmented musculature system, known as myotome which exhibit a three dimensional intricate configuraturation. On each side of the vertebral column, there are two distinct bundle of skeletal muscles. These bundles are sub-divided into an upper and lower mass, situated beneath the septum. Together, these muscle masses form fillet in fish. Here the upper portion is called dorsal and lower portion is called ventral muscle.every muscle cells in fish spans the entire length between two myocommata and run parallel to the longitudinal direction of the fish. Horizontal septum separates the fish musculature into the dorsal and ventral muscle regions. Epiaxial muscle are those located above the horizontal septum and hypoaxial muscle are located beneath it. Hypaxial muscles also circumvent the body cavity. Vertical septum divides the fish muscle into the left and right regions. It is shown in **plate 14 and 15**. There are two types muscle, white muscle and red muscle. The red muscles are concentrated along the lateral line and may or may not be sharply differentiated from the white muscles. In lateral views, the superficial red muscle began at a position just posterior to the operculum extending towards the tail along the lateral line and ended in the last caudal spine. The red muscle became thinner towards both dorsal and ventral sides where it overlaid the white muscle much more thinly than in the vicinity of horizontal septum. In both species, there is a similar pattern of increasing relative proportion of red muscle as one move toward the caudal fin.

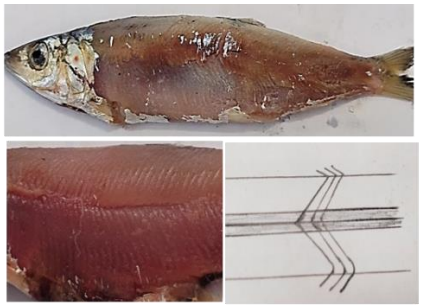


Plate 11 : Myotome structure of *Dussumiera acuta*

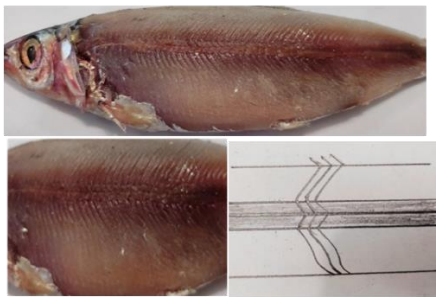
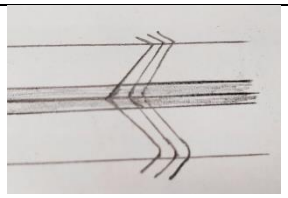
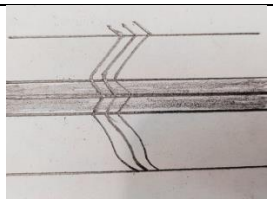


Plate 12 : Myotome structure of *Sardinella fimbriata*

Table 4.1.1: Summary of muscle characteristics of Rainbow Sardine *Dussumieria acuta* and Fringe scale Sardine *Sardinella fimbriata* fish samples**.**

Attributes	Fish Species	
	Rainbow Sardine	Fringe Scale Sardine
Direction of Myoseptums		
Number of Myotoms	60-65	55-61
Form of Myotoms	Broken over epi-axial and hypoaxial lines. Also broken over horizontal septum. Straight over dorsal side and wavy over ventral side.	Broken over epi-axial and hypoaxial lines and horizontal septum. Straight over dorsal side and wavy over ventral side.
Ordinary Muscle Color	Light red	White
Dark Muscle Color	Red	Red
Width of Dark Muscle	Thin over horizontal septum. Not so deep.	Wide over horizontal septum. Deep.

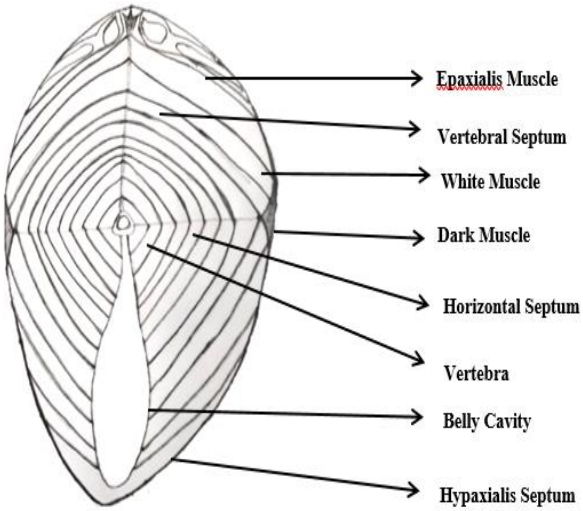


Figure 4: Belly cavity and musculature of Rainbow Sardine

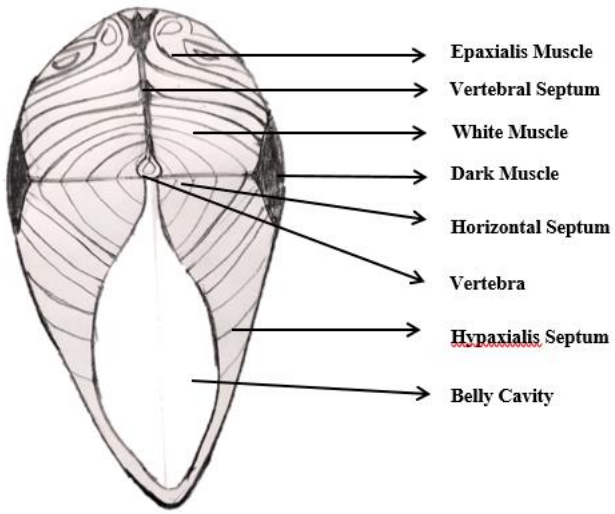


Figure 5: Belly cavity and musculature of Fringe Scale Sardine

The results also shows that in both fish species, muscle tissue are mostly white which constitute about 90% of skeletal muscle and certain amount of about 10% dark tissue of a brown or reddish colour. The dark muscle is located just under the skin along the side of the body. The proportion of dark to light muscle varies between two fish species. Rainbow Sardine *Dussumieria acuta* contains 3.86% dark muscle and 96.21% white muscle. On the other hand, Fringe scale sardine *Sardinella fimbriata* contains 7.87% dark muscle and 92.32% white muscle It is known that, along the ratio of red and white muscle varies along the length of the fish.

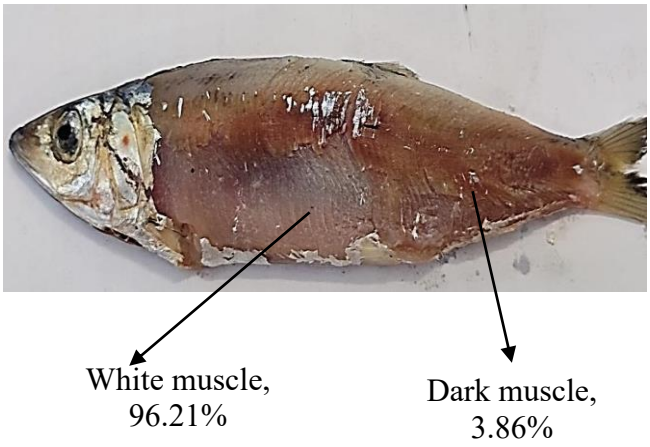


Figure 6: Dark and White Muscle Percentage of Rainbow Sardine

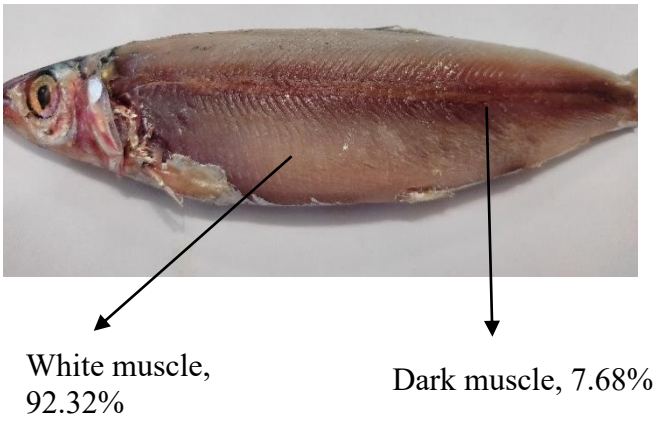


Figure 7: Dark and White Muscle Percentage of Fringe Scale

4.1.2 Muscle yield: Table 4.1.2: Processing yields of total muscle, white and dark muscle, carcasses and intestinal parts of Rainbow Sardine and Fringe scale Sardine fish samples

