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Safety and Quality Aspects in Dry Fisheries Sector of Chalan Beel, Bangladesh: Improve Techniques, Product Promote and Awareness Development

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Safety and Quality Aspects in Dry Fisheries Sector of Chalan Beel, Bangladesh: Improve Techniques, Product Promote and Awareness Development

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By

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Dedicated

To My

All Family Members

DECLARATION

I hereby declare that the thesis entitled **"Safety and Quality Aspects in Dry Fisheries Sector of Chalan Beel, Bangladesh: Improve Techniques, Product Promote and Awareness Development"** is the result of an original study carried out by me independently under the guidance and supervision of **Dr. Fawzia Adib Flowra, Dr. M. Manjurul Alam and Dr. M. Afzal Hussain,** Professor, Department of Fisheries, University of Rajshahi, Bangladesh. I also declare that this work has not been submitted in full or in part for awarding of any other Degree to this or any other university or institute. I further confirm that no part of the thesis is cited from any other sources (published or unpublished) without acknowledgement.

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This is to certify that Md. Bayezid Alam, Ph.D. Fellow (Session 2014-2015, Registration No. 1479, Roll. No. 14616), Faculty of Agriculture, University of Rajshahi, Rajshahi-6205, Bangladesh, has carried out the research work on **"Safety and Quality Aspects in Dry Fisheries Sector of Chalan Beel, Bangladesh: Improve Techniques, Product Promote and Awareness Development"**. He has fulfilled all the requirements and regulations relating to the nature and period of research for the Degree of Doctor of Philosophy.

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ABSTRACT

The study was conducted with a view to evaluating safety and quality aspects of dried fish prepared from traditional (trad.) technique implying conventional practices in open condition and experimental (exp.) method with setup of different drying techniques for five fish species (*Channa punctatus*, *Mystus vittatus*, *Channa striatus*, *Wallago attu* and *Puntius* sp.) from January 2015 to December 2017 in five fish drying areas of *Chalan Beel* under the upazila of four districts namely Singra Upazila of Natore; Atrai of Naogoan; Chatmohor and Vangura of Pabna and Tarash Upazila of Sirajganj district in northern area of Bangladesh. Different low cost drying techniques, viz. Black Polythene Sheet (BPS), White Tin Sheet (WTS), Black Tin Sheet (BTS), White Plastic Tunnel (WPT), Hanging Box (HB) and Traditional Method (TRD) were used. Among all the techniques WPT was found to be most suitable with the highest average temperature of 38.14 °C whereas the lowest (23.98°C) was in HB; relative humidity ranged from 33.20 (WPT) to 64% (HB); average drying time varied from 25.20 (WPT) to 35.0 hour (BPS). In nutritional composition, the highest protein content was 79.71 in *C. striatus* (exp.) and the lowest was 50.33% in *Puntius* sp. (trad.); highest fat content was 18.50 in *Puntius* sp. (exp.) and the lowest was 3.12 % in *C. striatus* (trad.); highest moisture level was 20.90 in *C. striatus* (trad.) and the lowest was 9.21% in *Puntius* sp. (exp.); and the highest ash content was 29.9 in *Puntius* sp. (trad.) and lowest was 14.97% in *C. punctatus* (trad.). In case of minerals, the highest level of iron was 15.2 in *M. vittatus* (exp.) and lowest was 3.57 mg/100g in *C. striatus* (exp); the highest amount of calcium was 190.60 in *M. vittatus* (trad.) and lowest was 20.83 mg/100g in *C. striatus* (exp.); the highest potassium content was 90.47 in *W. attu* (trad.) and lowest was 70.80 mg/100g in *C. striatus* (exp.); and phosphorous content ranged from 229.78(*C. striatus*) to 535.45 mg/100g (*M. vittatus*) and 261.62 (*C. punctatus*) to 450.08 mg/100g (*Puntius* sp.) in traditional and experimental sample respectively. In terms of heavy metals, the sequence of accumulation was Copper (Cu)> Lead (Pb)> Chromium (Cr)> Cadmium (Cd). In case of hygiene indicator bacteria, total coliforms were found in all trad. samples with highest count of 4.5×10^3 cfu/g in *Puntius* sp. and in exp. samples total coliforms were detected only in *W. attu* (1×10^2) and *C striatus* (1×10^2 cfu/g). Fecal coliforms were found in *C striatus* (1.5×10^2), *W. attu* (2×10^2) and *Puntius* sp. (2.5×10^2 cfu/g) only in trad. sample. In terms of pesticidal residues Chlorpyrifos pesticide was detected in *W. attu*, *C. punctatus* and *C. striatus.* In shelf-life assessment, after 8th month of storage the sensory score ranged from 1.88 (*Puntius* sp.) to 5.42 (*C. punctatus*) and 4.5 (*Puntius* sp.) to 7.25 (*C. punctatus*) in traditional and experimental samples respectively. The highest Total Volatile Base Nitrogen (TVB-N) value was 115.5 in *C. striatus* (trad.) and lowest was 65.45 mg/100g in *Puntius* sp.(exp.); the highest Peroxide Value (PV) was 45.50 in *C. striatus* (trad.) and lowest was 18.5mEq/kg in *M. vittatus* (exp.); the highest p^H was 8.05 in *C. striatus* (trad.) and lowest was 5.75 in *Pintius* sp.(trad.); and the highest Standard Plate Count (SPC) was 6.19 in *C. striatus* (trad.) and the lowest was 4.71 LogCFU/g in *M. vittatus* (exp.). In case of sensory evaluation regarding various packaging methods after 4th and 8th month of storage, vacuum package demonstrated comparatively satisfactory performance obtaining better sensory score varying from 7.05 (*Puntius* sp.) to 8.20 (*C. punctatus*) and 4.80 (*W. attu*) to 7.10 (*C. punctatus*) respectively, followed by nitrogen, normal sealed air pack and unsealed or open package having relatively lower score. In term of status of awareness regarding harmful effects of pesticides, 51.7% of the respondents were involved in abuse. Besides, 7% of them used tube well water and 68.3% were found to be habituated to washing hands with soap or ash before drying operation. Most of the (55%) drying yards had no toilet facility. In this scenario regarding educational level of the dried fish processors, most of them (49%) were primary qualified. In addition, majority (77%) of the processors were engaged in borrowing capital from commission agents (*Arotders*). Income of dried fish processors varied between 5001 to 10000 BDT per year.

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General Introduction

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General Introduction

1.1. Background

Fish enjoys a very special consideration and place in human civilization from times immemorial and fisheries and agriculture farming have evolved rather parallel. Interest in fish eating dates back to the dawn of history and hunting of fish was not uncommon in prehistoric times. With the course of time, idea of fish preservation was started. New Stone Age (10000 BC) has also given evidence of salmon smoking practices. Bronze Age (3500 BC) was the time when salting of fish started and trading in dried fish was also in vogue with ancient civilizations of Egypt, Mesopotamia and Indus valley. Iron Age (1000 BC) saw the great trades in dried, smoked and salted fish in Greece. The empirical findings of the fish preservation methods, like salting, drying, smoking and potting in vinegar, of the medieval times have come down to the present times practically unchanged in their utility (Srivastava, 2000). During that time, fishes were mainly captured from open water source through fishing. In fact, fishing, in a broad sense, is the last remaining hunting activity of man (Clucas and Ward, 1996). However, intensive fishing along with various fish preservation techniques has evolved to meet the continuously increasing demand.

The ever growing human population has increased the need for food supply. Because they are good protein sources, the demand for fish and shellfish products has increased. Worldwide, people obtain about 25% of their animal protein from fish and shellfish (Bahnasawy *et al.*, 2009).The international community made unprecedented commitments in September 2015 when UN (United Nation) member states adopted the 2030 Agenda for Sustainable Development. The 2030 Agenda also sets aims for the contribution and conduct of fisheries and aquaculture towards food security and nutrition. In 2014, 46 percent (67 million tonnes) of the fish for direct human consumption was in the form of live, fresh or chilled fish, which in some market share the most preferred and highly priced forms. The rest of the production for edible purposes was in different processed forms, with about12 percent (17 million tonnes) in dried, salted, smoked or other cured forms, 13 percent (19 million tonnes) in prepared and preserved forms, and 30 percent (about 44 million tonnes) in frozen form. Fish and fishery products represent one of the most-traded segments of the world food sector. Trade in fish and fishery products has expanded considerably in recent decades, fuelled by growing fishery production and driven by high demand. Given the present global context, fish can be produced in one country, processed in a second and consumed in a third. However, further outsourcing of production to developing countries might be constrained by sanitary and hygiene requirements that are difficult to meet (FAO, 2016). Being a developing country, Bangladesh is also struggling to maintain adequate food safety standards in respect of different processed food items including fisheries products, particularly for domestic consumption.

Bangladesh is fortunate enough having an extensive and huge inland water resources scattered all over the country in the form of small ponds, *beel* (natural depressions), lakes, canals, small and large rivers, and estuaries covering an area of 4.69 million ha among which *beel* and flood plain cover an area of 114161 ha and 2695529 ha respectively. Fisheries is the second largest export earning sector which contributes to GDP about 3.65% and to foreign exchange earning about 1.97%, and this sector provides the country with 60% of animal protein intake (DoF, 2017). Bangladesh has the third largest aquatic fish biodiversity in Asia, after China and India, with about 800 species in fresh, brackish and marine waters. It has been able to secure 4^{th} position in inland open water capture fisheries and 5^{th} position in culture fisheries respectively (FAO, 2014). In the year 2015-16, Bangladesh exported 2229MT dried fishes earning 301 million taka after satisfying country's demand (DoF, 2017). Dry fish (*shutki* in Bengali) is one of the popular food items in Bangladesh. It is the staple source of protein in many areas of Bangladesh. About 20% of total fish caught are sun dried and mostly consumed in the domestic market annually (BBS 2005). Dried fisheries products receive great place in delicious dish in different countries also. In Bangladesh fish drying activity both with marine and fresh water fishes is pronounced and has gained importance and popularity as it is relished by many people of coastal, central and North-eastern districts (Nowsad, 2007).

Rice and fish dominate the diet of Bangladeshis to such an extent that the old proverb, ''*machee bhatee bangali*,'' which can be translated as ''fish and rice make a

Bengali,'' continues to hold true. Fish is an essential and irreplaceable food in the rural Bangladeshi diet (Roos *et al*., 2003). In Bangladesh, fish is an irreplaceable animal-source food in the diet of millions, both in terms of quantity – accounting for approximately 60% of animal protein intake at 18.1 kg consumed per person per year – and frequency of consumption, far exceeding that of any other animal-source food (Belton *et al*., 2014), which is playing a pivotal role through increasing supply to meet the demand of ever growing population of the country. However, despite improvement in some food and nutrition security indicators (JPGSPH and HKI, 2012), malnutrition, largely caused by inadequate micronutrient intake, remains widespread with 41% of children under five years suffering from stunted growth (NIPORT, 2013). Therefore, the fisheries and aquaculture sector has been recognized as a key resource in tackling food and nutrition security issues and features prominently in the national development agenda (Government of the Peoples Republic of Bangladesh, 2005a,b, 2006, 2011).

It is well-known that fish is considered as a delicacy and very popular and palatable food in Bangladesh. Data from the Household Income and Expenditure Survey 2010 showed that fish is by far the most frequently consumed nutrient-rich food group, followed by leafy vegetables, fruit, eggs, milk and meat. In the 14 days preceding the survey, 71 % of households had consumed fish, whereas only 2 % had consumed meat. Poor households had smaller fish intakes than rich households, and a larger proportion of the total fish intake was made up of small fish species in poor households compared to rich households. A large proportion of small fish was consumed as dried fish Bangladesh Bureau of Statistics (BBS, 2012). Nutritional deficiency is prevalent throughout the world, particularly in poor rural and urban areas where limited economic resources prevent diversity in diets. Moreover, economically distressed people living in vulnerable areas which lack cheap protein source cannot afford to buy other expensive protein-rich diets such as chicken, beef, milk etc. In this case, dried fish can be a useful means of tackling the deprivation and ensuring nutritional security.

Fish drying is relatively simple method and was first developed before the recorded history began. In the ancient times, dry and preserved fish were important as an export item to the economies of British North America (especially the fishing ports of Newfoundland, New England, Nova Scotia). Preserved cod was the favorite staple food of Iceland for centuries. Dry fish has also extreme popularity and is widely consumed in Catholic Mediterranean countries, notably Portugal, Spain, and Italy. Processing of dried fish, having immense demand, was considered to play a significant role to ensure food security through providing nutrition, particularly protein, in fisheries resource starved areas. In Europe, the air dried or sundried cod (known as 'stockfish'), though once was an important traditional commodity, is on the decline at present. The English when they first took up the Newfoundland fishing seriously at the end of the sixteenth century, started drying and barreling up of cod, which became vendible in France. The dry fishery used only about half as much salt, which they obtained in strictly limited quantities from the Portuguese ships. What they had learnt from their experience with Iceland stockfish was applied to Newfoundland's small fish, with scanty supplies of salt to produce a hard, dry cure, meeting the demands of warmer countries (Cutting, 2002). It has also been reported that for many centuries in Iceland and Norway, the stockfish of Cod was prepared or preserved through heading and hanging in the open air at low ambient temperature; and they gradually dry over a period of about six weeks to a moisture content of about 15%. This product had a shelf-life of several years if stored correctly, and finally these finished dried products or stockfish was exported mainly to African countries and to Mediterranean areas (Clucas and Ward, 1996). However, sun-drying, the oldest way of fish processing, has been introduced in Bangladesh by the Arabian saints and businessmen who have been believed to be pioneer in the production and marketing of dried fish products throughout the world since the Egyptian civilization (Kreuzer, 1974). In fact, dried fish has been relished as a pleasing delicacy in Bangladesh for several centuries ago.

Preservation of fish by sun drying, salting, smoking, acid curing or a combination of these methods forms the basis of preparation of traditional fish products of many countries. Asia is the largest producer of cured fish products. Amongst the highest producer in Asia are China, Japan, Indonesia, Philippines, India and Korea. In Africa also, a large fraction of fish consumed is marketed in dried or in dried and smoked form. In south-eastern and Far East Asian countries situated east of India, salted products with or without sun drying are produced in addition to traditional fermented fish sauce and paste. In India salted and/or sundried products are most common though fermented fish product is produced for local consumption in certain region of Eastern part of India (Sen, 2005).

Apart from having mammoth marine fisheries resources in Bangladesh, with respect to freshwater fisheries resources, the country also possesses diverse and abundant aquatic resources with 267 freshwater fish species (Thilsted, 2010), and an annual production of 3.1 million tonnes (Belton and Thilsted, 2014). These immense aquatic resources offer huge prospects of fish processing and preservations in diversified way. Generally, in Bangladesh fishes are preserved by freezing, salting, drying, smoking etc. Sun drying is one of the most important low cost methods of fish preservation in this country. Dried product plays an important role particularly in providing nutrition of the poor and economically disadvantaged people of the country. The production of sun-dried products is increasing because of its increasing demand by the people. In developing countries including Bangladesh, there are no outlets for chilled and frozen products, particularly for fresh or marine fish, as compared to the facilities developed for shrimp processing. In addition, due to lack of good inland communication and refrigerated storage, during glut period considerable amount of fish is subjected to drying in Bangladesh (Islam, 2004).

Fish is highly perishable and get spoiled more rapidly than almost any other food, soon becoming unfit to eat and possibly dangerous to health through microbial growth, chemical change and breakdown by endogenous enzymes. Therefore, post-harvest handling, processing, preservation, packaging, storage measures and transportation of fish require particular care in order to maintain the quality and nutritional attributes of fish and avoid waste and losses. Moreover, the expansion in the consumption and commercialization of fish products in recent decades has been accompanied by growing interest in food quality and safety, nutritional aspects, and wastage reduction (FAO, 2016). Among various fisheries products, dried fish is considered to be a promising source with respect to mitigating post-harvest losses and addressing nutritional deficiency among common people. Although dried fish do not give similar flavor, test or texture of fresh fish, it is preferred and consumed by a large number of people of the whole world because of its characteristic taste and flavor developed in the products during the drying process. But the quality of the product is not always ensured. However, about 20% of the artisanal catches undergo sun drying and are consumed in the domestic market of Bangladesh (Coulter and Disney, 1987). The physical and organoleptic qualities of most of the traditional sun dried products available in the market are not satisfactory for human consumption (Kamruzzaman, 1992; Saha, 1999). In recent days, frequent complaints from consumers regarding the quality of the dried fish products are commpn, and the major constraints associated with sun drying of fish are infestation of the products by fly and insect larvae, contamination and spoilage during drying and storage (Islam, 2004). Since most of the consumers are gradually getting concerned as well as aware of the safety and quality aspects of every food items; and moreover, given the unwholesome processing method and injudicious or deliberative abuse of pesticides in dried fish, consumers feel discouraged and even panicked to buy it nowadays. As a result, consumers' confidence gets undermined gradually losing faith in dried fish products. Therefore, considering all the prevailing problems of dried fish sector of *Chalan Beel* area, the present study aimed at addressing these problems through some interventions such as-improvement of fish drying techniques, assessment of nutritional and safety aspects of traditional and experimental samples, observing awareness status and knowledge among dried fish processors regarding safe and quality dried fish production, evaluation of the performance of improved packaging for dried fish products in respect of extending shelf-life.

1.2. Improved drying techniques

Nowadays, technological development in food processing and packaging is ongoing in many countries, with increases in efficient, effective and lucrative utilization of raw materials, and innovation in product diversification. Preservation and processing techniques can reduce the rate at which spoilage happens and thus allow fish to be distributed and marketed worldwide. Such techniques include temperature reduction (chilling and freezing), heat treatment (canning, boiling and smoking), reduction of available water (drying, salting and smoking) and changing the storage environment (packaging and refrigeration) (FAO, 2016). Sun-drying is a widespread and traditional practice which is unlikely to decline because the alternatives are often either unavailable or beyond the financial resources of both processors and consumers (James, 1977). However, with the technological advancement in different food processing sectors, dried fish processing techniques also deserve some technological improvements.

Every year about 25-30% fish and fishery products are thought to be lost due to various reasons. This post- harvest loss in fisheries obviously exerts immense pressure on food security of the country, which requires immediate attention to resolve. Although rooms exist to triple the fish production, the present post-harvest loss is devastating, and 50% reduction of such loss can save TK 8000 crore per annum (Nowsad, 2007). Many studies revealed very high level of post-harvest loss during pre-processing, processing, storage, and transportation of fishery products (Nowsad, 2005; 2006). Despite making important contribution to national economy, health, food security and improving livelihoods of many fish processors, dried fisheries sector has not received due attention and remained neglected, however, suffering from many problems. Due to lack of improved techniques of drying and preservation, infestation of sun-dried fish by the blowfly and beetle larvae causes up to 30% loss of the products (Bala and Mondol, 2001b; Nowsad, 2005).

Fresh fish meat contain up to 80% of water by mass and it is considered as highly perishable material, which results in an extremely short shelf-life when left unprocessed (Bala and mondol, 2001b). Several preservation methods are followed over the world to extend shelf-life of fish. One of these methods known to be ancient and simplest technique is "drying" and it is considered as least expensive method of fish preservation. (Balachandran, 2001). In addition to that, drying is a useful method which is used to improve stability of the fish by reducing microbiological activity, and in which the moisture content of fish gets reduced rapidly to shelf stable moisture level (Shitanda and Wanjala, 2006). Moreover, sun-drying of fish is the most economical method; however, there are several disadvantages and issues encountered during this drying process, which include contamination by dust, sand, slow drying, blowfly infestation, attack by rodents, ants, insects, chickens, dogs etc. All these factors lead to poor quality dried fishes which are unhealthy for human consumption (Chavan, 2011a). To reduce the processing losses or quality deterioration during the drying and to retain the excellence of dried product, it is necessary to dry the fish in the close chamber with preventing product from dust, insect, larva, birds and animal (Sengar, 2009). In case of drying technique, during initial stage, evaporated vapor makes the surrounding environment humid. Therefore, strong air flow is needed to carry away the vapor rapidly. Theoretically, moisture content of the final product is expected to be reduced to less than 15-16% where most of the microbiological and enzymatic activities are slowed down or stopped. In practice, however, water content is not reduced to this theoretical 15-16% (Gopakumar, 2002b).