Processing yield	***Dussumieria acuta***	***Sardinella fimbriata***
Total body weight (g)	17.70	30.58
Carcass weight with skin (g)	4.15	4.15
Intestinal part weight (g)	0.86	2.43
Carcass percentage with body weight (%)	23.44	26.42
Total muscle weight (g)	12.69	20.2
Dark muscle weight (g)	0.49	1.55
White Muscle Weight (g)	12.20	18.65
Muscle percentage with body weight (%)	71.57	66.05
Dark muscle percentage with total muscle (%)	3.86	7.68
Muscle percentage with total muscle (%)	96.21	92.32

Table 4.1.2 shows that average total body weight of Rainbow Sardine was 17.70g. Total carcasses and intestinal parts of this fish species was 4.15 g and 0.86g, respectively, which is the 28.31% of the total body weight. On the other hand, muscle yield of this fish species was 12.69 g in which 0.49 g dark muscle and 12.20g white muscle. Muscle yield in percentage was 71.69% in which dark muscle represents in total muscle 3.86% and white muscle 96.21%. In case of Fringe scale Sardine fish samples, average total body weight of the fish was 30.58g. Carcases and intestinal parts were 8.80 g and 2.43g, respectively, which is the 34.37% of the total body weight. In this fish species, total muscle yield was 20.2g in which 1.55g dark muscle and 18.65g white muscle. Muscle yield from this fish species was 60.99% in which dark muscle represents 7.68% and white muscle 92.32%. From the study it is clearly

evident that muscle yield including proportion of white muscle in these two species are quite high and suitable for processing of fillets and other value-added products due to high muscle yields and also higher proportion of white muscles.

4.2 Proximate Composition

4.2.1. Proximate composition of different types of muscle

Table 4.2.1 Chemical composition of different types of muscles of *Dussumiera acuta* and *Sardinella fimbriata* fish

Species	Fish Muscle type	Moisture (%)	Protein (%)	Lipid (%)	Ash (%)
Dussumiera acuta	Dark	71.80 ± 0.18^{a}	24.02 ± 0.14^{b}	2.48 ± 0.13^{c}	21.70 ± 0.10^{a}
			$*85.17 \pm 0.27^{b}$	$*8.79 \pm 0.47^{a}$	$*6.02 \pm 0.33^{a}$
	White	72.68 ± 0.21^{b}	$24.75\ 0.24^{a}$	1.02 ± 0.16^{a}	1.45 ± 0.17^{a}
			$*90.58 \pm 0.17^{a}$	$*3.72 \pm 0.60^{c}$	$*5.30 \pm 0.59^{a}$
	Mixed	71.94 ± 0.15^{a}	24.13 ± 0.12^{b}	1.90 ± 0.15^{b}	1.71 ± 0.09^{a}
			$*85.99 \pm 0.93^{b}$	$*6.76 \pm 0.51^{b}$	$*5.80 \pm 0.54^{a}$
Sardinella fimbriata	Dark	72.07 ± 0.29^{b}	24.03 ± 0.12^{c}	2.23 ± 0.10^{c}	1.67 ± 0.07^{c}
			$*88.00 \pm 3.96^{a}$	$*6.78 \pm 2.41^{a}$	$*5.20 \pm 1.55^{a}$
	White	73.47 ± 0.17^{a}	25.06 ± 0.16^{a}	0.82 ± 0.03^{a}	0.75 ± 0.05^{a}
			$*94.77 \pm 0.55^{a}$	$*3.08 \pm 0.12^{a}$	$*2.88 \pm 0.21^{b}$
	Mixed	72.27 ± 0.09^{b}	24.54 ± 0.91^{b}	1.96 ± 0.08^{b}	1.23 ± 0.33^{b}
			$*88.49 \pm 0.38^{a}$	$*7.06 \pm 0.30^{a}$	$*4.43 \pm 0.40^{a}$

*****Values indicate dry weight basis composition. Data are mean values of three determinations ± SD. Means in identical rows with various letter combinations (a-c) in superscript differ considerably ($p < 0.05$, ANOVA, Tukey-HSD).

As shown in the table 4.2.1, Moisture contents were in the range of 71.80 ± 0.18% to 72.68 ± 0.21%. with highest value in white muscle and lowest value in dark muscle in *Dussumieria acuta*. The mean moisture value of white muscle is significantly

different ($p<0.05$). Protein content in dark muscle, white muscle and mixed muscle of the *Dussumiera acuta* ranged from 24.02 ± 0.14% to 24.75±0.24%. On dry weight basis, protein content was in the range of 85.17 ± 0.27% to 90.58 ± 0.17%. Protein content of white muscle was significantly different ($p<0.05$) in both wet and dry basis. Lipid content of the different muscles of *Dussumiera acuta* varies considerably, ranging from 1.02±0.16% to 2.48 ± 0.13%. On dry weight basis, highest lipid content was found in dark muscle 8.79±0.47% and lowest value 3.72±0.60% in white muscle of the same fish species. Significant difference ($p<0.05$) was observed in both dry and wet basis. There is little or no variations ash content among the different muscle types of *Dussumiera acuta*. The ash percentages of dark, white and mixed muscles are 1.70±0.10%, 1.45±0.17% and 1.71±0.09% on wet basis and 6.02±0.33%, 5.30±0.59% and 5.80 ± 0.54 on dry basis.

In *Sardinella fimbriata* moisture content in different types muscle varies from 71.80 ± 0.18% to 72.68 ± 0.21% highest value was found in white muscle and lowest in dark muscle. The mean moisture value of white muscle protein contents were in the range of 24.03 ± 0.12% to 25.06 ± 0.16% in wet basis. Here mean values are significantly different ($p< 0.05$). On dry basis, the mean protein percentages are 88.00±3.96%, 94.77±0.55, 88.49±0.38% in dark white and mixed muscle. Protein percentage of white muscle is significantly different ($p< 0.05$). Mean lipid value was found in the range of 0.82±0.03% to 2.23 ± 0.10% in wet basis and 3.08±0.12% to 6.78± 2.41%in dry basis. The mean lipid values are significantly different ($p<0.05$) in both dry and wet weight basis.There is little or no variations in ash content among the different muscle types of *Sardinella fimbriata* which ranged from 0.75±0.05% to 1.67± 0.07%. in dry basis the range is 1.23±0.33% to 5.20± 1.55%. Mean ash contents are significantly different in dark, white and mixed muscles in both wet and dry weight basis($p<0.05$). (table 4.2.1)

4.2.2. Proximate composition of muscles from different parts of fish body

Table 4.2.2 Chemical composition of of muscles from different body parts of *Dussumiera acuta* and *Sardinella fimbriata* fish

Species	Region of Fish Muscle	Moisture (%)	Protein (%)	Lipid (%)	Ash (%)
Dussumiera acuta	Head	73.56±0.28[a]	24.01±0.17[b]	0.72± 0.06[c]	1.71 ± 0.07[a]
			*90.83±0.41[a]	*2.72± 0.19[c]	*6.46± 0.25[a]
	Middle	71.47±0.27[b]	24.96 ± 0.28[a]	1.82± 0.05[b]	1.68 ± 0.14[a]
			*87.69± 0.48[b]	*6.39± 0.21[b]	*5.90 0.51[a]
	Tail	71.24±0.56[b]	24.55±0.53[ab]	2.46±0.12[a]	1.75±0.06[a]
			*85.35±0.30[c]	*8.55±0.47[a]	*6.08±0.17[a]
Sardinella fimbriata	Head	73.58± 0.22[a]	24.07±0.08[b]	0.67±0.06[c]	1.68±0.10[a]
			*91.11±0.52[a]	*2.53±0.20[c]	*6.35 ± 0.35[a]
	Middle	71.93±0.24[b]	25.38±0.47[a]	1.87±0.19[b]	1.62±0.20[a]
			*86.66±1.93[b]	*6.53±0.66[b]	*5.66±0.73[a]
	Tail	71.34±0.39[b]	24.76±0.31[ab]	2.35±0.19[a]	1.55±0.07[a]
			*86.39±0.56[b]	*8.18±0.67[a]	*5.41±0.22[a]

*****Values indicate dry weight basis composition. Data are mean values of three determinations ± SD Means in identical rows with various letter combinations (a-c) in superscript differ considerably ($p < 0.05$, ANOVA, Tukey-HSD).

As shown in the table 4.2.2, moisture content range in the muscles of head, middle and tail region of *Dussumiera acuta* were 71.24± 0.56% to 73.56±0.28%, with highest value in head and the lowest in tail region. Moisture percentage of head region is significantly different ($p<0.05$). Protein content of the muscles of head, middle and tail regions of *Dussumiera acuta* were 24.01± 0.17% to 24.96 ±0.28% and 24.55 ± 0.53, highest value was found in middle region and lowest in head region in wet basis. Again on dry basis the range was 87.69 ± 0.48% to 90.83± 0.41%. Here highest value was found in head region. Mean protein values were significantly different ($p<0.05$) in both dry and wet basis. In *Dussumiera acuta* mean lipid content range was 0.72 ± 0.06% to 2.46±0.12%. On wet weight basis, here highest lipid percentage was observed in tail region and lowest in head region. On dry weight basis, the range is

2.72±0.19% to 8.55±0.47% in head and tail muscle respectively. Percent lipid content were found significantly different ($p<0.05$) in head, middle and tail region in both dry and wet weight basis. In *Dussumiera acuta* ash content in the muscles of head, middle and tail were 1.71± 0.07%, 1.68±0.14% and 1.75±0.06%. On wet weight basis and the values are 6.46 ± 0.25%, 5.90±0.51% and 6.08 ± 0.17 respectively.

In *Sardinella fimbriata*, moisture content range in the muscles of head, middle and tail region of were 71.34±0.39% to 73.58±0.22%, with highest value in head and the lowest in tail region. Moisture percentage of head region is significantly different ($p<0.05$). Protein content of the muscles of head, middle and tail regions were 24.07 ± 0.08% to 25.38± 0.47% in wet weight basis and on dry weight basis the range was 86.66 ± 1.93% to 91.11±0.52%. Mean protein values were found significantly different ($p<0.05$) in both dry and wet basis.In wet weight basis, lipid content range in the muscles of different organs of *Sardinella fimbriata* was from 0.67± 0.06% to 2.35± 0.19% on wet weight basis and the range was found 2.53±0.20% to 8.18± 0.67%. Highest values were found in tail region and lowest in head region. Here, the lipid values are not significantly different in both wet and dry weight basis ($p >0.05$). In the samples of *Sardinella fimbriata*, in different body parts, ash content on wet weight basis were 1.68 ± 0.10%, 1.62 ± 0.20% and 1.55± 0.07% respectively in head, middle and tail. Again on dry weight basis the mean ash values were 6.35±0.35%, 5.66±0.73% and 5.41±0.22%. The results indicated that there was no significant difference ($p >0.05$) in mean ash value in both wet and dry weight basis.

4.2.3 Proximate composition of cooked fish samples

Proximate composition of *Dussumiera acuta* and *Sardinella fimbriata* raw, boiled and fried samples are presented in table 4.2.4.

Table 4.2.4: Chemical composition of raw, boiled and fried samples of *Dussumiera acuta* and *Sardinella fimbriata* fish

Fish Name	Fish Sample	Moisture	Protein	Lipid	Ash
Dussumiera acuta	Raw	71.94± 0.15[a]	24.13 ± 0.12[c]	1.90± 0 .15[b]	1.71 ± 0.09[c]
			*85.99 ±0.93[b]	*6.09 ± 0.37[b]	*6.76 ± 0.51[b]
	Boiled	67.68 ±0.65[b]	27.80 ± .35[b]	1.50 ± 0.28[b]	3.02 ± 0.06[b]
			*86.02±0.62[b]	*4.62 ± 0.79[b]	*9.35 ± 0.24[a]
	Fried	56.46± 1.09[c]	34.44 ± 1.20[a]	5.48± 0 .72[a]	3.73 ± 0 .18[a]
			78.89± 1.67[a]	*12.54±1.62[a]	*8.56 ± 0.61[a]
Sardinella fimbriata	Raw	72.27± 0.09[a]	24.54 ±0.19[b]	1.96 ± 0.08[b]	1.23 ± 0.10[c]
			* 88.49 0.38[a]	*7.06 ± 0.30[a]	*4.43 ± 0.40[b]
	Boiled	70.98 ±0.35[a]	25.42 ± 0.38[b]	1.71 ± 0.06[b]	1.89± 0.08[b]
			*84.52±4.15[ab]	*7.86 ± 1.49[a]	*6.72 ± 0.52[a]
	fried	55.21± 1.01[b]	35.61± 0.81[a]	5.98 ± 0.32[a]	3.20 ±0.35[a]
			*79.90 ±1.49[b]	*13.07±0.61[a]	*7.02 ± 0.91[a]

*****Values indicate dry weight basis composition. Data are mean values of three determinations ± SD. Means in identical rows with various letter combinations (a-c) in superscript differ considerably ($p < 0.05$, ANOVA, Tukey-HSD).

From table 4.2.4. Moisture content in raw, boiled and fried *Dussumieria acuta* fish were 71.94 ± 0.15%, 67.68 ±0.65%, and 56.46± 1.09% respectively. Moisture of raw sample significantly changed in both boiled and fried sample ($p<0.05$). Mean protein value of raw, boiled and fried *Dussumieria acuta* fish were 24.13 ± 0.12%, 27.80 ± 0.35% and 34.44 ± 1.20% in wet weight basis. Changes of protein percentage is significant ($p<0.05$) in both boiled and fried sample. In dry weight basis the percentage is 85.99±0.93%, 86.02±0.62% and 78.89±1.67%. Here protein percentage of fried sample showed significant difference. Lipid value decreased with boiling and increased with frying operation. For *Dussumieria acuta* lipid value decreased from 1.90± 0.15% to 1.50 ±0.28% with boiling and with frying operation it increased to

5.48±0 .72%. In dry weight basis the percentages were 6.09 ± 0.37%, 4.62 ±0.79% and 12.54 ±1.62 for raw boiled and cooked sample. In both dry and wet weight basis the lipid value of fried sample was significantly different ($p<0.05$) from others. Mineral content increased in both case of boiling and frying operation. In *Dussumiera acuta* mineral value rises from 1.71 ± 0.09% to 3.02 ± 0.06% with boiling and with frying it resulted in .73 ± 0.18%.in dry weight basis,.the ash percentages were 6.76± 0.51%. 9.35±0.24%, and 8.56±0.61%. Significant difference ($p<0.05$) was found here in both dry and weight basis.

Moisture content in raw, fried and boiled *Sardinella fimbriata* fish were 72.27± 0.09%, 70.98±0.35% and 55.21±1.02%. Here fried sample was significantly different ($p<0.05$). Mean protein value of raw, boiled and fried *Sardinella fimbriata* fish were 24.54±0.19%, 25.42±0.38%, 35.61± 0.81% and in case of dry weight basis, the values are 88.49± 0.38%, 84.52±4.15% and 79.90 ±1.49%. In both dry and wet weight basis fried fish showed significant difference. In *Sardinella fimbriata,* lipid declines from 1.96 ± 0.08%, 1.71±0.06% and 5.98±0.32%. Similar changes are found in dry weight basis. The lipid percentages in raw boiled and fried samples in dry basis were 7.06 ± 0.30%, 7.86 ± 1.49%, 13.07 ±0.61%. Lipid value of fried fish is significantly different ($p< 0.05$). In *Sardinella fimbriata* ash percentage increases from 1.23 ± 0.01% to 1.89 ± 0.08% and with frying it increased to 3.20 ± 0.35%. Here fried sample showed significant difference ($p< 0.05$). In dry weight basis mineral content of raw boiled and dried fishes were 4.43±0.40%, 72 ± 0.52% and 7.02 ± 0.91%. Boiled and fried sample showed significant difference ($p< 0.05$) in dry weight basis. (Fig. 4.2.6 (a) and Fig. 4.2.6 (b)).

4.3 Sensory Evaluation of Cooked Fish: Changes in muscle color, texture and smell were observed in boiled and fried samples and compared with raw muscle**.** It indicated the changes in muscle color, texture and mainly the severity or level of smell produced by a fish in raw, boiled and fried stage. This data is important for processing because fishes with different severity level of smell, muscles may need different types of care in processing. Our selected panel have reported following data.

Table 4.2.3: Organoleptic characteristics of raw, boiled and fried samples of *Dussumiera acuta* and *Sardinella fimbriata* fish

Sample Name		Muscle Color			Texture			Smell		
		White	Light Red	Red	Firm	Soft	Burst	Strong	Medium	Low
Rainbow Sardine	Raw	-	100%	-	-	80%	20%	80%	20%	-
	Boiled	100%	-	-	40%	60%	-	20%	80%	-
	Fried	100%	-	-	40%	60%	-	20%	80%	-
Fringe Scale Sardine	Raw	20%	80%	-	100 %	-	-		100%	-
	Boiled	100%	-	-	100 %	-	-	40%	60%	-
	Fried	100%	-	-	20%	80%	-	-	-	-

According to the obsevations of our panelists, both fish *Dussumieria acuta* and *Sardinella fimbriata r*aw muscle was light red in color with boiling and frying it changed to white. The raw muscle texture was soft with boiling and frying it did not changed considerably in case of *Dussumieria acuta*. The fish *Sardinella fimbriata* is characteristically have firm texture in raw condition which remains same with boiling and in case of frying it became soft. The smell of the fish in raw muscle was strong, after boiling it emitted stronger smell than raw muscle. However, after frying the fishes with dark muscle content exhibited comparatively stronger smell.