Most of the low cost technologies such as sun drying are time consuming. One of the best ways of alleviating this problem is to enhance the quality of the product by improving traditional processing techniques of drying so that they are accepted by high income group and this will contribute to uplifting the income of fishermen as well as processors (Gopakumar, 2002a). Traditional sun-drying is carried out in the open air, using the energy of the sun to evaporate the water and air currents to carry away the vapour. Normally, term 'drying' implies the removal of water by evaporation. As water is essential for the activity of all living organisms, its removal will slow down, or stop, microbial or autolytic activity. The evaporation rate or drying rate of fish could be augmented introducing various mechanical dryers that allow drying regardless of weather conditions and produce a more uniform product. However, these types of improved drying approaches cost more to set up, therefore, these should be custom made using locally available material to suit local conditions. Among mechanical dryers, solar dryer has drawn considerable interest and attention in which the energy of the sun is collected and concentrated to produce elevated temperatures for an increased drying rate. If the temperature of the air is raised, the amount of water which it can hold will increase, the Relative Humidity (RH) will be reduced, and the air will be able to absorb additional water vapor. In solar dryer a black surface is used to absorb heat energy from the sun more effectively and the heat collection units is connected to a drying chamber to supply a flow of warm air. In this dryer, it is not necessary to expose the fish to the direct sun rays that can cause problems with case hardening and partial cooking if the temperature is not adequately controlled. In this case, the movement of moisture from the deeper layers to the surface of the fish muscle gets prevented. This can result in a fish which is dry on the surface and looks fully dry but is wet and spoiled in the centre. It can be a particular problem with some designs of mechanical and solar driers when the temperature is more elevated above ambient (Clucas and Ward, 1996).

Generally, conventional method of sun drying is fraught with problems such as contamination by dust and insect infestation because the fishes are dried on mats spread on bare ground due to spoilage (BOSTID, 1988). Traditional sun drying has some other disadvantages which include dependence on weather; longer drying period, no control over the operating parameters; contamination with dust and sand; infestation with insects, their eggs and larvae resulting poor quality of the product and short shelf life. Furthermore, the physical and organoleptic qualities of most of the traditional sun dried fish available in the market do not meet the expected standard for human consumption (Coulter and Disney, 1987). To arrest these problems, many designs of solar dryers have been developed for the preservation of fish. One of such dryers was designed by Doe *et al.* (1977) in Bangladesh. Solar drying is one of the most attractive and promising solar energy systems, as it is simple, does not require much initial investment, and can be very effective, especially in tropical regions (Fudholi *et al.* 2010). Generally, the solar tent dryer is made up of a polythene sheet worn over a wooden frame. It works through evaporative drying following the green house principle. When set up in the sun, solar energy passes through the transparent polythene and gets trapped within it thereby raising the internal temperature. Cool air flowing in through an opening gets heated up and moves out moisture from fish laid on racks in the dryer. Solar dryer accelerates the drying process considerably resulting in a high quality product with extended shelf-life (Oghenekaro, 2009). However, another type of dryer, known as *Hohenheim* type solar dryer which was developed in Germany in the early sixties were tried in Bangladesh in order to assess its suitability in drying mangoes, pineapples and fish (Bala and Mondol 2001b; Bala and Hossain 1998). The quality of the dried fish produced by this type of dryer was good in terms of organoleptic characteristics, infestations and contaminations (Ahmed *et al.*, 1979).

To design low-cost, simple and viable solar drying technique considerable interest has been shown in which the Polythene tent or tunnel dryer works as a solar tent dryer, and where the heat of air gets elevated by black surface and is allowed to pass through the fish and escape out through a vent or opening. However, in solar tent dryer, the air temperature is known to increase the levels of 60°C or more in tropical climate, which will adversely affect the nutritional as well as physical properties of fish, and it is considered as a disadvantage (Balachandran, 2001).

With the advent of modern methods and technologies in all aspects of life, fish processors have also become interested in using improved mechanical dryer for drying fishes. It is expected that that these dryers should be efficient in achieving higher drying temperatures and reduced humidity. These also should be capable of increasing drying rates producing lower moisture content in the final products. Considering all these aspects in the present study, some improved techniques of drying such as tunnel shaped solar dryer, perforated drying rack of black tin sheet, black polythene sheet and white tin sheet covered with mosquito net, were developed with a view to making an assessment among these techniques in respects of their drying performance.

1.3. Nutritional Composition of dried fish

Hunger and malnutrition are the world's most devastating problems and are inextricably linked to poverty. A total of 842 million people in 2011-13, or around one in eight people in the world, were estimated to be suffering from chronic hunger, regularly not getting enough food to conduct an active life (FAO, IFAD and WFP 2013). It is widely acknowledged that fisheries have the immense capacity to address the challenges and contribute positively towards eradication of hunger, food insecurity and malnutrition. In many low-income countries with water and fisheries resources, fish is important for livelihoods, income and as food for the rural poor who are suffering from under nutrition, including micronutrient deficiencies (Thompson and Subasinghe, 2011).

Fish, being an important component of the diet for people throughout the world, has high protein content and nutritional value. According to Ayyappan and Diwan (2003) it supplies approximately 6% of global protein. In addition, approximately 16 percent of animal proteins consumed by the world's population are derived from fishes, and over one billion people depend on fish as their main source of animal proteins (FAO, 2000). In most developing countries where there is high rate of malnutrition, fish provides nutritious food which is often cheaper than meat and therefore available to a larger number of people (Ogunleye and Awogemi, 2008). Fish is often the cheapest source of animal protein and is, therefore, important in the diets of the lowest income group (Allison, 2001). Fish flesh contains four basic ingredients in varying proportions: water, protein, fat and minerals, and quantity of carbohydrate found in fish flesh is usually negligible. Flesh from healthy fish contains 60-84% water, 15-24% protein, 0.1-22% fat, and minerals usually constitute 1-2%. In general, the seasonal variation in fat content is accompanied by an inverse variation in the amount of moisture in the flesh, which means the sum of the fat and water content is more or less constant. Protein content tends to vary less widely from one species to another; there is generally little seasonal variation in a particular species (Clucas and Ward, 1996). In twenties and thirties the discovery of vitamins A and D placed fish in esteemed position because of the revelation that fish are generally rich in them. Thilsted *et al.* (1997) and Roos *et al.* (2007) reported that vitamin A, calcium, iron and zinc are present in commonly consumed small fish species of Bangladesh.

Fish can therefore be considered as an irreplaceable animal-source, providing essential nutrients including animal protein, essential fats, minerals and vitamins. Small fish, eaten whole or as fish products, e.g. dried fish are particularly rich in protein, calcium and other micronutrients (Srivastava, 2000).The dried fish retains all the nutrients from the fresh fish, only in concentrated condition; it is therefore rich in proteins, vitamins, iron, and calcium. Laureti (1998) opined that dried fishes often are an alternative to fresh fishes in many places. Besides, dried fish can be considered as a good supplement to diets in many areas of the world. It contains 60-65% of muscle building protein along with 7-20% harmful cholesterol-reducing fatty acids which are essential for good human health (Ravichandran *et al.*, 2012). Dried fish are the predominant food bringing vital protein to people in rural areas of least developed countries (Graikoski, 1973). Moreover, it is also a rich source of protein, lipid, calcium, iron and zinc (Basu and Gupta 2004). Besides, they contain considerable amount of unsaturated fatty acids, especially omega-3 fatty acids, which are regarded as preventive compounds (Payap, 2011).

From the nutritional point of view, the characteristic properties of fish or fish products, which determine the degree of excellence, include both wholesomeness and sensory attributes. An important criterion for determining the wholesomeness of fish or fish products in respect of nutritive value is protein content (Balachandran, 2001). In Bangladesh dried fish is considered as a rich source of low cost dietary animal protein and is used as a substitute of fresh fish. The sun-dried fishes contain up to 60-80% protein (Hoq, 2004). On the other hand, another major feature of proximate composition fish is fats, the source of concentrated energy. Fish fat is a source of highly unsaturated fatty acids called polyunsaturated fatty acids (PUFA) belonging to ω-3 series more particularly Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acid (DHA) which have a beneficial effect on blood lipid composition (Clucas and Ward, 1996). Due to high degree of unsaturation, the fatty acids in fish are very sensitive to atmospheric oxygen or other oxidizing agents those initiate oxidation at elevated temperature. Copper, iron etc. accelerate oxidation process (Nowsad, 2007). Fish which store fat in musculature show an inverse relationship between fat and water contents. Fat and water together constitute approximately 80% of the fresh fish muscle (Balachandran, 2001). Besides providing a good amount of protein and beneficial fat, a large number of inorganic elements or minerals also come from fish. There are, however, considerable variations in the content of individual elements. Important minerals with nutritional significance are calcium, phosphorus, potassium, magnesium, sodium iron etc, and they are usually present in a form which is readily available. In most species, the total mineral or ash content ranges from 1 to 2%. If fish bone is consumed, particularly in canned or dried, small, whole fish, a valuable source of calcium and phosphorus is used (Clucas and Ward, 1996).

Knowledge of the nutrient composition of important foods is an invaluable tool in understanding the links between food production, access and nutrient intakes, and in devising policies and programs such as development of improved production technologies (Thilsted and Wahab, 2014). In case of nutritional aspects of fish, the main constituents referred to as proximate composition includes water (moisture), crude protein, crude fat or total lipids and mineral matters (ash). In addition to these major constituents, fish also contains some minor constituents like non-protein nitrogenous compounds, vitamins and carbohydrates. However, proximate composition of fish depends upon the genus and the species. Moreover, in the same species of fish the composition is variable and considerable difference occur due to age, sex and sexual maturity, habitat, diet and fishing season (Sen, 2005).

1.4. Safety aspects of dried fish

Consumption of unsafe food is a serious threat to public health in Bangladesh. At present, most of the foodstuffs, be it manufactured or processed, are unsafe for consumption or adulterated and contaminated in varying degrees. This problem persists at every level of food from production to consumption (Ali, 2013). Similarly, in case of fish and fish products, Bangladesh has been experiencing problems with respect to food safety. Fish, in Bangladesh where malnutrition remains a significant development challenge, are irreplaceable animal-source food in the diet of millions. From last couple of decades, Bangladesh has made tremendous strides in increasing fish production. However, the safety and quality issues have not been dealt with due attention and remained unfocused, which has turned out to be a matter of great concern for the consumers putting their health at risk. To cope with the future demand of food and address the prevailing problems, Bangladesh has set the objectives and goals of country's food policy, and one of the prime objectives of this policy is to ensure adequate and stable supply of safe and nutritious food (NFP, 2006). In addition, Bangladesh is an honored member state of United Nations (UN), and the Sustainable Development Goal (SDG) adopted by UN entails quality fish products for good health and wellbeing. Bangladesh is one of the leading fish producing countries of the world; however, to continue its venture in fish and fishery products, proper implementation of Good Aquaculture Practice (GAP) and Hazard Analysis and Critical Control Points (HACCP) along with introduction of certification process for fishery products both for domestic and export market need to be ensured (Naser, 2016).

Fish is one of the highly perishable commodities and the public requires continuous reassurance of its quality and safety. Because of a large number of species with widely differing appearance, composition and flavor, consumers often become confused if particular species or products made from them are good as well as safe to eat. With the changing of time, quality and safety consciousness of consumers are likely to increase. In Bangladesh, however, most of the quality control and quality assurance programs of the competent authorities are aimed at maintaining quality of export oriented-oriented products, which constitutes only 1% of our total harvest. Regrettably, the quality control of the rest 99% fish which are consumed domestically are totally ignored (Nowsad, 2007). Consequently, the quality and safety issues in respect of dried fish have not been adequately addressed as well.

Like other food processing operation, fish processors have the responsibility of providing safe, wholesome and quality product to the consumer. Absence of lack of consideration to food safety at various stages of processing may pose serious threat to public health. Therefore, food safety management system is now in force in many countries to ensure that all unit operations of a process are controlled to preclude any health hazard which include pathogenic microorganisms, pesticides, heavy metals and other harmful chemicals or extraneous matters (Balachandran, 2001). Fishery products have been recognized as carriers of health hazards such as disease causing microorganisms *Salmonella* sp. and *Vibrio* sp., in addition to parasites, natural toxins, heavy metals and other pollutants (Venugopal, 2002). Like other fishery products, dried fish are also likely to suffer from these hazards which primarily include biological hazards, particularly microbial or pathogenic bacterial hazards resulted from unhygienic handling and processing within contaminated atmosphere, pesticide residues and in some cases heavy metal contamination.

In traditional drying, good hygiene is rarely practiced, which encourages microbial contamination. During the monsoon, when the humidity is high, drying up to the expected level is not achieved by traditional methods. Therefore, by this time, the fish can absorb the moisture and it serves as a habitat for microbial population such as bacteria, fungi and viruses and insect attack (Azam, 2002). The quality of dried fishes is adversely affected by the occurrence of microorganisms. Fish acts as a reservoir of large number of microorganisms. The majority of these microorganisms are non pathogenic causing only spoilage to fish but some are pathogenic and causes food poisoning. The quality deterioration of foods during processing, storage and distribution is mainly caused by microorganism. The microorganisms present in foods are closely connected to the microflora of the environment. The microorganisms associated with fish are also directly related to the fishing ground, environmental factor harvesting method, storage and transportation. For example, fish taken from in-shore coastal waters of estuaries may be carrying bacteria, such as *Salmonella*, *Shigella* and *Escherichia coli*, which are associated with pollution (Clucas and Ward, 1996). Moreover, each microbial growth during storage will depended on the preservation condition. Therefore, microbial and biochemical quality assessment are necessary to ensure the food safety to any processed product (Azam *et al.,* 2003b). The microbial safety of seafood is an important concern of consumers as the major share of the outbreaks related to consumption of fish are caused by bacteria such as *Clostridium botulinum, Escherechia coli, Salmonella, Staphylococcus, Vibrio* sp. and *Bacillus cereus* (Fleming *et al.,* 2000). In addition, fishery products are also recognized as a carrier of food borne bacterial pathogens like *Salmonella*, *vibrio* sp. *Escherechea coli* and *Listeria* sp. (Venugopal *et al.,* 2002).It has been reported that serious disease outbreak had occurred in both man and animals after consuming some dried fish and feed prepared from dried fish (Storey, 1982). The quality and safety aspects of dried fishes are adversely affected by the occurrence of microorganisms. Determination of microbiological quality of such processed fishes is very important for guarding consumers' health and hygiene (Lilabati *et al.,* 1999). The presence of the pathogenic loads in dried fishes is acquiring importance in view of safety and quality of the sea food (Ponda, 2006). The common sources of contamination are air and dust in and around fish drying place, contaminated coastal water and soil and unhygienic handling (FAO, 1982). Therefore, hygienic atmosphere of fish drying yard is necessary for safe and quality dried fish.

Pesticides use in dried fish is another crucial problem with respect to ensuring safety and quality in dried fish products. Nowadays, most of the consumers express concern when they learn about the indiscriminate use of pesticides in dried fish, which ultimately leads to erosion of confidence regarding safety of dried fish. It has been reported that with respect to the quality, traditional dried fish contaminated by both insects and insecticides comprises about 60% of the total dried products that is considered to be unfit for human consumption (Nowsad, 2005), which depicts alarming picture indicating dire situation prevailing in dried fish products from food safety perspective. Generally, pesticides are not applied during dry and good weather; however, during rough and humid weather, particularly in the monsoon period the dry fishes absorb moisture so rapidly that the fish become susceptible to beetle and mite infestation. For protection of dried fish from infestation processors apply insecticides whatever available, and all of them are commonly used in agriculture. All of these insecticides are health hazardous both for users and consumers (Bhuiyan *et al.*, 2009). In tropical climates under highly humid condition, heavy infestation of unsalted dried fish is caused by beetles resulting in quality deterioration in dried fish (Nowsad, 2005). In humid weather, commercial dried fish processors often apply several harmful insecticides to avoid such insect infestation (Bala and Hossain, 1998a). In spite of having serious lethal effects on consumer's body, use of harmful pesticides is the most popular and commonly practiced preventive and curative control measure against insect infestation. Most commonly used pesticides are Dichlorodiphenyltrichloroethane (DDT) and nogos. However, both are banned for any use in Bangladesh (Nowsad *et al.*, 2010).

When the storage time of dried fish is prolong and if further infestation is found, the product is treated with the pesticides again. However, during drying, *Nogos, Nuvacron, Endrin, Malathion, Dimacron*, etc. are popularly used, while in storage of the product, *DDT, Basudin*and *Malathion*are preferred ones. Most of the pesticides of first category and the DDT of second category are banned for any use in Bangladesh. (Nowsad, 2007). In a study on pesticide residues in dried fish, Bhuiyan, *et al.* (2009) reported that the results obtained from screening of DDT and Heptachlor are alarming for Bangladesh. All of the samples contained invariably health hazard organochlorine insecticides DDT and Heptachlor. It has also been expressed that the level of concentration of DDT in dry fish is a great concern but the more concern is the fact that such a dangerous poison is still being used in some popular food items such as dried fish, though it is banned in the country (WHO, 2005). DDT is a slow poisoning substance. It can transfer from generation to generation through breast milk (Solomon and Weiss, 2001). Exposed to DDT occupationally have an increased incidence of non-allergic asthma (Brown, 2007), diabetes (Jones *et al.*, 2008), an elevated risk of cancers of the liver and biliary tract (Rogan and Chen, 2005). In fact, not a single pesticide is safe for health, but its extent of adversity mainly depends on the nature of treatment, period of application and the dosages (Walker and Greeley, 1990). Therefore, it is evident that prolonged exposure to pesticides through dried fish is likely to causes serious health problems. Moreover, if the present problem of rampant pesticide application in dried fish persists and goes on unabated, the efforts with respect to promoting food safety in dried fish will not achieve the desired outcome.

Apart from microbial and pesticide contamination, safety and quality assurance of dried fish may be undermined sometimes by another hazard named heavy metals which usually come in fish from polluted environment of water through bioaccumulation. In the last two decades there has been a growing interest in assessing the levels of heavy metals in food including fish. Such interest aimed at ensuring the safety of the food supply and minimizing the potential hazardous effect on human health. Some of these metals are toxic to living organisms even at low concentrations, whereas others are biologically essential and become toxic at relatively high concentrations. When ingested in excess amounts heavy metals combine with body's biomolecules, like proteins and enzymes forms table biotoxic compounds, thereby mutilating their structures and hindering them from the bio reactions of their functions (Duruibe *et al*., 2007).

In the last decades, contamination of aquatic systems by heavy metals has become a global problem. Heavy metals may enter aquatic systems from different natural and anthropogenic (human activities) sources, including industrial or domestic waste water, application of pesticides and inorganic fertilizers, storm runoff, leaching from landfills, shipping and harbor activities, geological weathering of the earth crust and atmospheric deposition (Yilmaz *et al.*, 2010).At present, most of the water bodies are contaminated by agricultural, industrial and municipal waste as a pollutant and those are accumulated by runoff into these resources. Aquatic organisms are silent victims of chlorine sub-lethal toxicity resulting from different types of pollutants (Bernet *et al*., 1997). Heavy metals intake by fish in polluted aquatic environment results in the accumulation of metals in tissues through absorption and humans are exposed through the food web. This causes acute and chronic effect on humans (Fidan *et al.,* 2008).