4.4 Determination of Cooking loss

Table 4.2.4 shows the loss of weight with two cooking application (boiling and frying) of *Dussumiera acuta* and *Sardinella fimbriata*

Fish Name	**Cooking Loss (%)**	
	Boiling	**Frying**
Dussumiera acuta	14.38%	38.10%
Sardinella fimbriata	10.73%	36.25%

4.5 Gel Forming Ability

4.5.1 Measurement gel strength by puncture test

Table 4.3.1 Breaking forces of washed and unwashed muscle pastes of *Dussumiera acuta*. *Sardinella fimbriata* Fish at 40, 50 and 60^0 C heating temperature

Fish Name	Sample type	Breaking Force at 40^0 C (g)	Breaking Force at 50^0 C(g)	Breaking Force at 60^0 C (g)
Rainbow Sardine (*Dussumiera acuta*)	Washed	224±4.35	320±9.48	250±3.60
	Unwashed	96 ±2.0	145 ±5.29	117± 3.60
Fringe Scale Sardine (*Sardinella fimbriata*)	Washed	181 ±3.60	304±6.24	251±6.24
	Unwashed	110±5.56	249±5.50	210± 5.03

Data are mean values of three determinations ± SD Means in identical rows with various letter combinations (a-c) differ considerably ($p< 0.05$, ANOVA, Tukey-HSD).

Resulting fish muscle pastes were subjected to different heating temperature (40, 50 and 60^0 C) in water bath for a certain period of time (120 minute). After cooling down in ice for 1 hour breaking force was measured. At 40^0 C the breaking force is 224±4.35 g and 96±2.0 g respectively for washed and unwashed muscle paste in case of *Dussumiera acuta*. Highest breaking force was found at 50^0 C for both washed and unwashed fish muscle paste. Breaking force of gels from washed muscle is 320±9.48 g and 145±5.29 g for unwashed muscle. The gel strength decreased at 60^0 C heating temperature and it showed a breaking force of 250±3.61 g and 117± 3.61 g respectively for washed and unwashed muscle.

In case of *Sardinella fimbriata* at 40^0 C temperature, breaking force was found 181 ±3.606 g and 110±5.568 g for washed and unwashed muscle respectively. At 50^0 C washed and unwashed muscle showed a breaking force of 304±6.245g and 249±5.508 g. At 60^0 C this fish muscle paste showed a reduction in value of breaking force,

which are 251±6.245 g and 210± 5.033 g for washed and unwashed muscle respectively. Highest breaking force was found at 50^0 C. (Fig. 4.3.1)

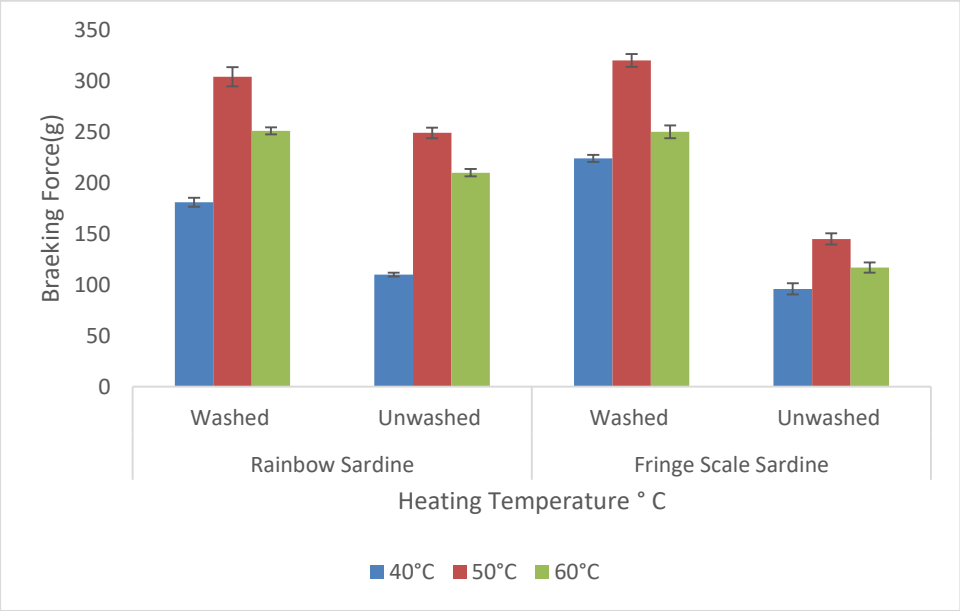


Figure 8: Gel forming ability of washed and unwashed mince of Rainbow Sardine (*Dussumiera acuta*) at different heating temperature Fringe Scale Sardine (*Sardinella fimbriata*) fish at 40°, 50° and 60° C heating temperature

4.5.2 Measurement gel strength by folding test

Grade found in folding test of the gel:

Fish Name	Temperature ° C	Grades on folding of gel at different temperature	
		Washed	Unwashed
Dussumieria acuta	40	D	D
	50	B	C
	60	C	C
Sardinella fimbriata	40	B	C
	50	A	B
	60	B	C

Folding test is another important indicator of gel quality testing. Folding test was carried out by following the table 3.1. From the table 4.5.2 we find that in case of *Dussumieria acuta*, 40° C incubation temperature produced a D grade gel in both washed and unwashed meat paste. At 50^0 C heating temperature produced B grade gel which is of better quality than unwashed one (C grade). At 60^0 C incubation temperature C grade gel had been produced from both washed and unwashed ones. In case of *Sardinella fimbriata*, 40^0 C incubation temperature produced a B grade gel in washed and C grade in unwashed meat paste.50^0 C heating temperature produced A grade gel in both washed and B grade for unwashed one. At 60^0 C incubation temperature B grade gel had been produced from washed meat paste and C grade gel from unwashed ones

CHAPTER-5: DISCUSSION

5.1 Myotome Structure and Processig Yield

5.1.1 Myotome structure: Skeletal muscle displays a broad array of shapes, sizes, anatomical positions and physiological arrays. They have a composite structure encompassing not only muscle fibre but also connective, adipos, vascular and nervous tissue. Muscle fibers, intramuscular connective tissue, and intramuscular fat are pivotal factors influencing the quality of meat and fish flesh. Producers, processors, distributors, and consumers, have the options of specify particular quality critera on on their intended usage of the products. The current study clearly shows that white muscle fibers have a larger diameter than dark muscle fiber. According to the study of Kiessling et al. (2006) findings shows that, white muscle fiber is tightly packed with myofibrils that occupy 75–95% of the fiber volume are supported by the results. The findings also indicate that both fish species' muscle tissue is predominantly white, making up roughly 90% of their skeletal muscle, with the remaining 10% being dark tissue that is brown or reddish in color. Along the side of the body, the black muscle is situated just beneath the skin. It is known that along the length of the fish, the ratio of red to white muscle varies. From head to tail, Bone (1966) estimated that *Scyziorhinus canicula* (L.) varied by around 6-20%. Similar results were reported for a 36 cm *Gadus merlangus*, which showed 2% of red muscle at 0-35 cm from the head and 14.30% at 0.79 cm. The percentage was 11.70% at the sample location (Love et al., 1974). According to the results of the current study, the muscle cells in this fish run parallel to one another and are joined by connective tissue sheaths (myocommata), which are attached to the skeleton and the skin. Myotomes are collections of parallel muscle cells. It is clear that fish with an active lifestyle have a higher percentage of red fibers in their trunk musculature. The deep-sea fish (Macrouridae and Chimaeridae) are a distinct family that are distinguished by having small hearts, low hemocrits, and a high water content. These fish have little red muscle and are probably slow-moving in nature. Blaxter et al. (1971) provide other examples. There are a lot of reports on the characteristics of white and dark muscle fiber. Low mitochondrial concentrations and a sparse capillary network are found in white muscle fibers (Johnston, 1981; Keissling et al., 2006). White fibers are used for

burst activity, such as running from predators and catching prey, since they contract quickly but tire easily (Love, 1970). While fish with more active lifestyles typically have a higher proportion of red muscle. Red muscle only makes up around 10% of the skeletal muscle of fishes (Greer-Walker and Pull, 1973). The ratio of dark to light muscle fluctuates according to the fish's activity. Up to 48% of the body weight of pelagic fish, or species that swim more or less continually, such as Herring and Mackerel, may be made up of black muscle (Love, 1970). Demersal fish, or those that feed on the bottom and only sometimes move, have relatively little black muscle. For movement, fishes primarily need two different types of muscles. According to Sänger and Stoiber (2001), red fibers are tiny in diameter, have a dense capillary network, and have high mitochondrial densities. For prolonged swimming activities fuelled by aerobic metabolism, such long distance migrations, red muscle fibers are recruited (Johnston et al., 1977; Rome et al., 1984). Fast-oxidative (pink) fibers are another kind found in some species, and they are similar to red and white fibers in both form and function (Johnston, 1981, Patterson et al., 1972). The meat's dark color is caused by the high myoglobin concentration, which gives it a reddish brown hue (Chaijan *et al.*, 2004). 40–50% of all fish caught worldwide have dark muscle (Hultin and Kelleher, 2000). The white muscle is utilized for quick bursts of swimming, whereas the black muscle, which is situated just beneath the skin, is used for slow, continuous swimming (Tsukamoto, 1981). According to Bone (1978), referenced in Kiessling et al., (2006), these are the red and white muscles that are most suited for swimming slowly for an extended period of time and quickly for a brief period of time. Fish use a mix of their paired and unpaired fin motions as well as the undulations of their segmental myotomal muscles to move through the water. Because aquatic mobility requires more energy than terrestrial locomotion, fish muscles are really more specialized than those of terrestrial animals (Johnston, 1981). Compared to bottom-dwelling fish like flounder and cod, active fish like tuna, herring, and mackerel have more dark muscle (Kobayashi et al., 2006). According to Hiratsuka et al., (2011), headless skipjack tuna comprise 13–16% black muscle, which enables this species of fish to swim quickly for longer stretches of time without becoming exhausted. According to Suzuki and Watabe (1986), the amount of lipid in white meat might differ depending on the species and the time of harvest. Dark muscle, which contains more lipid, is therefore more susceptible to lipid oxidation than white muscle (Shahidi and Spurvy, 1996).

Bony fishes' muscular systems help them move around. Myomeres and myosepta—collectively known as myotomes make up muscles. They have developed specific capabilities that help them acquire prey or fend off predators effectively. The many components of the bony fishes' muscular systems were investigated in this activity, and their roles were also familiarized. Red muscular fibers, commonly referred to as sluggish muscles, are employed for long-distance, energy-efficient swimming. Commonly, red muscles are located in limited areas along the lateral line. These muscles have a smaller diameter (24–45 m) and make up less than 10% of the entire musculature. According to Kiessling et al. (2006), this muscle type has a good capillary supply, a high concentration of mitochondria, lipid droplets, and glycogen reserves. Red muscles have a high myoglobin content as well as a totally aerobic metabolic focus (Rhodes University, undated). Fast muscles, often known as white muscular fibers, have thicker diameters (50–100 m) than red muscles. They have a decreased blood flow, which results in a decreased oxygen supply. White muscles have anaerobic metabolism (conversion of glycogen to lactate), which results in stresses that are 2.7 times higher than those of red muscles. However, white muscles are energy inefficient, suggesting that they are better suited for short, sharp bursts of movement (such prey capture and escape response) and are not suitable for prolonged swimming (Rayner et al., 1967, Rome et al., 1984). Most fish species have few organelles, such as mitochondria, and low amounts of lipid droplets and myoglobin (Kiessling et al., 2006).

5.1.2 Processing yields of the experimental fish: Wastes from the fish processing industries include skin, scales, stomach contents, and bones. The usage of certain organic wastes is not very common. This substantial manufacturing volume does, however, result in the production of byproducts that are not meant for human use. Fish processing industries produced over 37,900 tonnes of non-food items in 2016 (FAO, 2018). Backbones, belly flaps, fish fins, gills, heads, liver, roe, skin, viscera, and flesh stuck to the bones are some of these aquaculture by-products (Vázquez et al., 2019). Knowing the processing yields of these marine fish species is crucial for efficient processing and exploitation of these fish species for various value-added products.

There are a lot of reports on processing and various bodily components for efficient use. By fishing fish size and species, season, and zone, the ratio of food fish to by-

products changes (Rustad et al., 2011). According to the study, bones can make up 9%–15% of a fish's total weight, while the head makes up 9%–12%, the viscera 12%–18%, the skin 1%–3%, and the scales 5% (Villamil et al., 2017). Gelatin (a type of protein) is primarily found in fish skins. The use of gelatin in the food, pharmaceutical, and photographic industries is well known. According to Gudmunsson and Hafsteinsson (1997), gelatin is often made on a big scale for the commercial market from skin and bones of mammalian origin (mostly beef and pork). In addition to making fish gelatin, Choi and Regenstein (2000) proposed that commercial usage of skin and bones, which are typically disposed as trash, can be successfully exploited through proper waste management and as well as economic advantage. An important supply of protein, lipids, and minerals can be found in the fish skin and scales that are thrown away as dressing losses (Iqbal, 2002). However, compared to mammalian collagen, fish collagen generally contains more amino acids, which may account for the lower temperature of denaturation (Grossman and Bergman, 1992). Cod has been reported to have had its gelatin extracted (Gudmunsson and Hafsteinsson, 1997). Gelatin was isolated from the skin of black and red Telapia in 2000, and the physiochemical properties were identified. They came to the conclusion that gelatin's viscosity and melting points suggested it may be employed in applications other than those for cold water fish gelatin (Grossman and Bergman, 1992). In some regions of the world, the head is also consumed as food, but most often it is lost during dressing. The leftover parts, including the head, fins, skin, and scales, can be fed to chickens (Choi and Regestein, 2000).

5.2 Proximate Composition

5.2.1 Proximate composition of different types of muscle: The proximate composition of any products gives a first indication about the nutritional aspects of those products. The analysis of moisture, protein, lipid, ash levels in fish hold significant importance for a variety of stakeholders including consumers, manufacturers and scientists from multiple perspectives. Beyond providing insights in to the nutritional profile of fish, such studies contribute to enhancing its processing and preservation methods (Mridha et al., 2005) and regular assessment of the physiological condition of fish from fisheries point of view (Cui & Wootton, 2001) The chemical makeup of fish can be used by nutritionists to identify readily available sources of high protein low fat human food (Foran et al., 2005; Mozaffarian et al.,

2003). It will aid food scientists to develop high protein food with high nutritional value (Mohamed et al., 2010). Nowadays, appropriate knowledge about the proximate composition is increasingly finding application in various profound areas.

The findings obtained from the current investigation show that moisture contents were in the range of 71.80 ± 0.18% to 72.68 ± 0.21%. with highest value in white muscle and lowest value in dark muscle in *Dussumieria acuta*. In *Sardinella fimbriata* moisture content in different types muscle varies from 71.80 ± 0.18% to 72.68 ± 0.21% highest value was found in white muscle and lowest in dark muscle. The mean moisture value of white muscle is significantly different ($P<0.05$). There are some minor variations in moisture contents among dark, white and mixed muscles of both fishes investigated in the present study. White muscle was found to possess higher water percentage. It is known that water makes up the majority of the bodies of all animal including fish and serves as the route for the movement of numerous nutrients the exchange of chemical energyand a number of cytoplasmic event. Numerous studies have indicated that in the majority of fish species, moisture content typically falls within the range of 60% to 80% (Aberoumand, 2014; Love, 1970). However, in certain fish varieties, moisture content has been observed to exceed these values significantly, such as approximately 90% in the case of Bombaye duck, Harpadon nehereus, and several other deep-sea bottom-dwelling fish species.

It is widely believed that fish protein has been considered as a highly nutritional both in qualitatively and quantitively (Khalili Tilami & Sampels, 2018). It is a complete protein where all the essential amino acids are present in adequately and therefore, mainly responsible for building and repairing muscle tissues, improving blood quality and immunity. In *Dussumiera acuta* Protein content in dark muscle, white muscle and mixed muscle of the *Dussumiera acuta* ranged from 24.02 ± 0.14% to 24.75±0.24%. For better understanding in analysing data, the values obtained from various muscles were calculated on dry weight basis. On dry weight basis. Protein content was in the range of 85.17±0.27% to 90.58±0.17%. Protein content of white muscle was significantly different ($P<0.05$) in both wet weight and dry weight basis. In *Sardinella fimbriata* mean protein value of white muscle were in the range of 24.03±0.12% to 25.06 ±0.16% in wet basis. Here mean values are significantly different ($p < 0.05$).