Heavy metals entering the aquatic ecosystem can be deposited in aquatic organisms through the effects of bio-concentration, bioaccumulation via the food chain process and become toxic when accumulation reaches a substantially high level (Huang *et al*., 2003). In fish, which is often at the higher level of the aquatic food chain, substantial amounts of metals may accumulate in their soft and hard tissues. Pollutants enter fish through a number of routes: via skin, gills, oral consumption of water, food and non-food particles. Once absorbed, pollutants are transported in the blood stream to either a storage point (i.e. bone) or to the liver for transformation and/or storage (Obasohan *et al*., 2008).

Some heavy metals like Cd, Cr and Pb are nonessential metals and their toxic effect on human health is well known even at low concentration, while metals as, Cu, Na, Ni, Zn, Fe etc. are essential metals; however, the toxic effect of them on human health begins when they are present at high levels (Bryan, 1976). Lead has been of particular concern due to its toxicity and ability to bioaccumulation aquatic ecosystems, as well as persistence in the natural environment (Anim *et al*., 2011). Some effects of Pb poisoning include deficiency in cognitive function due to destruction of the central nervous system, abdominal pain and discomfort, formation of weak bones as Pb replaces calcium and causes anemia due to reduction of enzymes concerned with synthesis of red blood cells. Lead also leads to decreased fertility, causes cancer and other minor effects like vomiting, nausea, and headache (WHO, 2008). Cd can be found in soils under agriculture from insecticides, fungicides, sludge and commercial fertilizers. Ingestion of Cd can rapidly cause feelings of nausea, vomiting, abdominal cramp and headache, as well as diarrhoea and shock. With respect to Cd, target organs include liver, placenta, kidneys, lungs, brain and bones (Reilly, 2002). Hexavalent Cr is very toxic and mutagenic when inhaled and is a known human carcinogen. Breathing high levels of the element in this form can cause irritation to the lining of the nose and breathing problems such as asthma, cough, shortness of breath, or wheezing where long term exposure can cause damage to liver, kidney circulatory and nerve tissues, as well as skin irritation (Dayan and Paine, 2001). Moreover, chronic assimilation of heavy metals is known to cause cancer (Nabawi *et al.,* 1987). In the present study, fish samples were collected from *Chalan Beel* which has been subject to intensive agricultural activities and has been experiencing massive amount pesticides and inorganic fertilizer application during dry season, which is likely to cause adverse effect on aquatic environment and result in heavy metal pollution. Therefore, it is important to monitor heavy metal in fish, water and sediment. Normally, fresh fish are used to estimate heavy metal concentration; however, in this study, dried fish is used as sample. In the study, after determining concentration, health risk assessment was figured out through target hazard quotient. This risk assessment is the fastest method used to evaluate the impact of the hazards on human health (Zhang *et al.*, 2001) and moreover, estimated daily intake and target hazard quotient are indices that are often used (USEPA, 1997).

1.5. Assessment of shelf-life of dried fish

Fish is an exceptionally important component of the human diet and enormous fish processing activities are carried out throughout the world to provide a huge variety of fisheries products up to the expectations of the consumer. Fish, however, is more susceptible to spoilage than certain other animal protein foods (Cutting, 1996). Processing of fish involves primarily the application of preservation techniques in order to retain quality and increase shelf-life. Among them drying is a simple and effective method of preservation which is practiced in many countries of the world to attain extended shelf-life. However, in order to ensure quality of dried fish products coupled with expected shelf-life, good raw fish is a necessary. In fact, good quality of raw materials supply is essential prerequisite for the production of any products with desired shelf-life and required quality. Fish is perishable and must be processed within a few hours of being caught, because no form of processing or preservation can improve the quality of spoiled fish (Lliyasu *et al.*, 2011). Fish is a low acid food and is therefore, very susceptible to the growth of food poisoning bacteria. As a result, appropriate method of preservation is needed to counteract these processes and prolong shelf-life (Cutting, 1996).

After a certain storage time which is considered to be suitable period for storage or shelf-life, the quality of dried fishes is naturally deteriorated or spoiled making it unfit for consumption. Shelf-life is simply defined as the end of the satisfactory period indicating the point at which the consumer is no longer willing to repurchase the product and therefore, refuses to buy the product again. This fact of suitable storage period is applicable with respect to all fish and fish products. Usually, quality deterioration takes place due to spoilage. Spoilage begins as soon as the fish dies or is caught and this process continues. It is the result of a series of complicated changes brought about in the dead fish by enzymes and bacteria. Enzymes are responsible for causing irreversible changes through autolysis, while the changes generated by bacteria occur in the same way as those produced by autolysis but they are caused by the bacterial enzymes. The bacterial load of the fish or fish products will continue to multiply until they are eaten which are accelerated by the ambient temperature. There will always be bacteria present; however care should be taken during handling or processing in order to control the numbers. It is known that, below 4°C, bacterial growth is significantly retarded and at 60°C, most species will be killed (Clucas and Ward, 1996). Various types of parameters, though differ with the method of processing and preservation, are used for the assessment of quality and wholesomeness of fish and fish products in order to determine shelf-life. From public health, aesthetic and nutritional consideration, it is necessary to monitor the parameters for fish and fish products regularly to evaluate the quality so that only safe and good quality fish and fish products having desired shelf-life can reach the consumers (Sen, 2005).

The shelf-life as well as quality of fish and fish products can be estimated by sensory evaluation, microbial methods or chemical methods. With respect to sensory evaluation or organoleptic test, freshness or the extent of spoilage of raw fish and dried fish is judged to a very satisfactory level based on the appearance, odor and texture. During spoilage or quality deterioration throughout the storage period, the changes in odor, flavor and texture of the fish flesh appear to run parallel to certain chemical changes and concentration of those chemicals serves as spoilage indices. Therefore, determining the concentration of the chemicals and bacterial process are useful in evaluating the extent of spoilage in order to have the impression regarding shelf-life (Balachandran, 2001).

At the low Water Activities (WA) of well produced dried fish, the vast majority of bacteria are inactive so bacterial spoilage is not normally a significant problem with regard to quality. This is particularly so for non-salted fish. However, one group of salt loving bacterial (halophiles) can be a problem in salted fish. Giyatmi *et al.* (1992) who reported that the breakdown of fish muscles releases moisture and the moisture uptake from the surroundings promote microbial growth. With respect to bacterial load count, total number of microbial flora is changed with the time of storage in fish or fish products. The number (total plate count or viable bacterial count) per gram of fish or fish products indicate the degree of freshness from the microbiological point of view. Hence, number of total bacteria is one of the main factors affecting the quality and shelf-life of perishable food like fish and fish products. According to IS (2001) (Indian Standard IS:14950) the limit for Total Plate Count (TPC) is 1×10^5cfu/g in the dried products. Besides, Surendran *et al.* (2006) reported that at 37°C in fresh fish the acceptable limit is 5×10^5cfu/g but for cooked or dried fish the permissible limit is 1×10^5cfu/g.

Besides this, in case of chemical spoilage indices such as TVB-N (Total Volatile Base Nitrogen), spoilage of fish and fish products by bacteria is accompanied by the release of several volatile compounds or bases like trimethylamine, ammonia etc. For salted and dried fish the range is 100-200 mg/100g beyond which the products are considered as unacceptable (Connell, 1995; Nowsad, 2007). A European Union directive on fish hygiene specifies that if the organoleptic examination reveals any doubt as to the freshness of the fish, inspectors must use TVBN as a chemical check (Castro *et al.*, 2006).

Oxidation of lipids is also another cause of spoilage. The oils and fats of fish generally have a much higher level of unsaturated fatty acids than other foodstuffs. This means that a reaction between the oxygen in the air and the fish fats and oils is highly likely to take place causing rancidity if the products are exposed in the air for longer period, which ultimately affects shelf-life. The fish oil unexpectedly gets oxidized in the presence of atmospheric oxygen, degree of unsaturation and rise of temperature are influencing factors for enhancing rate of lipid oxidation (Tuschiya, 1961). Also the cause of such lipid oxidation may be the pro-oxidant effect of sodium chloride (Rao and Bandyopadhay, 1983). Rancid fish or fish products have characteristic flavors and odors which may be unpleasant and lead to consumer rejection. The consumer may expect some degree of rancidity in dried fish, but the nutritional value may also be reduced because the oxidized oils have a lower nutritional value than non-oxidized oils. In addition, there is evidence to suggest that rancid oils can be toxic. In fatty fish oxidative rancidity is one of the most crucial quality problems. The degree of oxidation of the fat is measured by peroxide value (Clucas and Ward, 1996).The recommended Peroxide Value (PV) with respect to good quality fish or fish products is 20mEq/kg (Connell et al., 1976). However, PV sometimes does not necessarily correlate well with the sensory assessment of rancidity (Islam *et al.*, 2005)

1.6. Dried fish products in different packaging techniques

Packaging is an essential requirement virtually for every product, whether it is a food or any manufactured item. Apart from selling aspect, packaging has several vital functions; for food products, packaging is also a means of conserving and preserving. Packaging requirements will vary with respect to the product packaged. Packaging technologies are important to protect products against deteriorative effects, which may include microbial, biochemical, and physical activities from environmental influences. This involves retardation of spoilage, extension of shelf-life, and maintenance of quality in packed food. Other functions of packaging include containment, convenience, marketing and communication (Restuccia *et al.*, 2010).

In tune with the commercial requirements and consumer preferences, rational changes and improvements have been brought about in fish packaging. The ideal packaging to be used must be impermeable to moisture, oxygen, flavor volatiles and insects. However, with respect to dried fish packaging, some problems are associated such as puncture of the packaging material, breaking up of dried fish when packaged in regular shaped package and moisture absorption accompanied with oxidative rancidity leading to spoilage (Balachandran, 2001). Rancid fish have characteristics flavors and odors which may be unpleasant and lead to consumer rejection. Rancidity is accelerated by exposure to air, so adequate packaging is necessary to overcome rancidity and beetles infestations problems (Clucas and Ward, 1996).

Dried fish products are prone to fungus attack, insect infestation and rancidity development. Depending upon the moisture content of the product and relative humidity of the environment, there may be absorption or desorption of moisture, affecting the quality of a product, which creates problems in its marketing (Sen, 2005). To reap the benefit of an effective packaging and produce quality dried products good raw fish and hygienic processing technique are prerequisite; since the raw fish quality once get deteriorated and affected by hazardous microorganisms or chemicals during processing, there is no way to improve the quality of the final dried products through any means of preservation and packaging. A well dried fish product having expected level of moisture and other biochemical attributes will go bad if it is not well packaged because of the hygroscopic nature and vulnerability of fish to lose oil through oxidation when exposed to the atmosphere (Folorunsho *et al.*, 2015).

The principal requirement of packaging of dried fish products is to deny access to insect and to prevent rehydration and consequent increase in water activity leading to microbial spoilage (John, 2006). Early forms of packaging for fish products consisted mainly of wooden crates, bamboo/palm baskets, and wooden pickling barrels etc. Nowadays, metal, glass, paper, and particularly plastics, have become more important. However, the packaging and presentation of many fisheries' products in developed countries is now extremely sophisticated. The storage life of some fish products can be extended by packaging them in a modified atmosphere of nitrogen, carbon dioxide and oxygen. With respect to extending shelf-life coupled with desired quality, some interrelated factors concerning improved packaging has drawn attention, which are developments on new food packaging materials for vacuum packaging and gas packaging as a response to consumer demands for products with fresh characteristics, consumer concerns about preservation additives in packaged products, and favorable consumer perception of Modified Atmosphere Packaging (MAP) technology (Ashie *et al.*, 1996).

Materials used for modified atmosphere packaging must be highly impermeable to gas. Carbon dioxide inhibits bacterial spoilage, and oxygen can prevent colour change and bleaching; nitrogen, which is an inert gas, dilutes the mixture, and also acts to decrease the rate of lipid oxidation that results in rancidity (Clucas and Ward, 1996).Vacuum packaging is practiced for long-term storage of dry foods and the shelf-life extension of seafood. Vacuum-packaging in combination with chilling was found to be effective in delaying spoilage and thereby significantly extending dried fish products shelf life in tropical environments (Ochieng, 2015).This method is commonly known to be used for a variety of fish and shellfish products, including smoked or dried fish. Vacuum packaging technique consists of the removal of air from pack, which requires high gas barrier packaging films such as polyvinylidene chloride or polyester. In vacuum packaging, removal of oxygen reduces aerobic bacterial spoilage, fat oxidation and rancidity, and extends the shelf-life of the pack. However, in some cases anaerobic atmosphere of vacuum packed food can lead to the growth of *C. botulinum*, and it becomes more likely when the pack is subjected to temperature-abuse (excess of 3°C) (Clucas and Ward, 1996).

Nowadays, the physical and organoleptic qualities of most of the sun-dried products available in the market of Bangladesh are not satisfactory for human consumption. Frequent complaints from the consumers about the quality of the products are very common incident. In the traditional storage of dried fish in Bangladesh, no proper measures of packaging are normally taken to protect the fish against unfavorable environmental conditions. Therefore, alternative affordable, safe, hygienic and environmental friendly methods must be developed and adopted for fish drying and preservation (Farid, 2014b). To get the effective results dried fish should be packaged on the drying or as soon as the drying is complete. If it is done properly, adults beetles and mites will not get chance to lay eggs on dried fish. After drying, dried fish must not be kept open or exposed in the room or storage house. Packaging of dried fish should be done with appropriate packaging materials like good quality polythene coated with polystyrene or polypropylene to avoid blackening and rancidity (Nowsad, 2007). Therefore, as proper packaging can contribute to preventing quality of dried fish during storage and marketing, this study will focus on the assessment with regards to the performance of various packaging techniques through evaluation of sensory attributes.

1.7 Status of awareness of dried fish processors

In recent years, dried fish and fishery products of Bangladesh are in decreasing trend in case of export market demand due to the use of low quality raw fish for the drying purposes, traditional drying practices, improper hygiene and sanitation facilities and indiscriminate use of unauthorized chemicals and insecticides at the different stages of handling, processing and storage of dried fish. Moreover, fish drying is usually performed in an open platform placing the fish on the mats, grass or sands. As a result, the fish is contaminated by dust, dirt or sand and pathogens (Hasan, 2016). Bangladesh is known to suffer from serious post-harvest loss every year mainly due to ignorance and negligence of the people involved in different stages from the harvest to retail distribution of fish and fish products, among them dried fish is notable. This low quality of fish and fish products is not only a matter of great concern of food security and public health but also of tremendous economic loss, which the fishers, fish traders and processors have been experiencing for years. Due this untoward situation in post- harvest fisheries particularly in dried fish processing, the quality and extent of small-scale fish processing have been in decline trend over the recent years. In order to mitigate this substantial post-harvest loss, particularly both qualitative and quantitative loss, it is imperative to raise awareness regarding safety and quality aspects along with hygiene and sanitation issues among fish traders and processors (Nowsad, 2014). The quantitative losses occur during different stages of handling and transportation. The most important contributing factors of post–harvest losses are probably associated with rough handling, improper and delayed icing, longer exposure to high temperature, contamination and lack of knowledge on sanitation and personal hygiene during processing and marketing (BOBP, 1985). With respect to sanitary and hygiene, traditional fish drying status is usually undeveloped and good hygiene is rarely practiced. The traditional dried fish processors lack adequate knowledge and facilities for maintaining proper sanitation (Flowra and Bhuiyan, 2013). As a result, the physical and organoleptic qualities of many traditional sun-dried products are unsatisfactory for human consumption.

In respect of every production, the manufacture or process of a high and consistent quality product should be the ultimate aim, and this can only be achieved if the principles of hygiene and sanitation are understood and practiced in befitting manner. For this purpose, processing sites should be selected as close to the source of raw materials having appropriately designed infrastructure and equipments, adequate supply of good and safe quality water, sufficient sanitary toilet facility with proper drainage system. Moreover, as many of the hygiene problems arise from staff themselves, they need to have basic understanding of good personal hygiene along with healthy habit, and they must be encouraged to wash their hands whenever necessary and should be provided with protective clothing to protect the processed products from contamination (Clucas and Ward, 1996).

In the interests of food safety and consumer protection, increasingly stringent hygiene measures have been adopted at national and international trade levels. In case of processing, despite technical advances and innovations in many countries, less developed economies still lack adequate infrastructure and services such as hygienic landing centers, reliable electricity supply, potable water, roads, ice, ice plants, cold rooms, refrigerated transport and appropriate processing and storage facilities. These factors, especially when associated with tropical temperatures, result in high post-harvest losses and quality deterioration, during storage or processing, on the way to market and while awaiting sale (FAO, 2016). In dried fish marketing channel people involved early in the production chain (fishing and drying) add relatively more value and make little profit due to small scale production, poor product quality, lack of market access along with illegal influence of commission agents and high transportation cost/toll/taxation etc.(Nowsad, 2007).

One of the major problems associated with the sun-drying of fish is the infestation of the products by the blowfly and beetle larvae. Under warm and humid condition, during sun-drying fish usually become subjected to infestation by blowfly larvae (Kordyl 1976). Because of the negligence and lack of awareness, in case of prolonged storage the extent of damage caused by beetle infestation in the country is much higher than blowfly infestation caused during processing where comparatively greater attention is paid. During prolonged or improper storage dried fish is also more likely to be infested by beetle and mites which cause heavy damage. Various pesticides are often deliberately used in dried fish to control blowfly and beetle infestations. Most citable of them are DDT and Nogos which are banned for any use in Bangladesh (Nowsad, 2007). This deliberative abuse is often encouraged due to inadequate regulatory monitoring and legal enforcement. However, some other factors such as insufficient training and motivation are also responsible for lack of awareness with regards to dose limits, residual effects etc. As a result, use of unsafe pesticides and their excessive dosages in dried fish create serious health problems to the consumers (Khan *et al.*, 2002b). However, some dried fish processors use salts to protect their products from insects. Out of ignorance, some of them use additional salt to increase the weight of dry fish but the quality of salts is very poor mixed with sand, dirt and contaminants, moreover, proper ratio of salt and fish is not maintained. Therefore, the prevailing situation may be improved through monitoring and maintaining good handling, sanitation and hygiene in dried fish production, and providing required training is also necessary in this regard (Flowra *et al.*2013).

Awareness of processors regarding food safety and healthy atmosphere along with necessary infrastructure is prerequisite for ensuring required standard of fish products. With respect to maintaining quality and wholesomeness for any fisheries products through hygienic and good manufacturing process, according to 'Fish and Fishery Products Official Controls Protocol' provided by DoF (2015), staffs handling fish products are to be in good health and observe adequate hygienic behavior and undergo training on health risks. In addition, fish processing equipments, containers and vessels along with potable water should be used to prevent contamination, and adequate number of toilets with effective drainage system, clean premises of processing area and hygienic and environment friendly waste disposal need to be ensured. Besides, as per provision of 'Fish and Fish Products (Inspection and Quality Control) Rules 1997' which deals with safety and quality issues of fisheries products, no person will carry out any fish processing or curing activities without having license from concerned authority; it also imparts that DDT or other harmful insecticides are completely prohibited except few specific bio-degradable insecticides with permitted dose approved by competent authority (DoF, 2010).

1.8. Study area, study period and sample fish species

The *Chalan Beel* represents a vast aquatic ecosystem with unimaginably rich biodiversity and also serves as a huge repository of freshwater fish. Being one of the the largest *beel* of the country, it is famous for producing substantial amount of fish every year. A considerable portion of its harvest is subjected to drying during glut period, particularly after rainy season. *Chalan Beel* is the largest wetland in the north-central Bangladesh and covers an area of about 375km^2. The central zone of *Chalan Beel* area belongs to Singra, Gurudaspur and Boraigram thana of Natore district and Chatmohar thana of Pabna district and Tarash, Raygonj and Ullapara thana of the Sirajgonj, Manda of Naogaon district (Bnglapedia, 2003). It consists of a series of *beel* connected to one another by various channels during the rainy season. Moreover, a very dense water network over the entire *Chalan Beel* is formed by rivers and their tributaries covering slightly above 150 square miles (375 sq. km.) which serve as a suitable habitat for freshwater fish (Samad *et al.*, 2009). It is located in north-west region of Bangladesh encompassing a vast area (In rainy season: 375 square kilometers and in dry season: 52-78 square kilometers). It was about 1088 square kilometers when it was formed and now it extends over four adjacent districts of (a) Atrai of Naogaon district, (b) Singra, Gurudaspur, Baraigram of Natore district, (c) Chatmohor and Bhangura of Pabna district and (d) Tarash, Ullahpara and Raigonj of sirajgonj district (Hossain *et. al*., 2009). In Rajshahi division, *Chalan Beel* is one of the country's biggest inland fishing zones, esteems the higher fishery trade flow (Nowsad, 2014). As a result, commercial inland fish drying yards have been developed mainly around the major capture fishing spots like Singra of Natore, Atrai of Naogaon, Tarash of sirajganj which are adjacent to *Chalan Beel* (Nowsad, 2005).

Many people living near the *Beel* area become involved in fish drying activities during winter, which play significant role in promoting livelihood security of the resource poor and most disadvantaged fish processors. Besides, fish drying practices of *Chalan Beel* area significantly contributes national food and nutritional security by satisfying domestic and export demand. In *Chalan Beel* area a total of 21 fish species were identified which are used for sundrying (Flowra *et al*., 2012a). Among different species of dried fishes, substantial amount dried *Puntius* sp. particularly *Puntius sophore*, which is the raw materials of semi-fermented fish product known as *Shidhal* or *Chepa* is produced in this *beel* area. A good amount of dried *Puntius* sp. from *Chalan Beel* area is exported to India. Due to the unique taste of freshwater dried fish, it has been playing an important role in gratifying the delicate feelings of tongue for many people; it is in good demand in the market as well. However, in spite of having significant impact on socio-economic wellbeing and food and nutritional security of the country, no attention has been paid on the fish drying sector of *Chalan Beel* and it remains neglected in many ways. Regrettably, the fish drying process of this area remains traditional and is practiced in unhygienic conditions which results in poor quality products. Besides, due to lack of awareness or negligence of fish processors, fish drying in this area is known to suffer from abuse of pesticide which also makes the dried products unsafe.

The present research was conducted from January, 2015 to December, 2017 in five popular fish drying areas adjacent to *Chalan Beel* where the number of fish drying yard was around 60-70 and the owners of this drying sites were engaged in fish drying business employing a good number of workers including female; the study areas were located in five upazila of four districts namely Singra upazila of Natore; Atrai of Naogaon; Chatmohor and Vangura of Pabna and Tarash upazila of Sirajganj District (Fig. 1.1).

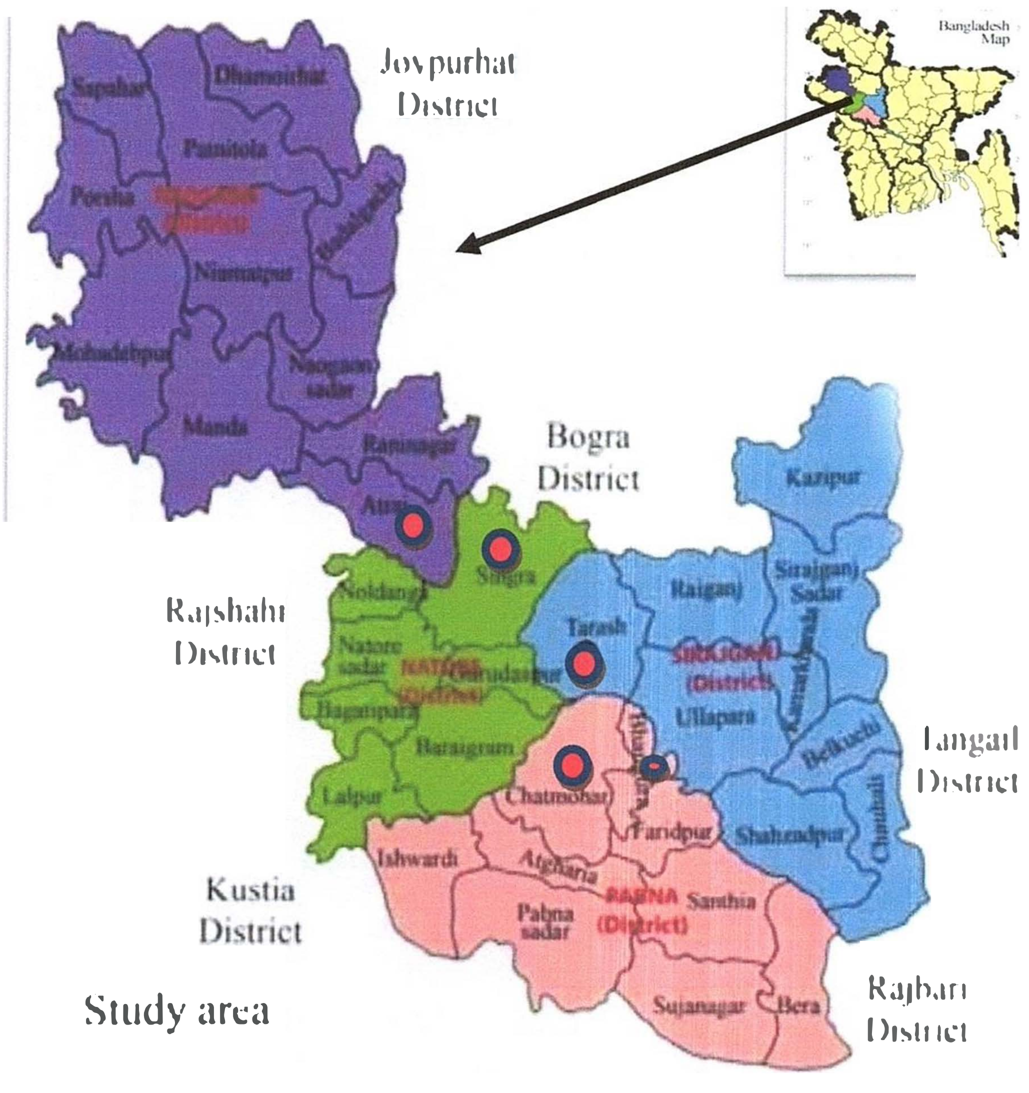
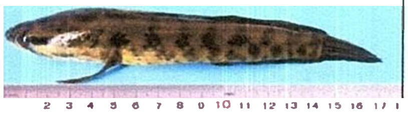
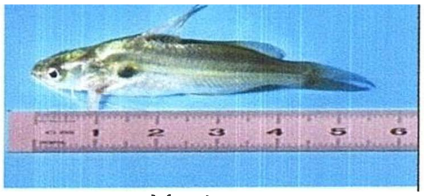


Fig.1.1 Map showing the location of five study areas of *Chalan Beel* (Source: Banglapedia, 2003)

Among available dried fish species, five popular fish species such as *Channa punctatus*, *Mystus vittatus*, *Channa striatus*, *Wallago attu* and *Puntius* sp. (mixed sample of various species of Puntius genus) were selected as sample species for preparing experimental dried fish by newly applied low-cost method (Table1.1). However, the traditional samples of the same species were collected from the fish drying yards located in *Chalan Beel* area which were prepared by sunlight in open air condition. Moreover, other survey based activities were carried out in all the drying yards selected from the study areas, while the trials for improved drying techniques were set up in Mohisluti drying area under Tarash Upazila of Sirajganj district.

Table1.1 Salient features of selected sample species for experiment

Sl. No.	Classification	Description	Figure
1.	Phylum: Chordata Class: Osteichthyes Order: Siluriformes Family: Siluridae Genus: Wallago Species: *W. attu* (Day 1878)	It is voracious feeder and well-known for its predatory behavior and is often termed as 'freshwater shark' and locally known as 'Boal'. As soon and the rivers and *beel* are flooded by rains they run up the shallow water for breeding which usually takes place during June and July. It is popularly consumed in both fresh and dried forms.	 *W. attu*
2.	Phylum: Chordata Class: Osteichthyes Order: Channiformes Family: Channidae Genus: Channa Species: *C. punctatus* (Bloch, 1794)	It is snake headed fish and locally known as 'Taki'. It is abundantly found in ponds, ditches, beels and swamps. It is voracious and predatory to small fish and fry. It is a most famous species for drying all over Bangladesh and very commonly used fish in *Chalan Beel* areas for drying purpose as well.	 *C. punctatus*
3.	Phylum: Chordata Class: Osteichthyes Order: Siluriformes Family: Bagridae Genus: Mystus Species: *M. vittatus* (Shaw and Shebeare,1937)	It is widely distributed all over Bangladesh and locally known as 'Tengra'. During glut period, substantial amount of this species is harvested in *Chalan Beel*. It is very famous for its unique test and its dried form is also a most preferred delicacy.	 *M. vittatus*

4.	Phylum: Chordata Class: Osteichthyes Order: Channiformes Family: Channidae Genus: Channa Species: *C. striatus* (Bloch, 1794)	It is a snake headed fish locally known as 'Shol'. The fish is carnivorous and subsists on variety of living creatures including fish. It prefers the habitat of setting mud of ponds, ditches, *beels* and swamps. They breed during the onset of monsoon and show parental care. Being fleshy in nature, it is usually dried after splitting. It is one of the most costly freshwater dried fishes.	 *C. striatus*
5.	Phylum: Chordata Class: Osteichthyes Order: Cypriniformes Family: Cyprinidae Genus: Puntius Species: *Puntius* sp. (Hamilton, 1822)	It is abundant in freshwater throughout Bangladesh. It is locally known as 'Punti'. It is commonly used for preparing semi-fermented fish product known as *Shidhal* or *Chepa*, and it is the prime contributor in dried fish production of *Chalan Beel* area.	 *Puntius* sp.

Given the various aspects and issues prevailing in the fish drying sector of *Chalan Beel* area, the present research is a way forward to promote the quality of dried fish through focusing on improved drying techniques, assessing nutritional quality and safety aspects along with shelf-life, packaging and evaluating the level of awareness with a view to ensuring safe and good quality dried fish production from *Chalan Beel* area. Therefore, the study was intended to address the following objectives:

1.9. Objectives

1. To Improve fish drying techniques.
2. To analyze nutritional quality of traditional and experimental dried fish.
3. To know the safety aspects in dried fish products.
4. To assess of shelf-life of dried fish.
5. To observe the awareness of dried fish processors from food safety perspectives.
6. To promote dried fish product through different packaging methods.

Chapter 2

Review of Literature

Chapter 2

Review of Literature

2.1. Improved Fish Drying Techniques

The information available in the literature suggest that dried fish prepared through traditional open method is more likely to suffer from several problems like contamination by foreign materials like dust, dirt sand etc., insects infestation and attack with pathogenic microorganisms which make dried fishery products of poor quality and unsatisfactory for human consumption, which also contributes to increasing post-harvest losses and undermining consumers' preferences. In traditional method dried fish processors often deliberatively use hazardous pesticides due to lack of awareness making the products unsafe. Moreover, unhygienic environment of production and storage also results in quality deterioration of dried fish products. Inadequate drying, improper storage and packaging are also responsible for reducing shelf-life as well as decreasing nutritional quality. Therefore, besides awareness development of dried fish processors, improvement of traditional fish drying techniques, ensuring nutritional quality and safety along with desired shelf-life are necessary for earning trust of consumer and harnessing the potentials of this less focused sector. Available literature reveals that using the solar radiation with improved solar drying techniques has attracted considerable interest and also recommends that solar dryer may have significant impact in controlling insect infestation, spoilage and contamination with higher drying rate over the traditional sun drying (Richards, 1981; Islam, 1982; Hussain *et al.*, 1992; Mansur *et al.*, 1993; Bala and Hossain, 1998b; Bala and Mondol, 2001b). Some necessary and relevant research works concerned with different chapters of this research have been reviewed here.

Doe (1977) stated that the materials used for the construction of tent include: polythene tent, wooden frames, PVC (black) polythene spread out on the base of the tent and a drying rack. In this sticks were simply dug into the ground, tied together and the polythene sheet fastened around the sticks using stapling pins. A flap was left under the tent to serve as access to the fish and also as air inlet.

Ahmed *et al.* (1979) stated that dried Silver Jew fish (*Johnius argentatus*) prepared by solar dryer were free from fly larvae infestation. Moreover, drying process was found to be quickened by this method.

Chakraborty (1981) reported that in tropical countries the solar tent drier may be the only scientific tool within the reach of poor fishermen living in remote fishing village and they can dry their extra catch employing this approach.

Ramachandran *et al.* (1988) conducted research on the design of solar drier such as solar tent dryer, solar cabinet drier (SCD) and found that all the solar-dried fish were of good quality marketable products but tent drier was found suitable for small scale processors.

Arata and Sharma (1991) reported that research performed so far on solar drying at various institutes has concluded that to meet the increasing demand for food preservation in developing countries, simple, cheap but efficient solar dryers equipped with a fan for ventilation and supplementary heat sources should be developed.

UNIDO (1991) reported that about 50 of total marine catch is dried in China. Dried products are to a great extent processed in traditional way of sun drying. However, in the major fish processing plants artificial drying through heated chambers or tunnel drying is quite common and some of the dried products from such plants have received good response from foreign markets like Japan paving the way for increased exports.

Balachandran (2001) reported that harnessing the solar radiation for solar powered driers has attracted considerable interest because of the absence of energy cost and possibility of producing a dried fish in good hygienic condition even when the relative humidity is high. When the temperature of the air of drying chamber is raised, its RH will be reduced; in other terms its capacity to hold water will increase and hence, can absorb additional quantities of vapor.

According to Bala and Mondol (2001b), drying air temperature at the collector outlet varied between 35.6°C to 52.4 °C in the month of February-March, 1999; 32.5

°C to 53.5 °C in the month of November- December, 1999; and 29.5 °C to 55.0 °C in the month of November-December, 2000.The temperature inside the collector increased along the length of the collector from the inlet of the collector.

According to Koyuncu and Sessiz (2002) a greenhouse type drier, a mesh platform and board platform air-type solar driers were designed, and compared. The greenhouse type solar dryer consists of a frame constructed from iron bar, plastic cover sheet, plastic mesh, insulation, black painted aluminum sheet, product door, air inlet and outlet channels. All dryers were tested under the same environmental conditions which revealed that the thermal efficiency of the greenhouse type solar dryer was approximately 15% and was 3-4 times faster than the air-open dryers and no important differences between mesh and board platform were observed.

Islam *et al.* (2006) reported that among three models of low-cost solar dryer 1st model had a corrugated iron sheet (tin) with black paint (10×3 feet) which was used as a heat absorber. The products to be dried were placed in thin layer on a bamboo splitting net inside the tunnel dryer. The size of the dryer was 20×4×3ft having drying capacity of 50kg and total. The 2nd model also had corrugated iron sheet (10×3 feet) with black paint which was used as solar collector like previous model and placed in one end of the drying unit normally at the side of direction of air flow which blow absorbed heat over the product. There were hanging bar inside the tunnel dryer (30×3×3ft) having drying capacity of 150kg. In 3rd model Hemp plant was used as an insulated material on the raised platform and black polythene as a heat collector was placed on them. To accelerate the wind flow through the tunnel wind diverter (canvas or tin made) was used at the side of direction of airflow which blows absorbed heat over the product. There were hanging bar inside the tunnel dryer (65×3×3ft) having drying capacity of 500kg. The dryer was made with ten small units (6.5×3×3ft). The total costs involved were 3060, 3530 and 9630 for 1st, 2nd and 3rd dryer respectively. The average temperatures inside the dryer were 29-43, 34-51 and 37-57°C; the relative humidity was 22-42, 27-39 and 24-41%; and the drying times were 30-42, 28-38 and 24-34 hours for 1st, 2nd and 3rd dryers respectively.

Nowsad (2007) mentioned generally, small fish spread in thin layer on the elevated racks takes a shorter duration to dry. Larger and thicker fish take longer time. In winter, when the relative humidity is less in the air (60-65%), 2-3 days are sufficient for drying small mixed fish. Average duration during drying season for different fishes are – jewfish: 2-3 days; ribbonfish: 3-4 days; Bombay duck: 2-3 days. Of course, this duration varies if it rains or the sky is cloudy.

Reza *et al.* (2009) conducted a study on optimization of marine fish drying by using solar tunnel dryer. Five commercially important tropical marine fish species in the Bay of Bengal such as silver jaw fish, bombay duck, big-eye tuna, chinese pomfret and ribbon fish were used and drying was performed at 45 to 50°C and 50 to 55°C temperature ranges. Moisture content of the fish samples reached 16% after 36 and 32 h of drying at temperature ranges of 45 to 50°C and 50 to 55°C, respectively. Products produced at 45 to 50°C were found to be excellent on the basis of flavor, color and texture. Their rehydration ability ranged from 65 to 80% with minimum in big-eye tuna and maximum in silver jaw fish. Values of total volatile base, peroxide and aerobic plate count of all the final dried products were within the acceptable limit.

Sengar *et al.* (2009) reported that dryer having a size 92 cm x 75 cm was constructed by locally available bamboo, which consists of three main parts, collector, drying chamber and inlet and outlet openings. Drying chamber designed in such way that it consist 16 trays of 70 cm x 50 cm size. Mosquito net was used for trays as it betters performance in humid region. Capacity of each tray is 0.6 kg. UV stabilized 200 micron plastic film was used for harnessing solar energy. This film surrounded around the drying chamber and fixed by Velcro strip. Bottom and topside of the dryer was provided with openings for air circulation. Total cost of this dryer was Rs. 1700/-.

Oghenekaro and Samuel (2009) reported that materials used for Kainji Solar tent dryer are: Transparent polythene tent, wooden frames, mosquito net, black igneous rocks, zip and drying rack. This dryer was constructed by obtaining five pieces of straight wooden poles each measuring 180 cm. Two of the poles were tied or nailed together at one end and the two other ends were dug 10cm into the ground at 160 cm apart. The same was done for the third and fourth wooden frames which are dug in an opposite direction at a distance of 194 cm apart. The fifth wooden frame was placed across the two pairs of wooden poles and fastened at both ends to form a tent-like structure. About 10 yards (50 μ thickness) transparent polythene was sewn into shape of the wooden framework above. The polythene tent was sewn to a height of 180 cm, top length of 184 cm and bottom length of 227 cm to fit and worn over the wooden framework . On one of the longer sides of the polythene cover, an opening was cut into the tent and screened with mosquito net. This opening serves as air inlet into the solar tent. At the extreme narrow tops of the triangular part of the tent, openings of 15 cm x 15 cm were made and screened with mosquito net to serve as outlet of the hot air from the dryer. On the opposite side of the net with the air inlet, a ½ meter zip length was sewn to serve as an access opening into the tent for the processor to handle and inspect the fish on the drying rack during the drying process. A fiber rope is passed around the base of the tent for tying the polythene tent firmly on the wooden structure, to prevent wind and insects from escaping into the tent. About 30 pieces of rocks with an average weight of 10 kg each were stacked within the base of the wooden framework. The rocks are painted black hence they serve as capacitor by absorbing, retaining and releasing radiant energy needed for the fish drying. The drying rack is a wire mesh framed with wood (70 x 150 cm) and suspended by two ropes of 150 cm each from the wooden frame above.