On dry weight basis, the mean protein percentages are 88.00 ± 3.96%, 94.77±0.55, 88.49 ± 0.38% in dark white and mixed muscle. Protein percentage of white muscle is significantly different ($p < 0.05$).

In both fishes, protein content was higher on dry weight basis in white muscle compared to the other muscles. In general, the protein content of fish muscle typically falls within the range of 15-25% (Ryu et al., 2021). In general it is widely accepted that protein content of the fish is considered to be low if it possess below 15%, high 15-20% and very high where protein content is above 20%. From the present study, it is clearly indicated that the muscles of *Dussumiera acuta* and *Sardinella fimbriata*, protein content of muscles were more than 20%, which means the fish muscles examined were in the group of very high protein content. Moisture, crude protein, and lipid contents between ordinary and dark muscle were found to differ significantly. In general, the crude protein content of ordinary muscle was higher than dark muscle. Protein concentration varies depending on the kind of muscle, with dark muscles often having lower levels of both protein and hydration than light muscles.

Lipid is regarded as the third major constituent in fish muscle and it typically found in the range of 6% to 20%. It is predominantly situated in various parts of the fish including the subcutaneous tissue, liver, muscle tissue, mesenteric tissue, belly flap, and head. (Moradi et al., 2011). According to the Ackman (1994), fishes are categorized into four main groups based on the amount of lipid contents: Lean < 2 % fat: shellfish, haddock, cod; low fat (2%-4% fat: flounder, halibut, sole; medium fat (4% -8% fat): wild salmon; high fat (>8% fat): mackerel, farmed salmon, sablefish, herring Lipid content of the different muscles of *Dussumiera acuta* varies considerably, ranging from 1.02±0.16% to 2.48 ±0.13%. On dry weight basis, highest lipid content of was found in dark muscle 8.79±0.47% and lowest value 3.72 ± 0.60% in white muscle of the same fish species. Significant difference ($P<0.05$) was found in both dry and wet basis. In *Sardinella fimbriata*, mean lipid value was found in the range of 0.82 ± 0.03% to 2.23 ± 0.10% in wet basis and 3.08± 0.12% to 6.78± 2.41%in dry basis. The mean lipid values are significantly different ($P<0.05$) in both dry and wet weight basis.

Ash is an inorganic residue that is obtained from fully burned organic materials (Adewumi et al., 2014). It makes up 0.5% to 5% of the total fish body weight and ranks fourth in terms of quantity. According to Ndome et al. (2010), ash typically serves as a substantial source of nutrients for fish. There is little or no variations ash

content among the different muscle types of *Dussumiera acuta* and *Sardinella fimbriata*. In *Dussumiera acuta* the ash percentages of dark, white and mixed muscles are 1.70± 0.10%, 1.45 ± 0.17% and 1.71 ± 0.09% on wet basis and 6.02 ± 0.33%, 5.30 ± 0.59% and 5.80 ± 0.54 on dry basis. In *Sardinella fimbriata* which ranged from 0.75± 0.05% to 1.67 ± 0.07%. in dry basis the range is 1.23 ± 0.33% to 5.20± 1.55%. Mean ash contents are significantly different in dark, white and mixed muscles in both wet and dry weight basis($P<0.05$). Fish muscle and bones serves as an valuable reservoir of dispensable minerals with approximately 65% of minerals are stocked in the skeleton, notably in vertebra (Njinkoue et al., 2016). Rahman et al. (2020) reported that Variations in the mineral concentration of fish and shellfish are caused by a variety of factors, including food, species, environmental variables, primarily temperature, seasons, salinity, geographic location, and so forth. Moreover the mineral and trace element composition, which constitutes the overall ash content is recognized to be influenced by various factors including dietery habits, migration pattern, ecosyste and the environment, even among the species thriving the same habitat (Zaman et al., 2014; Palani et al., 2014). It is well known that most of the processors prefer fish muscles from the dorsal regions for the production of value-added different fish products. Ray liver is reported to contain a high amount of oil which is rich in vitamin A (Ormanci, 2006).

5.2.2. Proximate composition of muscles from different parts of body: There is little or no information is available on chemical compositions of the muscles of different body parts of the marine fish species available in Bangladesh. Therefore, studies on chemical composition of the muscles of different body regions of *Dussumiera acuta.*and *Sardinella fimbriata* were conducted and the results are shown in table 4.2.

As shown in the table 4.2.2 and figure 4.2.3 (a) and 4.2.3 (b), moisture content range in the muscles of head, middle and tail region of *Dussumiera acuta* were 71.24± 0.56% to 73.56±0.28%, with highest value in head and the lowest in tail region. Moisture percentage of head region is significantly different ($P<0.05$). In *Sardinella fimbriata*, moisture content range in the muscles of head, middle and tail region of were 71.34± 0.39% to 73.58± 0.22%, with highest value in head and the lowest in tail region. Moisture percentage of head region is significantly different ($P<0.05$).

Protein content of the muscles of head, middle and tail regions of *Dussumiera acuta* were 24.01± 0.17% to 24.96 ± 0.28% and 24.55 ± 0.53, highest value was found in middle region and lowest in head region in wet weight basis. Again on dry basis the range was 87.69 ± 0.48% to 90.83 ± 0.41%. Here highest value was found in head region.Mean protein values were significantly different (P<0.05) in both dry and wet basis. Protein content of the muscles of head, middle and tail regions of were 24.07 ± 0.08% to 25.38± 0.47% in wet basis and on dry basis the range was 86.66 ± 1.93% to 91.11± 0.52%. mean protein values were found significantly different (P<0.05) in both dry and wet basis

There results obtained from the present study agrees with the finding of Ray fish where there were also significant differences in protein content between main body and tail ($p < 0.05$) (Tufan et al., 2013). Water and lipid exhibit n inverse relationship within fish tissue where the combined percentage of this two component will account forapproximately 80% (Svenning, et al., 2019). Although the range of oil and water combining percentages is not uniform, it is roughly 78-85%. (Cliff, 2016). Similar results were obtained from another study by Bekir Tufan et al. (2013) where there were also significant differences in protein content between main body and tail ($p < 0.05$).

In *Dussumiera acuta* mean lipid content range was 0.72 ± 0.06% to 2.46 ± 0.12% on wet weight basis, here highest lipid percentage was observed in tail region and lowest in head region. On dry basis the range is 2.72 ± 0.19% to 8.55 ± 0.47% in head and tail muscle respectively. Mean percentage lipid content were found significantly different (P<0.05) in head middle and tail region in both dry and wet weight basis. In wet weight basis, lipid content range in the muscles of different bodyparts of *Sardinella fimbriata* was from 0.67± 0.06% to 2.35 ± 0.19% on wet weight basis and the range was found 2.53 ± 0.20% to 8.18± 0.67%. Highest values were found in tail region and lowest was in head region. Here the lipid values are not significantly different in both wet and dry weight basis (P >0.05).

There was a variation in lipid contents among the muscles of different parts of the fish body. In the present study, lipid contents were 0.50±0.04%, 0.58±0.10% and 0.72±0.03%, respectively in the muscles of head, middle and tail regions of *Dussumiera acuta*. On dry weight basis, accordingly lipid contents were 2.23±0.33%, 2.27±0.44% and 2.26±0.17% respectively. Lipid content in the muscles of different organs of *Sardinella fimbriata* was also investigated. The values were 0.67± 1.26%,

0.80± 0.13% and 0.90± 0.06%, respectively muscles of head, middle and tail regions of *Sardinella fimbriata* fish samples. On dry weight basis, these calculated values were 2.26±0.17%, 2.26±0.33% and 2.66±021%, respectively. As shown in the table, lipid contents in the muscles of middle region were comparatively higher than those of tail and head regions. The result is in agreement with the findings of Bekir Tufan, et al. (2013) for ray fish. It is well known that lipid contents varies greatly among the species and within the species depending on locations, size, age, feeding and breeding conditions.

In *Dussumiera acuta* ash content in the muscles of head, middle and tail were 1.71 ± 0.07%, 1.68 ± 0.14% and 1.75 ± 0.06% on wet weight basis and the values are 6.46 ± 0.25%, 5.90± 0.51% and 6.08 ± 0.17 respectively. In the samples of *Sardinella fimbriata* , in different body parts, ash content on wet weight basis were1.68 ± 0.10%, 1.62 ± 0.20% and 1.55± 0.07% respectively in head, middle and tail. Again on dry basis the mean ash values are 6.35 ± 0.35%, 5.66 ± 0.73% and 5.41 ± 0.22%. The results indicated that there was no significant difference ($P > 0.05$) in mean ash value in both wet and dry weight basis. The results indicated that there was little or no variations of ash contents among the muscles of different regions of the fish body and in between two fish species investigated in the present study.