Sultana *et.al* (2009) reported that rotating dryer essentially consists of Thai aluminium structure bearing hooks and stainless steel ring. The aluminum structure is supported by S.S. pipe and bearing. Nut bolts are used to join interconnected parts of the dryer. The dryer is operated by 0.75 HP motor having speed regulator. In the present study the rotating dryer was operated at speed of 90 rotations per minute (RPM). The whole system is placed vertically on raised 2" × 2" angel platform. Hooks and stainless steel structure are used to hang large size fishes and round shaped plastic net was used as additional platform for drying of small fishes. When the system is on, the dryer rotates and ambient air passes over fishes, which enhance the drying process. However, a Hohenheim type solar tunnel dryer was also used for drying marine fish products which was constructed using locally available materials and the size of the dryer was 20m×2m with 20m2 drying area. The solar tunnel dryer consists of a flat plate air-heating collector, a tunnel-drying unit and four small fans to provide the required airflow over the product to be dried. Both the collector and the drying unit are covered with transparent polythene sheet. Black paint is used as heat absorber in the collector.

Kituu *et al.* (2010) stated the solar tunnel dryer system consisted of two chambers: the tunnel and the chimney sections. The tunnel is used for heating the drying air before it enters the chimney. The two chambers are completely sealed from light to preserve light sensitive nutrients in fish. The tunnel section of the dryer measures 2.24 m long, 1.20 m wide and 0.54 m high, and has a 19 mm thick rectangular galvanized iron (GI) collector plate, which is painted black for enhanced absorption and emission of solar energy, and a glass cover plate. The bottom plate of the tunnel section was made of aluminum painted GI sheet, to reflect energy incident on the surface. At the base of the exhaust pipe it has a solar-driven 12 V, 0.16 A 1.92W d.c. suction fan, capable of delivering 1.2 m3/s of air.

According to **Chavan *et al.* (2011a)** the AIT solar tunnel dryer has a width of 1.8 m and a total length of 8.25 m. The first 4 meters serve as a solar air heater, and the remaining 4.25 meters constitutes the drying tunnel. The side height for the air flow is 0.07 m to accommodate the trays with the products. The air flow rates were controlled by using five AC- driven fans of 14 W capacities, which are placed in front of the collector. The covering sheet is tilted like a roof to prevent water entering or even flooding during rainfall. At the end of the dryer, an aluminum mesh prevents any insects from entering the dryer.

Komolafe *et al.* (2011) reported that a simple convective fish dryer was designed and constructed to alleviate the problems associated with fish processing in Nigeria. It is made up of five main parts namely; the base frame which is fabricated from 40 x 40 x 3 mm angle iron bar with dimensions of 865 x 498 x 770 mm.; the drying chamber measuring 808 mm (length), 438 mm (width), and 648 mm (depth).; the drying cage/net measuring 720 x350 x 36 mm which is constructed with a stainless wire mesh of 2.8mm diameter; the fan housing consisting of 3 fan blades measuring 520 x 100 x 2 mm; and three electric heating elements (3000 w, 6000 w, and 9000 w, respectively). The no–load evaluation (temperature profile) of the dryer showed the highest temperature of 110°C/drying chamber temperature in 30 minutes which is expected to give higher drying rate than the natural sun drying and open–fired drying methods.

Rahman *et al.* (2012) developed a dryer using single layer as well as double layer transparent plastic wavy sheet (plastic tin) fabricated in the dimensions of 18' x 2.5' x 2.5'. Locally available materials such as sliced woods, transparent plastic wavy sheets (plastic tin), etc. were used as the main materials to construct the dryer. Several horizontal wooden bars were set in parallel position along the top of the width of the dryer to hang the fish by dual fishing hooks were used. During the bad weather and at night, an electric heater was used to produce hot air and an electric table fan was used to blow out the moist air.

Hubackova *et al.* (2014) reported the solar dryer consisted of a solar air heater collector, drying chamber with drying trays and a blower, connected to the top of the drying chamber. The collector width, length, and depth were 1.50 m, 1.47m, and 0.12m, respectively. The solar collector array consists of a solid transparent plastic cover, an insulator, and a black painted aluminum absorber. Air enters into the drying chamber trough the collector by natural convection mode. The chamber dimensions are 1.50m long, 0.60m wide and 1.10m tall. The values of ambient temperature, ambient relative humidity (RH), and solar radiation ranged between 26.3° C and 37.6° C, 30.6% and 55.8% respectively. Temperature and relative humidity of the drying air ranged between 46.4° C and 61.4° C and 11.4% and 29.6%. It is observed that drying air temperature and drying air relative humidity have showed a contradictory run.

Joshi *et al.* (2014) reported in case of solar tent drier used in present study, the side facing the sun had top half covered with transparent sheet and the bottom half covered with black polythene sheet. Remaining sides covered with black polythene sheet, which absorbs solar radiations and heats the air within, thus enhancing the natural convective flow of air during drying which took 58 hours for drying fish.

Relekar *et al.* (2014) stated that raised bamboo platform of dimensions 2.0x1.0 m was fabricated using split bamboo. The bamboo platform was raised above the ground using the plywood stand of 0.5 m for better circulation of air from the both the sides of fish and it required 82 hours for drying fish.

Mustapha *et al.* (2014) Five different solar driers with a square size of square size of 2 9 2 ft. Inside the driers were placed a wooden stand having a dimension of 1.5 9 1.5 9 0.5 ft (length, width, and height), and a 1.7 9 1.7 ft wire mesh in which the fish species were placed was put on top of the stand. The solar driers were constructed from inexpensive and readily available materials were used for drying of the two fish species. The driers used were as follows- Plastic drier: This was constructed using a thermopile plastic material. Mosquito net drier: This was constructed by using plywood for the frame (edges). The dryer was subsequently covered with mosquito net all around the wooden frame. Glass drier: This was made of transparent glass. Aluminum drier: This was constructed from aluminum sheet. The dryer was, however, coated both inside and outside with black paint. Glass drier containing black stones: This is similar to the glass drier in every respect but with a black (igneous rock) stone placed in it. The highest drying time, efficient performance, drying effectiveness, and high acceptability of the organoleptic parameters of the dried products were observed from the black stone-inserted glass drier.

Hasan *et al.* (2016) reported that in recent years, Bangladeshi dried fish and fishery products are decreasing trend of export market demand due to the use of low qualities raw fish for the drying purposes, traditional drying practices, improper hygienic and sanitation facilities and indiscriminate use of unauthorized chemical and insecticides at the different stages of handling and processing of dried fish. Moreover, fish drying is usually performed in an open platform or placing the fish on the mats, grass or sands. As a result, the fish is contaminated by dust, dirt or sand and pathogens.

2.2. Nutritional Composition of Dried Fish

Qudrat-i-Khuda *et al.* (1962) reported that the protein content of sun-dried shutki of both marine and fresh water fishes varied from 55.50 to 74.18% in *Labotes surinamensis* (Katkoi) and *Chanina marulius* (Gazar), respectively.

Rahaman *et al.* (1978) reported that the moisture, protein, lipid and ash content of sun-dried Rohu were 9.8%, 80.9%, 4.8% and 4.4% respectively.

Rubbi *et al.* (1978) observed that the market samples of sun-dried *Gadusia chapra* had moisture ranging from 9.61% to 18.64%.

Muraleedharan and Valsan (1980) developed an improved method in which strips of tuna were washed, dipped in saturated brine for 30 minutes, and then steamed for one hour before drying. The improved product has a protein content of 76.6% compared with 66.3% for traditional product.

Love (1980) observed that the live weight of majority of fish usually consists of about water (70-80%), protein (20-30%) and of lipid (2-12%).

Burt (1988) reported that if water activity of dried fish is reduced below 0.6 there can be no microbial activity. Many traditional dried fish processors use use salt as a means of lowering water activity. The salt act to bind water molecules and saturated solution of common salt has a water activity of close to 0.75. To prepare fully dried fish it is to be dried until their moisture content is close to uniform and water activity is close to, or below 0.75. Fully dried fish have a shelf-life of several months provided that they are properly packaged and stored.

Nielsen (1997) reported that sensory as well as organoleptic method will continue to be essential, even if better, cost-effective instrumental methods are developed. Sensory evaluation is used as a tool for grading according to product standards and for studying specific properties of fish species in connection with evaluation of quality, shelf-life, storage conditions and product development.

Mollah *et al.* (1998) studied the seasonal variation of the proximate composition dried *Rita rita* and found that the highest amount of moisture was 17.84%, protein 69.13%, mineral 1.41%, crude fiber 6.25% and lipid 13.92%.

Doe (1998) mentioned that the extent to which traditional dried fish producers adopt national and international guidelines is a measure of their commitment to quality assurance. Adoption of quality assurance measures is a necessary step in developing international markets for dried fish products.

Mansur (2001) mentioned that the major portion of the annual fish catch in Bangladesh is caught and marketed privately. Some species are exported as dried, salted, fermented etc. Usually these frozen, dried, salted and fermented freshwater fish and sea fish species are exported to those countries where a good number of Bangladesh citizen have been living for a long period.

Doe (2002) mentioned drying of fish substantially diminish the water activity in the tissue. It is found that lowering of water activity below 0.9 is sufficient to prevent the growth of the dangerous toxin forming pathogenic bacteria.

Azam *et al.* (2003) studied biochemical assessment of fourteen selected dried fish and observed that moisture content ranging from 18.23-24.46%, protein varied between 40.69-68.09%. Ash and fat content were in the range of 5.08-16.02% and 2.97-26.13% respectively.

Nowsad (2005a) described moisture content of the final product should be reduced to less than 15-16% theoretically, and then most of the microbiological and enzymatic activities are slowed down or stopped. In practice, however, water content is not decreased to that level. In commercial processing water content is often higher when storage times are short, where salt is used in the processing and where consumers prefer an intermediate moisture product. Local consumers generally prefer unsalted products. To prolong the storage life of such products insecticides are applied. Moisture content of unsalted products ranges from 18-23%, while those of semi-salted or salted products varies between 25– 30%. He also observed that bio-chemical assessment of fourteen selected dried fish and observed that moisture content ranging from 18.23-24.46%, protein varied between 40.69-68.09%. Ash and fat content were in the range of 5.08-16.02% and 2.97-26.13% respectively.

Sultana *et al.* (2008) conducted study to evaluate the quality aspects of marine dried fish i.e. silver jaw fish *(Johnius argentatus),* Bombay duck *(Harpodon nehereus)* and ribbon fish *(Trichiums haumela)* products produced in rotating and solar tunnel dryers, and findings revealed that Proximate composition such as moisture, crude protein, lipid and ash content of the dried fish muscles produced in rotating dryer ranged from 16.36% to 19.1%, 62.35% to 67.37%, 6.37% to 10.75% and 7.00% to 8.05%, respectively and in solar tunnel dried fish products, they were in the range of 14.05% to 19.71%, 57.64% to 69.21%, 6.92% to 15.40 % and 7.69% to 8.80 % respectively.

Chavan *et al.* (2011b) found that the initial moisture content of dried ribbon fish procured from market was 30.6 %, which was significantly higher as compared to ribbon fish dried in solar tent drier (17.85per cent), on raised bamboo platform (19.35per cent) and black polythene sheet (19.95%). In case of protein content, solar tent drier showed relatively higher values (44.13%) from the beginning of storage, followed by fish dried on raised bamboo platform (42.22%) and on black polythene sheet (41.35%), while the dried fish procured from market showed lower protein content (32.48%) as compared to fish dried by improved methods. The initial ash content of the dried ribbon fish procured from market was lower (15.35%) as compared to the ribbon fish dried in solar tent drier (16.67%), on raised bamboo platform (16.73%) and on black polythene sheet (16.70%).

Siddique and Aktar (2011) conducted a study on Changes of Nutritional Value of three Marine Dry Fishes (*Johnius dussumieri, Harpodon nehereus and Lepturacanthus savala*) during storage which showed that the mean percentage of moisture content increased at a significant level with the increasing of storing period, and also revealed that the mean percentage of protein, lipid and carbohydrate of three dry fishes (*Harpodon nehereus, Johnius dussumieri and Lepturacanthus savala* respectively) decreased greatly for 2 years storing period.

Sultana *et al.* (2011) found in a study on dried SIS fish that the maximum calcium content was found as 1.34% in *M. vittatus* and minimum was 0.80% in mixed SIS fishes. Maximum phosphorus content was 2.90% in *C. ranga* and minimum was 1.72% in *C. soborna*. Maximum iron content was found as 45.20 mg/100g in mixed SIS fishes and minimum was found as 16.85 mg/100g in *O. bacaila*. The maximum moisture content was found in *C. ranga* (13.50%) and the minimum in mixed SIS fishes (11.65%). The maximum protein content was recorded in the mixed SIS fishes (72.45%) and the minimum in *C. ranga* (52.65%).

Sulieman and Mustafa (2012) reported that chemical composition of dried fish samples prepared under controlled conditions using various types of fish was estimated during summer and winter. The contents of moisture, protein, ash and fat ranged as 4.3- 5.1, 50.0-52.2, 28.2-32.2, 6.7-8.0 % respectively in summer, while during winter the range was 4.1-5.0, 48.6- 53.0, 28.0-32.9, 7.1-8.8 respectively.

Flowra and Tumpa (2012) found the analytical data on chemical composition of freshwater dried fish showing that the moisture content varied from 12.13*(Puntius ticto)* to 18.18% (*Palaemon* sp.). Ash content was ranged from 10.78% (*Labeo bata*) to 15.67% (*Palaemon* sp.). Protein content of selected dried fishes varied from 28.20% (*Wallago attu*) to 51.19 % (*Palaemon* sp.); and fat content of the dried fishes varied from 5.38% (*Labeo bata)* to 15.86 % (*Wallago attu*).

Flowra *et al.* (2012b) stated that five dried fish samples of *Mystus vittatus*, *Channa punctatus*, *Chanda nama*, *Corica soborna* and *Trichuirus haumela* were selected for study in which moisture content ranged from 14.06% to 24.58%, protein varied between 44.08% to 65.65% (moisture basis) and 53.45% to 76.39% (dry matter basis), lipid content of the selected dried fishes ranged from 1.91% to 17.76% (moisture basis) and 2.31% to 21.54% (dry matter basis). Ash content varied from 9.63% to 22.73% (moisture basis) and 11.21% to 28.15% (dry matter basis).

Flowra (2013) stated that the moisture, ash, protein, phosphorus, calcium and iron of the dried small prawns were 40.04%, 36.77%, 32.80%, 409 mg/100g, 650 mg/100g and 4.80 mg/100g, respectively.

Haque *et al.* (2013) opined that the moisture content of traditional sun dried product of the two traditional sample collected from different area was found in the range of 19.08% to 25.86%. The protein content of traditional sun Bombay duck was found from 41.16% to 54.58%. The range of lipid and ash content was 5.16% to 7.18% and 6.95% to 21.41%, respectively.

Islam *et al.* (2013) conducted an investigation where the moisture content of the dried fishes obtained was in the range of 29.25 – 34.43% and the highest value obtained from *Channa punctatus* (taki) and the lowest from *Amblypharyngodon mola* (mola). On the other hand, protein content was found in the range of 32.02 to 41.38% with the highest value in *Channa punctatus* (taki) and the lowest in *Amblypharyngodon mola* (mola). There was a huge variation in lipid content which is in the range of 3.21 to 14.03% where the highest value in *Amblypharyngodon mola* (mola) and the lowest in *Channa punctatus* (taki). Ash content was in the range of 20.14 -24.40 % with the highest value obtained from *Amblypharyngodon mola* (mola) and the lowest value from *Puntius* sp. (puti).

Farid *et al.* (2014a) found that in fresh-process condition, the values of moisture (%), protein (%), fat (%), ash (%)and pH value were 29.77%, 41.48%, 5.10%, 22.80% and 6.2 in case of sun dried salted Shoal fish and 30.92%, 41.0%, 4.79%, 22.41% and 6.3 respectively in case of sun dried salted and turmeric treated Shoal fish product.

Aberoumand and Karimi (2015) narrated that protein content of *Hamoor* in the oven drying method was higher (%85.66±0.26) than others. The highest fat content (%5.56±0.04) from sun drying was found in *Hamoor* and the lowest (%3.22±0.12) was also observed in solar method for *Govazym* that can to be dependent on lipid oxidation during solar drying. The maximum amount of ash (%12.44±.0.27) was found for *Zeminkan* using the solar method and the lowest (%5.53±0.41) in oven method for *Hamoor*. The moisture content in oven method for fish *Govazym* was the highest (%14.35+0.13), but the lowest amount (%7.96+ 0.19) was found for *Zeminkan.*

Prashun *et al.* (2016) observed that moisture content ranged between 2.77% (*Barilius tileo*) to 8.92% (*Amblypharyngodon mola*). Protein content varied in the range of 28.63% (*Channa punctatus*) to 53.84% (*Chanda ranga*). Lipid content exhibited wide variation in the range of 4.42% (*Barilius tileo*) to 16.52% (*Chanda ranga*). Ash content ranged between 8.96% (*Noemacheilus beavani*) to 30.30% (*Tor putitora*).

Hasan (2016) found that the moisture content of traditional sun dried fishes ranged from 18.32% to 24.63% while in improved method it varied from13.24% to 15.99%.The protein content of traditional sun dried products ranged between 42.08% and 56.46% and it was from 62.01% to 65.02% in improved method. The lipid content of traditional sun dried products was from 5.15% to 7.86%, while in improved method it was in the range of 8.57% to 6.90%. The ash content ranged from15.76% to 24.17% and 11.43% to 13.17% in traditional and improved method respectively.

Abraha *et al.* (2017) noted that the average moisture, crude protein, total lipids, free fatty acid, peroxide, total volatile basic nitrogen and ash content of the solar tent dried products were 7.5 %, 79.32%, 3.74%, 0.50%, 14.66% , 19.65% and 9.90%, and for open sun rack were7.7% 75.32%, 3.20%, 0.54%, 13.66%, 21.80% and 9.20%, respectively.

According to Abbey *et al.* (2017) Tuna trimmings contained 80.71 g/100 g protein, whereas burrito contained 70.40 g/100 g protein. Concentrations of cadmium, arsenic, and mercury varied from <1.00 to 1 mg/kg. Lead was found at 0.04 mg/100 g in tuna frames and gills only. All fish byproducts contained high levels of iron, for example, trimmings contained 16.58 mg/100 g, whereas tuna frames and gills also contained 16.82 and 19.54 mg/100 g, respectively.

Jahan *et al.* (2017) narrated that chemical compositions were found to vary among the species. The protein, lipid, moisture and ash content of five samples ranged from

54.31 (*P. sophore*) to 68.90% (small prawns), 13.33 (*P. sophore*) to 19.33% (*L.rohita*), 11.55 (*L. rohita*) to 13.95% (*H. molitrix*) and 0.16 (small prawns) to 0.44% (*C. mrigala*), respectively. The highest value of carbohydrate was 19.23% (*P. sophore*) and the lowest was 1.75% (*C. mrigala*). The calcium, iron and phosphorus content of the selected species varied from 2.49 (*L. rohita*) to 2.55g/kg (small prawns), 0.043 (*H. molitrix and P. sophore*) to 0.184g/kg (*C. mrigala*) and 0.94 (*L. rohita*) to 1.91g/kg (*P.sophore*) respectively.

2.3. Safety Aspects of Dried Fish

Walker and Donegan (1984) reported that application of insecticides to the fish during drying and storage is highly effective way of combating infestation. To date over 30 active ingredients have been considered for use on fish; but only two have been given recommended maximum residue level (MRL). They are the synergized pyrethrins and pirimiphos-methyl. However, only pirimiphos-methyl gives effective control at concentrations which do not leave residues above the MRL.