5.2.3. Effect of Cooking on Proximate Composition: Fish is a major source of animal protein and it contains vitamins and minerals. The nutritive value of fish can be affected by processing or cooking methods. Studies had been conducted on the effect of cooking on proximate compositions of two m,arine species of Bangladesh. From our experimental data it is found that both *Dussumiera acuta, Sardinella fimbriata* showed a declination of moisture, lipid content and increase of protein and mineral value. Both *Dussumiera acuta, Sardinella fimbriata* showed a significant reduction of moisture content and increase of protein, lipid and ash value in frying. Puwastien et al. (1999) conducted a research on 8 freshwater and 8 marine fishes. In case of boiling operation most of the fishes showed a reduction of moisture, increase of protein. According to him fat and mineral value have not undergone significant changes.Kocatepe et al. (2011) investigated how several cooking methods (grilling, baking, frying, and microwave cooking) affected the anchovy's (*Engraulis encrasicolus*) proximate composition. The comparison of the cooked and raw fish revealed that the cooking methods had a substantial impact on the proximate

composition. The greatest quantity of water loss (49.55%) was found in fried anchovies. According to his study, compared to other cooking methods, frying resulted in greater water loss and lipid increase ($P < 0.05$), mostly because fish absorbs fat during frying. In comparison to raw or other cooked fish, fried fish exhibited an elevated level of fat, primarily because the fish absorbed the fat. The most protein, least fat, and most energy are found in grilled fish. According to these authors, grilling is the ideal method of cooking for a diet that is balanced. Dry matter increased as a result of the oil being absorbed during frying (Gokoglu et al., 2004; Steiner-Asiedu et al., 1991; and Unlusayin et al., 2001, Nurhan, 2007)

Gokoglu et al. (2004) investigated the effects of several cooking methods (frying, boiling, baking, grilling, and microwave heating) on the immediate composition and mineral of rainbow trout (*Oncorhynchus mykiss*). All cooking methods were known to significantly alter the quantities of protein, ash. The samples prepared in other ways, however, did not exhibit a noticeably higher fat content. Practically all types of fish considerably lost Mg, P, Zn, and Mn concentrations when they were cooked. Na and K concentrations rose in microwave-cooked samples, but Cu levels rose in fried samples. Fish cooked by boiling lost less of its mineral content than fish prepared using other methods. The findings demonstrated that, in comparison to raw fish, heating dramatically altered the fish's proximate composition and mineral concentrations. It has been found that baking and grilling are the best cooking methods for creating healthful meals.

The effects of various cooking techniques on nutritional attributes such as the relative content o certain Catfish have been studied (Weber et al., 2008; Ersoy and Ozeren, 2009). On the oxidative, proximate, and fatty acid composition of silver catfish (*Rhamdia quelen*) fillets, the effects of seven different cooking methods (boiling, conventional baking, microwave baking, grilling, deep-frying in soybean oil, canola oil, or partially hydrogenated vegetable oil) were evaluated. Each treatment reduced moisture content while raising protein content. The alterations in proximate composition were particularly noticeable in the fried fillets (Weber et al., 2008).

The result of our experimental data is quite similar with Abraha et al. (2018) who found that most of the cooking operation (oven drying, solar drying and smoking) causes a declination of moisture content. Mean moisture content of raw Anchovy was 62.86±0.03% which is reduced to 49.55±0.08% after frying. All cooking methods—

grilling, baking, frying, and microwave heating—reduced moisture content while significantly raising fat content ($P< 0.05$). Abraha et al. (2018) reported that, on the basis of wet matter, Protein value showed a rise from 20.7±0.62% to 32.3±0.54%. The effects of several cooking methods (grilling, frying, and steaming) on the protein solubility and proximate composition of golden grey mullet (*Liza aurata*) fillets were examined by Ghelichpour and Shabanpour in 2011. Fish that had been cooked all had increased levels of protein and ash. In terms of proximate composition, an increase in fat content and a reduction in moisture content were the most obvious changes. After steaming, the amount of fat in the fillets did not significantly alter, although it did after frying and grilling ($P< 0.05$). The isoelectric point of fillets was confirmed by the minimal protein solubility of fillets at a pH range of 5–6. Protein solubility of fillets was decreased by reducing pH after cooking. The solubility of the grilled sample was lower than that of the steamed samples.

The approximate composition of cooked African catfish was estimated by Ersoy et al., 2009 We employed baking, grilling, microwaving, and frying as our cooking methods. All cooked fish contained more protein and ash than raw fish. Only the fried fillets had more fat than the rest. The moisture content of grilled fish is lower.

According to earlier research (Gall et al., 1983; Steiner-Asiedu et al., 1991), processing and cooking techniques had little or no impact on the elements. However, Cooking techniques had significant impact on the mineral levels in some fish samples (Ackurt, 1991, Morris, 2004).

5.3 Cooking loss:

Studies were also conducted on effects of cooking on nutritional values, particularly composition of two marine fish species. There were some losses of nutritional values along with water. Probably, these losses are related to the loss of water due to lacking of water holding capacity of fish muscle during boiling and frying. Depending on the cooking method, the cooking loss varied. According to the current investigation, the cooking loss for fried and boiled was considerably highest (47.32%) and lowest (32.61%) respectively. The buildup and denaturation of protein brought on by heating in the muscles of golden grey mullet was what reduced their ability to store water. As a result, there was a noticeable drop in cooking. According to Niamnuy et al. (2008), during the course of the shrimp's boiling in salt solution, drip loss was noticed in the muscle. The moisture content of raw fish muscle was 68.95% which decreased to 67.68% after boiling and declined to 56.342% in case of frying. This result is similar

to that of Kocatepe, 2010. However, the decrease in the moisture content has been described as the change that makes the protein, fat and ash contents increase significantly in cooked fish fillets (Garcia-Arias et al., 2003). Declination of moisture content resulted in several changes such as dehydration and increase of protein and fat concentration 60.68a±0.28 ((Kocatepe et al., 2010). Turkan et al. (2008) reported that, characteristically, fried fishes have the minimum moisture value.

5.4 Gel Forming Ability of Fish Muscle

5.4.1 Effect of temperature on breaking force of fish muscle gels: Studies were conducted on the effects heating on gel strength of surimi prepared from two marine fish species, *Dussumiera acuta* and *Sardinella fimbriata* . Highest breaking force was found at 50^0 C for both washed and unwashed fish muscle paste of both species. This findings aligns with Hossain et al. (2004) who studied on gelling ability of silver carp (*Hypophthalmichthys molitrix*) and pangas (*Pangasius hypophthalmus*). They reported that, 50°C was discovered to be the ideal setup temperature for achieving the highest gel strength. A two-step heating technique (heating at 50°C for two hours, then 80°C for 30 minutes) produced better gelling results than a single-step heating process (heating at 50°C for two hours).

Nowsad et al. (1999) studied gelling Properties of tropical major Carp Muscle (Rohu, katla, Mrigel and silver Carp). Between 40 and 50 °C, gel strength was at its peak, and between 60 and 70° C, gel disintegration took place. Hossain et al. (2005) found that, in Queen fish (*Chorynemus lysan*) showed a breaking force of 425 and 534g for respectively washed and unwashed paste. In 50°C highest breaking force was found for both washed and unwashed ones. Gel strength decreased with the upgrade of heating temperature at 60° C. Gel forming ability decreased with 15 days icing storage. The characteristics and gel properties of the muscles from mackerel (*Rastrelliger kanagurta*) and sardine (Sardinella gibbosa) were examined by Chaijan et al. (2004). They reported that, Sardine mince gels have higher breaking force than Mackerel mince. Again among Sardine minces washed ones showed 41.89–55.28% higher breaking force than unwashed ones. The breaking force of the kamaboko gel made from washed sardine mince in NaCl solution was 47.17% higher than that of gels that were cooked directly. However, compared to one-step heating (directly heated gel), the breaking force of NaCl-washed mackerel mince increased only by 5.73% when heated in two steps (Kamaboko gel).

Three marine fish species—the silver Jewfish, ribbon fish, and Bombay duck were examined by Hossain et al. (2019) to ascertain their capacity for gel formation. In a single step heating technique, samples were heated to 40, 50, 60, 70, and 80° C in a water bath for 120 minutes. Since all fish samples exhibited the highest gel strengths at this temperature, gels heated to a temperature of 50°C were employed to test gel strength in this case. The breaking strength of the gel prepared using Silver jewfish decreased from 757.42 (0.76)g at the beginning to 434.67 (1.66)g after 10 days of ice storage. Similar reductions in breaking force were seen for ribbon fish, which went from 803 12 (1.35)g to 470 64 (2.21)g. Bombay duck's breaking strength, on the other hand, could only be measured up until the third day of ice storage and ranged from 204±31 (2.06)g to 160±75 (0.76)g. For the following days, the gels were too soft to measure. The Silver Jew Fish's initial folding test (FT) grade was 'AA' on day '0' but fell to 'B' after 10 days of ice storage. Similar outcomes were obtained for the Ribbon fish folding test (FT), in which the grade dropped from "AA" to "B," and the Bombay duck folding test (FT), in which the grade was "B," and the acquired gel was too weak to undertake a study on the gel-forming ability after three days of ice storage.

Ahmad et al. (2000) found that, after first step heating, the breaking forces of Silver Jewfish ranged from 956.57 (4.21 g) to 550.46 (1.24 g), Ribbon fish from 867.61 (3.53 g) to 537.57 (3.04 g), and Bombay duck from 210.30 (0.88 g) to 185.68 (1.15 g).

5.4.2 Effect of washing: Studies were also conducted on the effects of washing on the gel strength of fish paste prepared from both fish species, *Dussumieria acuta* and *Sardinella fimbriata* . Our experimental data showed that washed samples have higher breaking force good grades in folding test , which are indicators of superior gel forming ability. Both fish *Dussumieria acuta* and *Sardinella fimbriata* showed a marked rise of breaking force with washing. This result agrees with Hossainet et al. (2005) who found a prominent increase in breaking force of gel with washing. They found washed meat paste to show high breaking force than unwashed ones. Chaizan et al. (2004) prepared gel from Common Carp in three condition these are unwashed, washed with distilled water and washing with salt solution and found least breaking force in case of unwashed sample. It gradually increased with washing with distilled water and washing with salt solution. Chaizen et al. (2004) reported that, higher gel strength results in superior quality surimi and whiteness increases with removal of

dark muscles and dark muscle can be properly removed through washing and straining. This result is similar to Hossain et al. (2004) who conducted research on Silver Carp and Pangus and found higher breaking force of washed mince than unwashed ones.

Hossain et al. (2004) investigated the Effect of washing solution, washing period and salt concentration on gelling ability of Silver carp (*Hypophthalmichthys molitrix*) and Pangas (*Pangasius hypophthalmus*). For varying washing times (5, 10, or 15 minutes), both Silver carp and Pangas mince were washed with 0, 0.05, 0.1, 0.15, and 0.2% NaCl. For silver carp and angas, the absence of salt in the washing solution revealed values of 170 and 212 g.cm, respectively. The findings showed that a single washing with 0.1% NaCl and a washing time restriction of 10 minutes were necessary to get an acceptable quality surimi fish mince with 3 minutes of settling after agitation. The ability to make gels increases when salt content is increased, and the highest ability to produce gels was seen when the mince was washed with 0.1% NaCl, with values of 515 and 620 g.cm for silver carp and pangas, respectively. Both fish's capacity to create gel was diminished by washing in solutions containing 0.15 and 0.2% NaCl. These findings suggested that adding more salt to the washing solution could partially unfold proteins, increase sensitivity to denaturation, and weaken the gel matrix. Different salt concentrations (1.0, 2.0, 3.0, and 4.0% NaCl) were utilized to examine the effects of salt concentration on the gel properties of both fish minces. Regardless of the heating schedule, adding 3% NaCl to the fish minces while they were being ground exhibited the maximum gel strength. 50°C was discovered to be the ideal setup temperature for achieving the highest gel strength. A two-step heating technique (heating at 50°C for two hours, then 80°C for 30 minutes) produced better gelling results than a single-step heating process (heating at 50°C for two hours).

Washing results in superior quality gels with higher breaking force. Sarcoplasmic proteins could be eliminated with the proper washing, leaving concentrated myofibrillar proteins—which are crucial for gel formation. The strength and deformability of myofibril protein gels can be adversely affected by minor amounts of sarcoplasmic proteins (Haard et al., 1994; Hultin & Kelleher, 2000a, 2000b). These proteins do not form gels and have a potential to obstruct myosin cross-linking during the creation of gel matrix. Sikorski (1994) found a lower water retention capacity.

Sarcoplasmic proteins may also alter the rheological characteristics of fish gels. The heat treatment could cause some sarcoplasmic proteins to bind to the myofibrils, reducing the gel's tensile strength.

Hennigar et al. (1988), found that, the strength of the gel in the muscles of cod and flounder might be improved by washing with a NaCl solution, as shown by an improvement in fold test results. NaCl solution had no effect on the red hake muscle's gel strength, though. The findings of the current study are consistent with earlier research on the impact of washing on the ability of fish to form gels, as washed mince demonstrated greater gel strength than unwashed flesh.

5.5.3 Folding test: Folding test is another important indicator of gel quality testing. Folding test was carried out by following the table 3.1. In case of *Dussumieria acuta*, 40° C incubation temperature produced a D grade gel in both washed and unwashed meat paste. At 50^0 C heating temperature produced B grade gel which is of better quality than unwashed one (C grade). At 60^0 C incubation temperature C grade gel had been produced from both washed and unwashed ones. In case of *Sardinella fimbriata*, 40^0 C incubation temperature produced a B grade gel in washed and C grade in unwashed meat paste.50^0 C heating temperature produced A grade gel in both washed and B grade for unwashed one. At 60^0 C incubation temperature B grade gel had been produced from washed meat paste and C grade gel from unwashed ones. MI Hossain, (2005) carried out a research on Influence of ice storage on gel forming ability of ice stored queen fish (*Chorinemus lysan*). Here A grade gel has been produced by queen fish, after 15 days storage washed muscles and unwashed muscles turned into B grade and C grade gels.

The silver jewfish's initial folding test (FT) resulted in a "AA," then decreased to a "B." Similar to Ribbon fish, where the initial FT was discovered to be "AA" before decreasing to "A," the results for Bombay duck were somewhat different. The FT for Bombay duck was determined to be 'C'. *T. thalassinus, S. sihama, L. sawala,* and *C. macrolepidotus*' ability to produce gels was rated as grade AA in the folding test. The gels *J. belangari, H. neherius, C. madrasensis*, *P. diacanthus, A. hians, G. punctatus,* E. affinis, and C. talabon were determined by Ahmed *et al.* 2000 to be moderately elastic (A) in their research. While the gels of *C. guttatum* and *M. cordyla* were not discovered to be elastic (B), the gels of P. haste and D. zugei were found to have a little elastic character (B).

CHAPTER 6: CONCLUSIONS

Two marine fish species *Dussumieria acuta* and *Sardinella fimbriata* were studied in this experiment. Both fishes have higher amount of muscle yield which is more than 50% and this muscle can be better utilized for producing any value-added product. Dark muscle is a prominent character of both fishes. Dark muscle constitutes 3.86% in *Dussumieria acuta* and in *Sardinella fimbriata* , it is 7.87% of total muscle. Analysis of nutritional composition indicated that dark muscle contains higher lipid value and lower in protein and moisture. On the other hand, white muscle possesses higher protein and moisture percentage. Which contributes to their high lipid and protein content and places them in the high lipid and protein group of fish (Ackman et al., 1994). Food loses moisture when it is cooked because heat induces evaporation. This decrease in moisture may cause other nutrients to concentrate and alter the texture of food. Between two cooking application (boiling and frying), frying resulted in significant loss in moisture and rise in lipid content. These two fish have emitted characteristics aroma after cooking specially after frying. Both fish muscles have good gel forming ability. White part of the muscle can be better utilized by using it as an ingredient of surimi-based products. From the comparison of washed and unwashed fish meat paste in gel making, it was found that salt treated washed muscle paste produce highest breaking force at 50° C. From this study, it is evident that the low valued fish species (*Dussumieria acuta* and *Sardinella fimbriata*) have better nutritional profile and have the potential to be used in producing surimi-based value-added product.

CHAPTER 7: RECOMMENDATIONS AND FUTURE PERSPECTIVES

1. The studies should be continued on more fish species commercially available in our marine water in order to get a comprehensive result on muscle structure, muscle yield, chemical compositions and their suitability of fish species for producing value added products.
2. Small fishes which are available in our artisanal sector throughout the year but not effectively utilized should be brought under similar investigation.
3. There should be a comprehensive database to be built on the muscle properties and their nutritional values on the commercially available marine fish species of Bangladesh.
4. The study should also be continued to investigate the seasonal variations of nutritional values of the commercially important all marine fish species of Bangladesh

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Brief Biography of the Author

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