Golob *et al.* (1987) demonstrated that *Dermestes* species can be controlled by applying relatively safe pyrethroid and organophosphate insecticides which have been approved by Codex Alimentarius Commission.

Gjerstad (1989) reported that Pirimiphos-methyl is an approved insecticide for application to fish. Naturally occurring pyrethrins are used as dried fish protectants and source plants (*Chrysanthemum cinnerarifolium*) of which are cultivated in Kenya. However, pyrethrins are relatively unstable in day light and are also expensive to produce and market, particularly in countries where the plants cannot be cultivated.

Maruf *et al.* (1990) stated that the major quality control issues encountered in dried salted fish are the variable but often low quality final product, its high salt content, insect infestation and microbial contamination which induce a rapid rate of deterioration during transport, distribution and storage.

Reza *et al.* (2005a) reported that the widespread use of chemicals and insecticides before and after drying and during storage of dried fish products in the coastal region of Bangladesh.

Surendran *et al.* (2006) opined that Pathogenic indicator bacteria such as *E. coli* may not be in large numbers in water or food which cannot be detected by plating methods. In such cases MPN methods are used where large volume of samples can be used for inoculation. MPN method is used to detect the *E. coli* in water or food.

Ploetz *et al.* (2007) observed that in *S. cavalla* Pb concentrations were significantly lower in liver than in muscle samples. In contrast, Cu, Cd, and Zn levels were significantly higher in liver than in muscle samples. There was a significant correlation between mackerel fork length and Cd levels in the liver. Comparisons among metal levels within muscle or liver samples indicated a significant positive correlation between Pb and Cu levels in muscle. The values measured in the current study for the S. cavalla muscle averaged 0.421 lg Pb/g wet weights (1.82 lg Pb/g dry weights).

Yousuf *et al.* (2007) observed that out of ten marine fish most of the fresh fish had higher total and fecal coliform count ranging from 7-210 and 9-93MPN/g respectively and most of which exceeded allowable limit, while in case of dried fish only two dried fish among them were of low quality crossing the threshold limit.

Al- Weher (2008) reported that heavy metal concentrations varied significantly depending on the type of the tissue and fish species. Generally, *Oreochromis aureus* showed the lowest levels of both Cd, and Cu metals in all tissues except gills. The other two fish species, *Cyprinus carpio* and *Clarias lazera,* showed less difference in their heavy metal levels but it was a significant difference ($P< 0.05$). Cd and Cu recorded their lowest levels in muscle and their highest levels in gills. *Cyprinus carpio* fish species showed high values of Cu metal in all organs, except muscles, which might be due to the increase of agricultural influx and some other anthropogenic activity in that area.

Bhuiyan *et al.* (2008) Studies on the conservation of dry fish showed that a mixture of organochlorine (DDT and heptachlor) is used in dry fish in Bangladesh Khan *et al.* (2002) a study conducted on the dry fish consumers of Cox's Bazar show that consumption of 27.09g dried fish per day deposits a 1.3mg DDT in the human body.

Bhuiyan *et al.* (2009) reported that the concentrations of organochlorine insecticides dichlorodiphenyltrichloroethane (DDT) and heptachlor were investigated to estimate the current status of insecticides used in dry fish in different season and different species. Six most popular species of dry fishes namely Bombay duck (Loittya), Ribbon fish (Chhuri), Shrimp (Chingri), Hilsha shed (Ilish), Chinese pomfret (Rupchanda) and Indian salmon (Lakhua) were collected from Asadgonj (whole sell market for dry fish) of Chittagong, Bangladesh at different seasons, six samples at winter season (December) and six same samples at rainy season (July). The range of DDT concentration at winter was found 5.588 ppb to 250.758 ppb and at rainy season the range of concentration was found 11.054 ppb to 1107.427 ppb. The range of heptachlor concentration at winter was found to range from 0.401 to 2.480 ppb and at rainy season was found to range from 1.087 to 37.780 ppb. The concentrations of DDT and heptachlor were much higher in the samples of rainy season than those of the winter.

Malik *et al.* (2010) observed that in a study in lake Bhopal in case of *C· idella*, the highest accumulation of Pb was in gills (1.63 μg g−1*)* followed by liver (1.47 μg g−1*)*, muscles (1.32 μg g−1*)* and kidney (1.03 μg g−1*)*. All the tissues of *L. rohita* accumulated higher evel of Cd than those of *C. idella*. Gills were the target organs in both the species having 0.583 μg g−1 (*L. rohita*) and 0.417 μg g−1 (*C. idella*) due to their close relation with the external environment. The total amount of Cr was higher in *L. rohita* than in *C· idella* . The kidney of *L. rohita* was the major site for Cr accumulation (0.995 μg g−1*)* followed by liver, gills and muscles having mean concentrations of 0.982, 0.422 and 0.218 μg g−1, respectively .

According to FDA (2011) the level of bacterial contamination in fish at the time of capture and the nature of the pathogenic bacteria in fish depends on many factors such as the bacteriological quality of the harvest water, natural conditions when fish is captured, handling practices in different steps of marketing and processing as well as some other factors which influence the quality and safety of the fish.

Sinduja *et al.* (2011) observed that the pathogenic bacteria occurred in different species of seafood's varied in different season. The MPN readings for fecal indicators varied with the seasons. The poor quality of the dried fishes may be due to unhygienic processing, inadequate salting with poor quality salt and lack of air tight packing of the dried fishes.

Olayemi *et al.* (2012) reported that the microbial quality of cat fish (*Clarias gariepinus*) smoked with Nigerian stored products research institute (NSPRI) the total bacteria count was 2.0×10^{-1} cfug and *E. coli, Salmonella* spp. *Pseudomonas* spp. were identified.

Siddique and Aktar (2012) reported that the Samples were collected from six largest dry fish markets (three from Chittagong district and three from Cox's Bazar district) and four types of dry fishes were taken in this study are Ribbon fish (*Lepturacanthus savala*), Sin Croaker (*Johnius dussumieri*), Bombay duck (*Harpodon nehereus*) and Shrimp (*mixed species*). Total numbers of samples were 24 that were analyzed in the laboratory .The results of the study show that the mean concentrations of dichlorodiphenyltrichloroethane (DDT) in the samples of Ribbon fish, Bombay duck and Sincroaker were ranged between 130.85 - 153.47ppb, 125.21 - 181.4ppb and 119.86–208.65ppb respectively. The mean concentrations of dichlorodiphenyltrichloroethane (DDT) were found at a lower amount in shrimp sp. than the other.

Saritha *et al.* (2012) opined that bacterial and fungal colonies were observed in the commercial sun dried seafood and itis having contamination. This may be due to post harvest delay, improper transportation, unhygienic handling and processing during the salting and sun drying process, contaminated working floor, salt and water.

Sivashanthini *et al.* (2012) observed that experimental dried samples showed a count lesser than the standard value and seems to be of good quality for human consumption. While observing the total bacterial count with the time, it was noticed in all samples that in all samples bacterial count increased with time. This was due to the multiplication of bacteria which is already available in the samples and also by contamination from indoor air during storage.

Francis and Kombat (2013) observed that dried and smoked samples obtained from the retail markets recorded total heterotrophic bacteria counts ranging from $1.9 \times 10^4 - 5.9 \times 10^5$ cfu/g, while those obtained from the processing houses ranged from $1.2 \times 10^3 - 6.5 \times 10^4$cfu/g, which were within accepted limits (1×10^6cfu/g) for fish and fish products. There were counts of total coliform bacteria, yeast and moulds and *B. cereus* for the samples, but they were all within accepted limits, except for *B. cereus*, which recorded counts higher than accepted limits (1×10^4cfu/g) for some samples obtained from retail markets in both Tema and Accra.

Immaculate *et al.* (2013) reported that some are pathogenic causing diarrhea and are termed as enteropathogenic *E. coli.* The MPN values for *E. coli* recorded during summer were between MPN 6 - 20/100 ml. In post monsoon season the values varied between 7- 20/100 ml and in monsoon it varied between 15-45/100 ml, and also mentioned that washing the catches in polluted coastal water definitely adds the faecal indicator bacteria. Samples were considered positive when typical colonies appeared on selective plates. *Salmonella* sp. was not detected in the sample collected during summer season. In post monsoon season *Salmonella* contamination was detected in few samples and *Vibrio* was observed in most of the samples.

Mansur (2013) observed that in heavy metal analysis of the sun-dried fish samples of *L. rohita*, the concentration of Arsenic (As) was 0.001 µg/g, Cadmium (Cd) was 0.53µg/g, and Chromium (Cr) was 0.025µg/g. In the sample of sun-dried *C. striatus* As was 0.003 µg/g, Cd was 0.089µg/g and Cr was 0.054 µg/g; while in the sample of sun-dried *W. attu* As was 0.004, Cd 0.097, and Cr 0.068, which were within the acceptable limit for human consumption.

Oku *et al.* (2013) reported that the bacterial counts for fresh fish sample ranged from 4.0×10^{8}-2.30×10^{10}cfu/g and for smoked fish sample ranged from 2.51×10^{8}-3.1×10^{5} cfu/g in Yenagoa metropolis fish market in Nigeria. Twelve bacteria belonged to the genera Bacillus, *Pseudomonas, Proteus, Staphylococcus, Streptococcus, Corynebacterium, Lactobacillus* and *Klebsiella. Bacillus* was the most predominant with a frequency of occurrence of 50 and 58.8% for fresh and smoked fish respectively.

Oladipo and Bankole (2013) state that the fresh *Oreochromis niloticus* showed the highest total bacterial count of 1.8×10^{7} $cfug^{-1}$ and dried *Clarias gariepinus* showed the lowest total bacterial count of 2.0×10^{4} $cfug^{-1}$. Bacterial pathogens were also isolated from fresh and dried samples and the isolates were characterized and identified as *Pseudomonas fluerescens, Pseudomonas chlaroraphis, Pseudomonas putida, Proteus vulgaris, Pseudomonas microbilis* and *Enterobactcr aerogenes.*

Saha and Zaman (2013) evaluated heavy metals in the central market in Rajshahi where in raw fish the concentrations of lead were found from 1.44 (Mozambique tilapia) to 23.993 mg/kg (catla); Cadmium varied from 0.0223 (catla) to 2.11 mg/kg (wallago); Chromium was accumulated from 0.422 (rohu) to 1.225 mg/kg (catla).

Olatunde *et al.* (2013) reported that the Cd content of the fish samples was lower than Fe and Zn with the highest concentration of 0.081±0.004 mg/Kg in smoked *Chrysichthys nigrodigitatus* and Pb was below 0.05 mg/Kg in both fresh and processed samples of all fish species.

Relekar *et al.* (2014) observed that Ribbon fish dried in improved methods were absolutely free from total Coliform organism initially and during entire 120 days storage. While total Coliform organisms could be detected in dried ribbon fish samples collected from local market. It was recorded to be initially and increased during storage.

Yam *et al.* (2015) reported that total count, Yeast and molds, *Staphylococcus aure*us, Enterobacteriaceae, Aerobic spores, Anaerobic spores (*Clostridia* spp), Psychrophilic bacteria, Lactic acid bacteria, Halophilic microorganisms, *Salmonall*a and *Shigella* count of dried fish ranged from 2.2×10^{3} - 3.2×10^{4}, 0 - 6×10^{2}, 0 - 9.8×10^{2}, 0 - 6.7×10^{1}, 3.8×10^{1} - 6×10^{3}, 2×10^{1} - 5×10^{2}, 1×10^{1} - 4×10^{1}, 0 - 4×10^{1}, 4×10^{2} - 3×10^{3}, 0 - 2×10^{1} and 0.4×10^{1} -1.2×10^{2} respectively.

Edosomwan *et al.* (2016) mentioned that the mean levels of cadmium and lead (0.48±0.06 and 1.36±1.13 mg/kg) and (0.62±0.45 and 5.60±7.43 mg/kg) for *Clarias gariepinus* and *Channa obscura* were found to be higher than EU standard. Zinc, Cu, Cr, Fe and Mn had mean values of 2.2±0.85 and 3.18±3.36 mg/kg, 4.12±0.92 and 3.44±0.76 mg/kg, 0.11±0.02 and 0.26±0.3 mg/kg, 25.74±8.06 and 8.55±2.95 mg/kg, 1.8±0.56 and 0.6±0.21 mg/kg for *Clarias gariepinus* and *Channa obscura* respectively. The Estimated Daily Intake calculated were low and Target Hazard Quotient<1 with no risk of non-cancer toxic effect in both species.

Flowra *et al.* (2017) reported that in experimental dried fishes, no pathogenic bacteria were present but *Escherichia coli* and *Klebsiella* sp. were found in *Cirrhinus reba* and *Oxygaster gora* respectively in traditional dried fish.

2.4. Assessment of Shelf-life of Dried Fish

Kimura and Kiamakura (1934) recommended that TVB-N level of 10 mg/100g or less for fresh fish, 20–30mg/100g for beginning of spoilage and over 30mg/100g for spoiled fish.

Frazier and Westhoff (1978) stated that sun drying and smoke drying all associated with increased germicidal action with increasing temperature. He also mentioned that stated that, generally no microbe could grow in dried products with moisture content below 15%.

Troller and Christian (1978) suggested that the microbial stability of dried fish products during processing and storage is depended upon their moisture content.

Stirling (1985) reported that proper preservation prevents the growth of bacteria, fungi and micro-organisms as well as retarding fat oxidation which causes rancidity.

Reilly *et al.* (1985) stated that TVB-N is not reliable as indices of quality, but for most markets, TVBN is a determinant of quality of fresh fish because of its close relationship with sensory score and bacterial counts.

According to **ICMSF (1986),** the international accepted limit of APC of bacteria was for fresh and frozen fish is 1×10^5 cfu/g.

Mansur (1989) determined the total bacterial count of traditionally dried fishes. They found total bacterial count of 1.5×10^6, 1.0×10^5, 1.8×10^5, 1.6×10^5 and 1.6×10^5 cfu/g in *Labeo rohita, Barbus sarana, Channa staritus, Corica soborna* and *Gudusia chapra* respectively.

Prasad and Rao (1994) reported that TVB-N value of 200 mg% is recommended as the threshold value for spoilage of cured fish.

Wallace (2000) mentioned total volatile base nitrogen (TVB-N) is important compound provide a measure of the progress of spoilage that is independent of sensory assessment. Wallace has pointed out that TVB-N is better index of spoilage.

Azam *et al.* (2003) stated that the organoleptic score of fish samples dried in winter was higher (8) than that of summer (6.4) and TVB-N value was 62.23 in winter and 48.28 in summer whereas pH ranged from 7.37 to 8.27 in winter and summer respectively.

Islam *et al.* (2005) reported that the initial TVB-N values were in the range of 4.3-8.2 mg/100g of sample which increased to 38.7-51.31 mg/100g of sample, and initial PO values of the dried fish were in the range of 7.8-9.2 m eq./kg of oil of samples which rose up to 25.7-28.2 m eq./kg of oil after 90 days of storage period.

Surendran *et al.* (2006) opined that in fresh fish, the acceptable limit is $5\text{x}10^5$cfu/g at 37°C but for cooked or dried fish, the permissible limit is 1×10^5cfu/g at 37°C.

Nowsad (2007) described that a limit of 35-40 mg TVB-N per 100g of muscle is considered acceptable for good quality fish, while a value of 50-70mg/100g of muscle can be taken as upper limit beyond which fish is considered inedible. For salted and dried fish the range is 100-200mg/100g beyond which the products are marked unacceptable. He also reported that reported that below a water activity of 0.75 only the halophilic bacteria can survive, whereas at water activities below about 0.63 molds are found to fail to germinate and grow.

Mol *et al.* (2007) reported that 6 log CFU/g is considered to be the microbial limit of acceptability in fish.

Abolagba and Uwagbai (2011) studied on the comparative Analysis of the Microbial of Smoke Dried Fishes (*Ethmalosa fimbriata* and *Pseudotolithus elongatus*) sold in Oba and Koko Markets in Edo and Delta States, Nigeria at Different Seasons. Where the highest bacterial load was 1.1×10^7cfu/g. The bacterial count was significantly higher for the rainy season 1.2×10^7cfu/g than that of the dry season 9.2×10^6cfu/g.

Abowei and Tawari (2011) mentioned that dried fish, particularly sun dried salted fish tends to absorb moisture because, salt is hygroscopic. The uptake of moisture can be checked by, placing dried fish in polyethylene bags. Losses due to the uptake of moisture and consequently microbial damage can be prevented by storage in dry well aerated rooms. If the storage time will be prolonged, the fish can be re-dried in the sun or over afire periodically.

Adelaja *et al.* (2013) conducted an experiment on the comparison of microbial load associated with smoked fish (*Chrysichthys nigrodigitatus*) from Oyanlake and Ogun waterside in Ogun state. The average bacterial counts for all the samples ranged from 3.1×10^6cfu/g to 4.9×10^6 cfu/g in makun market while 6.8×10^6cfu/g to 13.8×10^6cfu/g in lafenwa market has the highest bacteria count. The microorganism isolated and identified in the markets include the *Bacillus* spp. *Micrococcus* sp. *Staphylococcus* *saprophyticus, Escherichia coli* and *Staphylococcus aureus* of which *Staphylococcus saprophytichs escherichia coli* and *Staphylococcus aureus* were high

Chavan *et al.* (2011a) reported During 120 days of storage dried mackerel decreased in quality. This was shown by the increase of biochemical contents as the result of decomposition of lipid and nitrogenous substances and the decrease of sensory scores. FFA contents increased gradually throughout the storage period. FFA value and PV increased slowly with storage period. The TVB-N contents also increased in dried mackerel throughout the storage period. Time series sensory evaluation of the shelf-life revealed that dried mackerel stored at ambient temperature is acceptable to the sensory panel until 154.

Sinduja *et al.* (2011) observed in his research that the microbial quality parameters varied with different seafood's in different seasons and the quality was found to be poor during monsoon season. The bacterial and fungal counts were increased with the increase of humidity of the environment and the moisture content of the dried seafood. The poor quality of the dried fishes may be due to unhygienic processing, inadequate salting with poor quality salt and lack of air tight packing of the dried fishes.

Saritha *et al.* (2012) reported that plate counts with representative sample unit having less than 5×10^5 CFU/g are good quality, while between 5×10^5 - 10^7 marginally accepted quality and plate count at or above 10^7 are considered unacceptable in respect of quality(ICMSF, 1986-44 p). In present study higher bacterial count such as 2.13×10^6 was observed for the sun dried fish *Paraupeneus indicus* which was not above the permissible limits.

Sulieman and Mustafa (2012) reported that Highest total viable count of bacteria (5.1 x 106 cfu/g) was observed in *garmout* and lowest (2.3 x 105 cfu/g) in *kas* during summer, while in winter, the highest total viable count of bacteria were observed in *garmout* fish (2.2×106 cfu/g) and the lowest (8.6×10 3) in *amoroko* fish. The sensory evaluation results of the dried fish samples show that there were insignificant differences in most of the sensory parameters of most of the dried fish samples. However, significant differences were recorded in appearance of dried fish products.

Enamul *et al.* (2013) studied on the comparison of quality of solar tunnel dried bombay duck and silver promfret with traditional sun dried samples. The acrobic plate count of raw fish sample was found 3.36×10^4 cfu/g and 4.30×10^3cfu/g for Bombay duck and Silver pomfretrespectly. In traditional sun dried fish sample the total aerobic bacterial count were in the range 2.88×10^4 cfu/g to 3.37×10^5cfu/g for both Bombay duck and silver pomfret whereas t he solar tunnel dried products bactrial load was found lower in Bombay duck 3.88×10^4cfu/g compared with silver pomfret 4.66×10^4cfu/g. The TVB-N value of solar tunnel dried fish sample was ranging from 22.40 mg/100 gm in silver pomfret and 27.30 mg/100 gm in Bombay duck which were within the range of acceptable limit for dried fish products.

Francis and Kombat (2013) found that traditional samples obtained from the retail markets had total heterotrophic bacteria counts ranging from $1.9 \times 10^4 - 5.9 \times 10^5$ cfu/g, while those obtained from the processing houses ranged from $1.2 \times 10^3 - 6.5 \times 10^4$cfu/g, which were within accepted limits (1×10^6cfu/g) for fish and fish products.

Haque *et al.* (2013) mentioned peroxide value of traditional sun dried fish sample were in the range of 16.88 to 39.22 meq/kg oil, whereas this values were in the range of 18.62 to 21.78 meq/kg oil for solar tunnel dried fish. The values of TVB-N for traditional sun dried products were in the range of 23.11 to 31.05 mg/100gm. The TVB-N value for solar tunnel dried fish sample was ranging from 22.40 mg/100gm in Silver pomfret and 27.30 mg/100gm in Bombay duck. Aerobic Plate Count (APC) of raw Silver pomfret and Bombay duck were in the range of 4.3x103 and 3.36x104cfu/g. Most of the traditional sun dried fish samples were shown to have much higher APC than the raw and solar tunnel dried fish samples and remained within the range of 2.88x104 to 3.37x105 cfu/g.

Immaculate *et al.* (2013) found that during monsoon season, the highest total plate count (TPC) was observed by post monsoon season and summer season. Higher total plate count of 10^6/g or above is considered to be of poor quality for fish. *P. schotaf*, *S. canaliculatus*, *L. parsia*, *S. fimbriata* had high TPC in monsoon which exceeds the permissible limit. The highest TVB-N values were observed in dry fishes during monsoon season and it ranged from 20.28 to 38.26 mg/100 g.

Islam *et al.* (2013) stated that the bacterial load of dried Puti, mola, taki and bele were 2.3×10^5, 2.5×10^5, 3.6×10^7 and 9.4×10^5 cfu/g, respectively.

Kwenin *et al.* (2013) studied on the microbial quality of solar-dried Tilapia (*Oreochromis niloticus*). The total plate count 2.453 log_{10}cfu/g of bacteria in fresh tilapia and 2.322 log^{10}cfu/g of bacteria in dried tilapia and the bacteria that were isolated were *Escherichia coli, Salmonella* spp. and *Staphylococcus aureus*.

Mansur *et al.* (2013) reported the quality and safety aspect of three sun-dried fish. The quality of the sun-dried fish samples were evaluated by examining physical properties, biochemical composition and reconstitution behaviour. The safety aspects of the sun-dried fish samples were studied by the detection of heavy metal total viable bacterial count (TBC) acrobic plate count (APC) and total volatile base-Nitrogen (TVB-N). Where the total bacterial count of the experimental samples ranged from 1.84×10^4 to 5.3×10^6 per g of the dried samples. The total volatile base Nitrogen (TVB-N) content of the dried fish samples ranged from 7.54 to 8.32%.

Olatunde *et al.* (2013) studied on the quality and shelf life assessment of variously processed catfish and Tilapia stared at ambient temperature. The total viable count of bacteria *Chrysichthys nigrodigitatus* was 5.5×10^5cfu/g and Tilapia zillii was 4.0×10^5cfu/g.

Pravakar *et al.* (2013) conducted an experiment on the quality and safety Aspects of Three Sundried Marine Fish Species Chinese Pomfret (*Stromateus chinensis*), Bombay Duck (*Harpodon nehereus*) and Ribbon Fish (*Trichiurus haumela*). The bacterial loads of traditional dried products were 3.8×10^5, 3×10^4 and 2.1×10^5cfu/g respectively. The total volatile base-nitrogen (TVB-N) content of three dried fishes were 17.55±0.88, 11.51±0.86 and 20.37±0.71 mg/100g respectively.

Relekar *et al.* (2014) narrated that gradually increased pattern showed in case of TMA-N, TVB-N and PV in all samples of dried ribbon fish while a variation of salt content was observed due to increased in drying time. Initial total plate count of ribbon fish dried in STD, RBP, BPS and market sample as recorded at $2.96x10^3$, $3.80x10^3$, $1.12x10^4$ and $2.30x10^4$ cfu/g respectively and the same increased to $5x10^3$, $6.30x10^3$.4.80x104 and $5.80x10^4$cfu/g, respectively at the end of 120 days storage. Initial total halophilic count of ribbon fish dried in STD, RBP, BPS and market sample were observed to be $2.40x10^2$, $2.44x10^2$, $5.50x10^3$ and $2.20x10^4$cfu/g respectively. It increased to $4.0x10^2$, $5.10x10^2$, $2.0x10^4$ and $1.4x10^5$ cfu/g, respectively at the end of 120 days storage study.

Farid *et al.* (2014a) found that the pH value of SDS (*sun-dried salted*) and SDS+T (*turmeric treated sun-dried salted*) shoal and fish-product increased significantly ($P<0.05$) with storage period. The pH value of fresh Shoal fish was 6.9 but when salt is added with the fish, pH value decreased due to increase of acidic compound and after that pH value increased in the time interval due to increase of basic compounds. In the study pH values were found to vary from 6.2 (0 day) to 8.3 (165 days) for SDS and 6.3(0 day) to 8.2 (180 days) for SDS+T Shoal.

Farid *et al.* (2014b) narrated that an experiment was carried out to assess the sensory-evaluation and changes in chemical-compositions of sun-dried salted (SDS) Shoal and Taki fish products stored at room temperature. TVB-N, pH and FFA value increased significantly ($p<0.05$) with the time of storage period and between these two salted products, these parameters rapidly increased in SDS Shoal than SDS Taki fish and at the end of 5 months SDS Shoal fish product became spoiled whereas SDS Taki fish still in fresh condition.

Farid *et al.* (2014c) conducted a study where TVB-N values were found to vary from 5.25 (o day) to 31.33 mgN/100 g (165 days) for DS (Dry Salted) and 5.28 (o day) to 34.99 mgN/100 g (165 days) for PS (Pickle Salted) Shoal. Significant statistical differences were found between the initial product and end product ($P<0.05$) after storage period. TVB-N values of the products storage at room temperature showed linearly increasing pattern throughout storage period. The initial organoleptic score of the sensory evaluation of DS and PS shoal was 9. But during storage period this score rapidly decreased and at the end of the storage period, the score was 5 in case of DS (165 days) and PS (150 days) Shoal.

Geetha *et al.* (2014) studied on the some aspects of biochemical and microbial analysis of sun dry fish *Trichiurus lepturus* linnaeus, 1758 from the east cost of Visakhapatnam, India. The bacterial counts ranged from 1.1×10^{4} to 2.5×10^{5}cfu/g. It also showed that of bacterial isolated from the dried fish, staphylococcus was the most predominant organism. The finding of this study showed that microbial load in the sample from villages was high due to clean and safe practices were not strictly followed.

Jinadasa (2014) mentioned that the limits of TVB-N for fishery products in Commission Regulation (EC) NO 2074/2005 ranged between 25 to 35 milligrams of nitrogen/ 100g of fish flesh. The present study revealed that based on that range of total volatile base nitrogen (TVB-N) content, 5% of yellow fin tuna, 8% of sailfish, 12% of sardine, 100% of squids and 42% shrimp were not fit for the human consumption.

Joshi *et al.* (2014) reported that for the fish dried in solar tunnel dryer the initial scores for appearance, colour, taste, odour, texture and overall acceptability were 9, 9.2, 8.8, 9, 9.5 and 9.2, respectively which declined to 8, 8.2, 7.8, 8, 8.5 and 8 respectively at the end of 60 days storage. While drying in raised bamboo platform, the initial scores for appearance, colour, taste, odour, texture and overall acceptability were 8.5, 8.5, 8.4, 8.6, 8.5 and 8.5, respectively which declined to 6.5, 6.6, 6.5, 6.5, 7 and 6.5, respectively in that storage duration.

Mustapha *et al.* (2014) reported that qualitative evaluation of some organoleptic properties of the dried fish samples assessed by means of sense organs of the volunteers showed that fish samples from black stone inserted glass drier had the highest acceptability. The taste, flavor, odor, appearance texture, shelf-life, and palatability were very good. Dried fish samples from the control was least accepted, because, its organoleptic parameters tested were not so good. The volunteers' assessments could be related to the organoleptic properties of dried samples, while the long shelf-life was due to low moisture content of the species after drying.

Pathak *et al.* (2014) conducted an experiment on the effects of drying process on biochemical and microbiological quality of Horse Macherel fish (*Megalaspis cordyla*) where the total plate count of bacteria were ranged from 1.77×10^5 to 1.91×10^5 log cfu/g. TMA-N value was ranged from 7.72 mg% to 8.24 mg% and TVB-N value was ranged from 24.45 mg% to 22.19 mg%.

Sulieman *et al.* (2014) studied on the microbiological characteristics as well as the safety of traditionally fermented fish product kejeik samples which are available in Singah city and Kusti city in Sudan. He reported that the highest count of aerobic bacteria was found in singah jil which was 7.6×10^4cfu/gm. The *Bacillus* isolated from kejeik samples were identified as *Bacillus cereus*, and the counts of it in Kejeik prepared from jil, Nawk and Garmut were 5×10^5, 2.3×10^4 and 1.0×10^4 cfu/gm respectively.

Flowra *et al.* (2017) reported biochemical analysis on 1st, 4th and 6th month reveals that the average highest bacterial load was 7.8×10^5 cfu/g in *Mastacembelus pancalus* on 6th month and lowest APC was 3.6×10^3 cfu/g) in *Channa punctatus* on 4th month whereas in experimental dried fishes the highest Aerobic Plate Count (APC) was 1.42×10^5 cfu/g in *Mastacembelus pancalus* on 1th month and the lowest APC was 5.2×10^2 in *Puntius* sp. on 4th month. From the 1st, 4th and 6th month storage the highest average value of Total Volatile Base Nitrogen (TVBN) was 38.08 mg/100g in *Oxygaster gora* while lowest TVB-N value was 23.13 mg/100g in *Amblypharyngodon mola* in traditional dried fishes whereas the highest TVB-N value was 31.77mg/100g in *Channa punctatus* and lowest TVB-N value was 17.02 mg/100g in *Chanda* sp inexperimental dried fishes. The lowest and highest average values of TMA in traditional dried fishes were 6.91mg/100g and 8.70 mg/100g in *Oxygaster gora* and *Mastacembelus pancalus* respectively.

Abraha *et al.* (2017) reported the average peroxide, total volatile basic nitrogen of the solar tent dried products were 14.66%, 19.65% and for open sun rack were13.66%, 21.80% respectively. Total Plate Count (TPC) of 3.2 ×103cfu/g and 5.7×10^3cfu/g was found within the average level for solar tent and open sun rack driers respectively. The quality of the fish products dried in the solar tent drier was superior compared to that of open sun rack-dried products.

2.5. Acceptability and Promotion of Dried Fish Products in Different Packaging Techniques

Connell (1957) reported that fresh fish species dried in the sun reabsorb water to a comparatively small extent and, when reconstituted, are very tough, almost rubber-like, fibrous, compact and dry in mouth. During drying and also during subsequent storage, certain irreversible changes occur which affect the texture and the reconstitute properties of the products.

Farber (1991) narrated that nitrogen is an inert tasteless gas, which displays little or no antimicrobial activity on its own. Because of its low solubility in water and fat, the presence of N_2 in a MAP food can prevent pack collapse that can occur when high concentrations of CO_2 are used. In addition, N_2, by displacing O_2 in the pack, can delay oxidative rancidity and also inhibit the growth of aerobic micro organisms. Nitrogen can also indirectly influence the micro organisms in perishable foods by retarding the growth of aerobic spoilage organisms. The second role of nitrogen in MAP is to act as a filler gas and keeps flexible packages from developing a vacuum.

Clucas and Ward (1996) mentioned that smoking or salted dried fish is vulnerable to oxidation and bacterial infection. Therefore, packaging used for dried fish products must be impermeable to water vapor, oxygen and flavor volatiles. For cured or dried fish vacuum packaging is suitable as long as proper controls are maintained during storage. Vacuum packaging consists of the removal of air from pack, which requires high gas barrier packaging films such as polyvinylidene chloride or polyester. In vacuum packaging, removal of oxygen reduces aerobic bacterial spoilage, fat oxidation and rancidity, and extends the shelf-life of the pack. However, in some cases anaerobic conditions can lead to the growth of *C. botulinum.* Besides, when labeling is done for a packaged product which is not destined for export, the producer must comply with the regulations prevailing in the country of origin. If the product is to be exported, the labeling must comply not only with basic export requirements, but also with the labeling laws of the importing country.

Clucas and Ward (1996) reported that in case of dried fish, *Dermestes* sp. can cause very heavy damage, particularly if the products are stored for long periods because then several generations can develop. Infestation by beetles is a real problem in India, especially during storage of large quantities of dried fish in go-downs, and in stores where fish are awaiting export. The presence of salt in fish can also reduce the damage caused by *Dermestes.* Another, common problem associated with dried fish is the development of rancidity caused by the oxidation of fish lipids. Rancid fish have characteristics flavors and odors which may be unpleasant and lead to consumer rejection. Rancidity is accelerated by exposure to air, so adequate packaging is necessary to overcome rancidity and beetles infestations problems.

Regenstein JM and Regenstein CE (1997) reported that packaging fish in gas is a challenge. However, fish packages have been more successful particularly when carbon dioxide or other highly soluble gas is used. The addition of nitrogen, a totally inert gas, to flesh foods produces the same anaerobic atmosphere obtained with the vacuum packaging. Again, depending on the bacteria present and their metabolism on the particular product, this effect may or may not be desirable. In some cases, particularly in fish and chicken, this absence of air leads to a preferential growth of anaerobic bacteria that often produce the most obnoxious odor. Moreover, some facts needs to be considered when dealing with MAP are- the better the initial quality, the better the product, and the impact of temperature-abuse on the packaged product.

Balachandran (2001) mentioned that moisture and oxygen are principally responsible for spoilage of dried fish. Access to oxygen will accelerate oxidative rancidity and the resultant flavor changes. Therefore, the packaging materials selected for dried fish should serve the purposes like- prevent gain or loss of moisture, be impermeable to volatile flavoring compounds, have good barrier properties against oxygen, be resistant to mechanical abrasion and puncture, be impermeable to light and finally should be inert in nature.

Sivertsvik *et al.* (2002) stated that over the last years, modified atmosphere packaging (MAP) has received increasing attention as a method of food preservation. MAP is defined as the enclosure of food products in gas–barrier materials, in which the gaseous environment is been changed.

Sen (2005) Modified Atmosphere Packaging (MAP) is done through the replacement of air in a pack by a different mixture of gases where the portion of each component is fixed when the mixture is introduced and no further control is exercised during storage. Longer shelf-life achieved attained through MAP expands the market potential and gives more time for sale. In addition, a consumer benefits with a dry high quality ready-to-cook or ready-to-serve fish product. However, any extension of storage life attributable to MAP may be lost if safeguards of chill storage are ignored. To derive maximum benefit from MAP, packs should be stored at a temperature as near to 0°C as possible and never above 5 °C.

Islam MT *et al.* (2005) conducted a study to observe the shelf-life of three sun dried fish products under different density of polythene packaging materials and plastic jar. The quality of three fish products were found good for 90 days by determining organoleptic and biochemical aspects. It was found that the color of solar tunnel dried Bombay duck, Silver jaw and Ribbon fish became whitish to light brown color with little difference among the species. Texture was firm and flexible and odor was very natural in all the samples. No insect infestation was observed. After 60 days of storage, the color of the products started to change from light brown to brown and exhibited with slight rancid odor, fibrous and soft texture.

Nowsad (2007) described that organoleptic or sensory method is generally used to assess the degree of freshness or quality attributes based on some orgaoleptic characteristics such as odor, colour, consistency of flesh, general appearance, eyes, slime etc. Usually, these characteristics are judged by panel members and the changes in quality of fish are assessed with certain interval during storage. In such sensory methods, subjective judgments are made by individuals. In this sensory assessment method, numerical scoring or ranking systems have been developed in order to evaluate the judgment. Instrumental or laboratory based methods are lengthy and time consuming. Consumers cannot wait for more than a day to buy fresh fish or other fishery products. However, the results of sensory evaluation seem to be more accurate.

Ravi-Sankar *et al.* (2008) MAP of fish products may pose a potential danger. The major concern in relation to safety of MAP fish products is the potential for growth and toxin production by *C. botulinum.*

Payap (2011) reported MAP is used to extend the shelf-life of perishable foods. Elevated CO_2 and modified atmospheres reduce microbial growth and enzymatic activity. Moreover, low temperature in combination with MAP and other treatment was the promising means to prevent or retard the growth of pathogen. However, proper sanitation and processing practices that prevent and reduce contamination on fish are needed.

Farid *et al.* (2014b) observed that there were significant changes in color, flavor, taste and texture in two dried fish such as Shoal and Taki which were subjected to Sun-dried-salting methods. With the lapse of storage time, both products produce a salty taste with different degree of smell, color and texture. He also opined that the changes of color from whitish to brownish may be due to lipid oxidation during storage period. This is quite clear from the present study that lipid oxidation presence of oxygen was more prominent than that of products stored in room temperature. In the study there was no fungal attack in sun-dried salted Shoal and Taki fish products. According to the panel's evaluation, the sensory properties of sun-dried salted (SDS) Shoal and Taki fish-products were in acceptable condition throughout storage period. The initial score of the sensory evaluation of SDS Shoal and Taki was 9. But during storage period this score rapidly decreased and at the end of the storage period, the score was 5 in case of Shoal (5^{th} month) and Taki (8^{th} month).

Ochieng (2015) conducted research on shelf life changes of the vacuum-packaged solar rack dried sardines during chill storage were he examined that at ambient stored Gunny bag and polythene air packaged samples had a shelf life of 14 and 30 days, respectively; chilled polythene air-packaged 45 days and chilled vacuum-packaged 90 days. Thus, vacuum-packaging in combination with chilling was found to be the best in delaying spoilage and thereby significantly extending dried fish products shelf life in tropical environments.

Folorunsho *et al.* (2015) narrated that three composite packaging materials; Paper-Polyethylene (PaPe,), Polyethylene-Paper (PePa) Polyethylene-Paper-Polyethylene (PePaPe) were developed for packaging of dried fish samples with Polyethylene used as control. Polyethylene-Paper-Polyethylene packages maintained better quality attributes of stored the general acceptance of the fish on the scale of nine for the composite materials ranged between 4.78 and 6.96 while that of control was 4.6. PePaPe performed better in resistance to moisture and oil migration. It also shows high protein retention and better sensory attributes. The packaging material maintained the quality attributes of stored catfish. It was effective in extending the shelf life of smoked fish.

Hasan *et al.* (2016) found ın organoleptic assessment that the color of all the traditional sun dried fishes differed from silvery to whitish depending on the species. Slightly sour or sour odor was observed in some of the products. Infestations by flies and insects were also observed in the dried fish products. The eggs and larvae of the insects were seen on the different parts of the dried fishes. The fungal growth was also observed in some of the dried fishes. Although the broken pieces were not commonly found in all the species, but few were observed in some of the products. On the other hand, the improved sun dried fishes were noticed to vary from whitish to yellowish color with slight variation. Texture was firm and flexible in all of these species. Insect infestation or broken pieces was not seen in these products during the storage period of experimental products.

2.6. Status of Awareness of Dried Fish Processors

Doe (1977) and Ahmed (1978) described salt treatment reduces the rate of blowfly infestation. Damage due to insects can be heavy where salt is not used and drying condition is poor, as much as 25-30% under very humid conditions in Bangladesh.

Walker and Greeley (1990) said not a single pesticide is safe for health, but its extent of adversity depends on the nature of treatment, period of application and the dosages. The effects are depended on the vaporization, dissolution and persistence characteristics of the pesticides. Generally organochlorine compounds are worst: persistency ranges from 7 to 15 years in nature.

Horner (1992) described sometimes brining is done for flavouring and glazing or for delaying spoilage. Sprinkling of grain salt is practiced as pre-processing of fish. The preservation is accomplished by other techniques, such as drying or smoking. Fish are treated for several minutes in 3-5% brine. Brining/sprinkling of grain salt is also done for long periods for preservation with salt prior to drying.

Niwa (1992) stated that People prefer the products that contain little or no salt. But in cloudy or rainy days fish require to be treated with 15-30% of salt. Small amount of salt makes the texture compact, reduces the effects of contamination, destroys some of the bacteria and helps release water from the fish so that drying becomes easier and quick. Salt also increases the weight of the dried products. Salt has a good access to the protein of fresh fish.

Bonell (1994) recommended that to reduce bacterial processes immediately on dead fish, it should be beheaded, gutted, washed and chilled to inhibit unfavorable enzymatic and microbial processes.

Gopakumar (1994) reported that packaging materials that were used for dried fish in India were coconut leaf baskets, bamboo baskets, or gunny bags. But none of them were found as an efficient packaging material for dried fish.

Clucas and Ward (1996) stated that Salting is a process where the common salt, sodium chloride, is used as a preservative which penetrates the tissues, thus checks the bacterial growth and inactivates the enzymes. The solar salts used in fish preservation are of many different grades and types depending upon the purity. High quality salt contains 99.9% NaCl; low quality salt may contain only 80% NaCl. Besides, water, sand, clay, dust and calcium and magnesium salts are the major impurities of solar salts. He also mentioned that there must be an adequate supply of good quality water for both processing and cleaning. The water should be free from suspended material, chemical pollutants, and above all those bacteria which indicate fecal pollution.

Sarker and Khan (1997) stated uncontrolled application of such unapproved insecticides in dried fish could be having serious consequences for consumers and dry fish processors/ laborers. The people involved in applying these potentially harmful chemicals are not equipped with protective clothing and other safety measures and do not understand the lethal effects of the chemicals they are using. The long term adverse impacts on their health are unknown but could be serious and deadly.

Neuschler (1998) found that in Bangladesh, a large quantity of dried fish is spoiled each year due to lack of proper drying, preservation and storage facilities particularly during the glut season.

Balachandra (2001) stated that *E. coli* faecal *Streptococcus* and *Staphylococcus*, *Salmonella*, *Shigella*, and *Vibrio cholera* are primarily found in intestine of man. The occurrence of Coliforms, E. coli and faecal Staphylococcus is indicative of faecal contamination. While the presence of few numbers of these bacteria is permissible in fish and fishery products, presence of some other like Salmonella is not permitted to any extent. Maintenance of proper hygiene and sanitation and disinfection of handling and processing equipments and places etc. are the preventative measures to be adopted.

Montville *et al.* (2001) narrated that during handling and preparation, bacteria are transferred from contaminated hands of food workers to food and subsequently to other surface. Poor hygiene, particularly deficient or absence of hand washing has been identified as the causative mode of transmission. Proper hand washing and disinfection has been recognized as one of the most effective measures to control the spread of pathogen.

Khan *et al.* (2002b) mentioned use of unsafe pesticides and their excessive dosages in dried fish cause serious health troubles to the consumers.

Bremner (2002) stated physical effects include loss due to birds, dogs etc., and the effects of beetle attack or fly larvae infestation. Preventative measures include proper packaging; use mechanical or enclosed dryers; salting and good house-keeping practices such as proper disposal of offal to minimise fly breeding. Chemical spoilage includes contamination from fuel oil. Insecticides etc which can be minimised by proper food-handling practices, hygiene and effective packaging. Microbial spoilage takes place due to effects of microorganisms such as coliforms and other pathogenic bacteria. Keeping handling equipments clean, using clean ice and salts and having good hygiene practices contribute to lowering of microbial load. Salting with proper amount helps to reduce the incidence of fly larvae infestation.

Clucas (2003) reported adult blowflies are attracted to the fish both visually, by the large amount of fish spread out to dry, and chemically, by the odours or volatile compounds released from the fish.

Azam *et al.* (2003) found that lack of proper amenities like proper handling during loading, unloading time and exposure of the fish to the high environmental temperature, lack of knowledge about scientific and hygienic methods of handling from the time to catch until it is processed into finished products contribute significantly to the loss of quality.

Reza *et al.* (2005b) stated that traditional drying of marine fishes of Bangladesh was carried out in sandy beaches of Cox's Bazar region where fishes were contaminated with sand, blowflies and microorganisms.

Nowsad (2005) stated that improper handling and processing that lead to spoilage as low quality products impose threats to the public health country wide. Large quantities of dried fishes are spoiled each year due to lack of proper drying, preservation and storage facilities, particularly during the dull or bad season.

Nowsad (2005a) mentioned that concentration of 6-10% salt in fish tissue can prevent the action of most spoilage bacteria. Very often salting is done in combination with sun-drying and smoking for variety of fish species.

Akinola *et al.* (2006) reported that despite the rudimentary nature of process of traditional methods, lack of control of over drying rate sometimes result to over-drying or under-drying, exposure of the fish to dust, dirt, insects infestation and contaminant such as flies, yet this method still remains predominant in Nigeria.

Nowsad (2007) mentioned that in glut period the fish only those are spoilt and partially spoilt and cannot be sold in the fresh wet fish market are employed for sun-drying. The raw fish is contaminated by pathogens or the other bacteria during gutting and dressing by unclean knife, container or tools. The fish are not washed before drying in most of the cases. Finally, the drying procedures do not comply with the regulations regarding public health and sanitation. He also stated that generally 5-7% salt is sprinkled over the unwashed and unsorted fish. Mixing time varies from 2-5 hours. Salt, however, hardens the fish and makes handling easier. If it rains for days together drying takes place by the action of wind only. In such operation, heavy salt treatment (10~20%) is prerequisite for maintaining the quality of the products. Physical assessment shows that the quality of salt used is very poor. Usually, low-cost unpurified solar salts, grayish to blackish in color, contaminated with mud, sand and other adulterants are used.

Nowsad (2007) mentioned that to establish the rights of fish-drying activities and dried fish business, small entrepreneurs had formed a cooperative society in 1995 named "Nazirartek Fish Traders Multipurpose Cooperative Society" initially having 104 members, and it consists of 250 members now.

Samad *et al.* (2009) observed in a study at *Chalan beel* area that washing of raw fish was done by beel water and poor quality salts were used for salting (rate: 50-250 g / kg fish) in most cases. Majority drying were done by spreading raw fishes on bamboo rack without any protection measure from insects or dust. Finally, maximum dried products were carried to Sayadpur (Nilphamary) dry fish wholesale market by the dry fish farmers or other middlemen.

Sugathapala *et al.* (2012) The quality of the final product could be improved by educating fishermen to use clean water and quality salt for processing and by introducing simple equipment such as solar or artificial dryers for drying, thus preventing contamination and dependence on weather conditions.

Flowra *et al.* (2012a) reported in a study on traditional fish drying in Sirajganj area of *Chalan beel* area that, the rate of mixing salt in the study area was found as 1kg salt for 13 kg of raw fish. At normal weather, the drying duration was recorded as 2-6 days depending on the size of the raw fishes. Plastic, jute sack and sometimes bamboo baskets were used for packaging purpose. All the dried fish products of the study area were carried to the Sayadpur dry fish wholesale market in Nilphamary district. Among the dried fish processors 44.19% were full time processors and48.57% were belonging to age group above 40 years. 85% dried fish processors were Muslim and the remaining 15%were Hindus. Literacy level was found poor (37.15% from primary education to higher secondary). 12.50% dried fish processors were found landless whereas majority (30%) were found with 0.001-0.668 ha land. Average monthly income was found to vary from Tk. 2000 to Tk. 15000.

Flowra *et al.* (2013) found in a study at Singra of *Chalan beel* that, when infestation took place, the dried product was treated with various pesticides by some processors. However, most of the dry fish processors also used salts to protect their products from insects. Some fish traders use additional salt to increase the weight of dry fish but the quality of salts is very poor and not proper ratio of salt and fish is maintained. In the study area the dry fish processors or laborers have no knowledge on pesticide action, dose limit and residual effects. And also recommended that to keep the dried product free from the insect infestation proper training should be necessary for improvement of traditional sun-drying, good handling, sanitation and public health.

Francis and Kombat (2013) observed that contamination of samples was attributed to poor processing, packaging, transporting and storage conditions used by the fish traders. Continuous education of fish traders to use general good management practices and regular hygiene inspections by the standards authority is however required to improve the microbial quality of processed fish in local retail markets.

Immaculate *et al.* (2013) found that the poor quality of dried fishes were mainly due to unhygienic processing and drying methods, inadequate salting, use of spoiled fish for processing and lack of air tight packing of the dried fishes.

Nowsad (2014) observed that the people engaged in sun drying do not have minimum knowledge on public health and sanitation. They carry pathogen, dust and dirt.

Indiscriminate use of insecticide in dried fish is a serious threat to public health and its residual effect is very dangerous. He also mentioned that the finished products are not properly packaged and remain exposed to air which cause oxidative rancidity and contamination leading deterioration of quality.

Sabiha *et al.* (2015) observed that in Tuker bazar areas few processors were found to use agricultural pesticides for long time storage and prevention of blowflies' infestation in dried fish. Most citable of them were DDT and Nogos. Both are banned for use in Bangladesh. As the processors have no knowledge about the action of pesticides, dose limit and residual effects of chemicals, they used 5-6 drops of pesticides in 80 litre of water during washing of fresh fish. The use of pesticide sharply reduced in sunny days. He also observed that after drying of fishes, packaging was done by plastic and jute made bags. Sometimes bamboo baskets (which are called 'tukri' locally) were also used for this purpose. Storage of dried fish was found to be performed in the 'Dangari' generally made of tin, wood and bamboo splits and used for temporary storage of dried fish until marketing. With respect to monthly income, she also reported that the seasonal income of drying enterprise might vary from area to area. This variation was due to the raw material availability, processing cost and demand of the consumers, and among them 26.31%, 28.94% and 44.73% fish drier enterprises were found in the income range of Tk. 10000-75000, Tk. 100000-500000 and Tk. 600000-1000000 respectively.

Adeyeye *et al.* (2015) reported that among smoked dried fish processors very few processors (1%) use disinfectants for their processing facilities and environment. The facilities used for processing are not properly cleaned always and this is a threat to food safety. The cleaning system in the entire processing site is not adequate. The materials provided for cleaning food are not adequately and suitably designed and this can easily harbor pathogenic organisms. Moreover, there was no adequate supply of potable water for cleaning, and no facilities of available for maintaining desired standard of personal hygiene.

DoF (2015) reported according to fishery product control protocol, every person involved in fish products handling and processing have to maintain high degree of personal cleanliness, wear clean and protective clothing, and observe adequate hygienic behavior. Infrastructure facilities and equipments should be of such quality that it can significantly minimize cross contamination. Adequate toilets are to be available with effective drainage system and there is to be a sufficient supply of potable water for cleaning raw fish and equipments. Waste products or by-products are to be eliminated in a hygienic and environment friendly way. And fish products at all stages of production, processing and distribution, are to be protected against any contamination likely to render the product unfit for human consumption.

Chapter 3

Improved Fish Drying Techniques

Chapter 3

Improved Fish Drying Techniques

3.1. Introduction

Mitigation of post harvest loss of fish in developing countries can remarkably contributes to ensuring food security. A significant percentage of these losses are related to improper drying of foodstuffs such as fish (Komolafe *et al.*, 2011). Fish being an extremely perishable food become inedible within twelve hours at tropical temperature. Spoilage commences as soon as the fish dies and processing with good preservation therefore needs to be done quickly to thwart the growth of spoilage bacteria (Clucas, 1975). However, simple preservation technique like removal of water through drying can slow down or stop microbiological and autolytic activity.

The purpose of the preservation is to reduce the moisture content of the fish because micro-organisms that are responsible for spoilage cannot survive without moisture. Some of the preservation methods include cooking (boiling and frying), salting, smoking and drying collectively known as curing (lowering the moisture content) and fermentation (lowering the p^H) (Peter and Ann, 1992). Drying is a dual process of heat and mass transfer of moisture from the interior of the product to the surrounding air (Hall, 1980). Drying basically involves the abstraction of moisture from the product by heating and the passage of air mass around it to carry away the released vapor (Mclean, 1980). The fundamental essence of drying is to minimize the moisture content of the product to such a level that inhibits deterioration within a certain period of time normally regarded as the "safe period" (Ekechuckwu, 1987).

There are basically two traditional methods of drying fish namely: open air/sun drying and smoking. Open air/sun drying is probably the oldest method used for preserving fish in the developing countries, because it is the simplest and cheapest methods of conserving fishes. This method involves spreading of products on the ground or on rack in the open air/sun during non-monsoon period. However, the methods of drying fish selected by a processor depend on fish species and consumer demand. Generally, fresh fish is exposed in sunshine often in tropical dry areas where moisture is low and the heat energy from the sun is extremely impressive, which results in loss of water from the fish before spoilage sets in (Aberoumand and Karimi, 2015). However, open sun drying is known to suffer many problems which often results in poor quality dried products.

Open sun drying is the most widespread method of drying fish at the artisanal fishermen level, but the method is likely to contaminate fish by exposing it to dust, excreta from birds and animals, and subject it to spoil by birds, blowflies' larvae and animals. Open sun drying process is sluggish in nature and in most cases, the fish dries to unstable moisture content that is conducive for micro-organisms proliferation, which makes the fish a source of food poisoning (Suzuki *et al.*, 1988). Therefore, alternative affordable, simple, hygienic, environmentally friendly methods must be developed and adopted for producing quality and safe dried products.

In order to get hygienic and safe dried fish, sun drying approaches can be improved considerably by raising the fish off the ground on wooden frames with racks. This allows air to circulate beneath the fish, thus facilitating drying from both sides. It also breaks the cycle of insect reproduction. Drying fish on racks with mosquito netting ensures that fish is more exposed to air and wind and it becomes less prone to contamination and insect infestation (Waterman, 1976). The introduction of a solar tent dryer for collecting and concentrating solar radiation to obtain elevated temperature during drying is considered as a good alternative to open sun drying of fish (Doe, *et al.*, 1977). It works on the principle that a black surface absorbs solar energy effectively and increases temperature to such level suitable for drying (Balachandran, 2001). It also acts as a greenhouse type solar dryer consisting of a frame constructed from iron bar, plastic cover sheet, plastic mesh, insulation, black painted aluminum sheet, air inlet and outlet channels showing enhanced thermal efficiency and drying rate (Koyuncu and Sessiz, 2002).

In traditional fish drying method fish is processed improperly in unhygienic conditions maintaining poor sanitation. It is usually done on open elevated rack or on the net spread on the ground, which makes the dried products vulnerable to contamination in many ways rendering it even unfit for consumption. Besides, due to lack of hygienic practices and covering of net in traditional drying, the products become more likely to be infested by blow fly and beetles which results in quality deterioration and quantitative loss. To prevent such infestation processors sometimes often apply of hazardous pesticide posing threat to public health. Therefore, improvement of fish drying method is important for maintaining the desired standard as well as for ensuring quality and safety of dried products both for domestic and export market.

To improve drying techniques some research works have been conducted to develop different models of dryers (Ahmed *et al.*, 1979; Islam, 1982, Bala and Hossain 1998b, Bala and Mondol 2001, Mazid and Kamal 2005, Islam *et al.*, 2006, Komolafe, *et al.*, 2011, Relekar *et al.*, 2014). However, any research, particularly focusing on improving traditional fish drying techniques prevailing in *Chalan Beel* area, has not been attempted yet. Regarding all researches, this study is an endeavor to introduce low-cost techniques made from locally available materials with simple approaches viz. perforated black and white color coated tin sheet, black polythene sheet, hanging box; all of which were covered with net and another technique designed using tunnel shaped frame covered with transparent polythene sheet which works as a solar dryer and capable of producing hygienic and safe dried fish preventing from insect infestation and other contaminations.

3.2. Materials and Methods

3.2.1. Installation and operation of dryers

Six different models of low-cost drying techniques were set up by using natural resources like sunlight and air at Moishluti drying site under Tarash Upazila of Sirajganj district which is a popular area for fish drying. This area has been selected as it is surrounded by vast area of *Chalan Beel* and located near big wholesale market which is a good source of quality and available raw fishes. All the drying techniques employed in the study were installed and managed with the cooperation of local dried fish processors.

3.2.2. Fabrication of different dryers

Six different dryers with various shapes and sizes including traditional one were constructed from inexpensive and locally available materials with the aim of evaluating performance and effectiveness of these improved low-cost drying techniques. The dryers used were as follows:

3.2.2.1. Black Polythene Sheet (BPS)

Black polythene surface absorbs heat efficiently producing elevated temperature and keeps it for longer duration which results in reduction in drying time. BPS dryer of dimensions 10×5ft with 20kg drying capacity was fabricated using black polythene sheet spread on raised bamboo-split rack (locally known as *Bana*) with 2 feet raised bamboo made platform and covered with a tunnel shaped frame which was covered with net to prevent insect infestation. The products to be dried were spread on black polythene sheet within dryer with a view to obtaining more heat.

3.2.2.2. White Tin Sheet (WTS)

Perforated white tin sheet allows for easy draining of any surplus water in fish at the beginning of drying and also facilitates movement of air both under and over the fish, thus allowing drying from upper and lower surface. WTS dryer having dimension of 8×4 ft with 15kg fish drying capacity designed using white perforated tin sheet which facilitates air circulation and dribbling of excess water of fish, were placed on 2 feet raised bamboo made platform and covered with net.

3.2.2.3. Black Tin Sheet (BTS)

Black perforated tin sheet absorbs heat from sunlight more efficiently maintaining sufficient temperature for fish drying which enhance drying performance with comparatively less time duration. It also facilitates ventilation from both upper and lower surface of tin sheet and trickling down of excess water. BTS method with 8×4 ft dimension having drying capacity of 15kg fish was constructed using perforated black tin sheet as black color is known to be capable of promoting solar heat absorption. It was also installed on raised bamboo made platform and covered with net which prevents insects from entering.

3.2.2.4. White Plastic Tunnel (WPT)

The covering transparent plastic sheet is tilted like a roof having tunnel shape to allow sufficient sunlight. WPT is a simplified design of solar dryer fabricated with the dimension of 10×5 feet having drying capacity of 20kg fish. In case of white plastic tunnel in the present study, whole tunnel was made with clear plastic supported by tunnel-shaped bamboo frame so that plastic does not sag, which was south facing to harness maximum air flow and placed on bamboo-split rack having 0.5 cm gap within each split and both opening of tunnel had net covering to prevent insect entry and allow moist air out of the drying chamber. A piece of black tin (3×2 feet) sheet was placed in the tunnel which serves as solar air heater through enhancing absorption of solar radiation and supplementing heat generation within the tunnel, thus promoting the natural convective flow of hot air over the products to be dried.

3.2.2.5. Hanging Box (HB)

Hanging box method is suitable for drying of comparatively bigger fish and it is also useful for the drying yard where drying place is inadequate. Hanging box with dimension of 3×2.5×2 ft and drying capacity of 8kg was made with thin iron rod and hanged on bamboo bar. Box was covered with net in order to resist insect attack having opening facility from one side. The products to be dried particularly big fish are placed on hanging bar and small fish are spread on the floor of the box.

3.2.2.6. Traditional Method (TRD)

Traditional method with 15×5 feet dimensions lacks net covering which makes the products to be dried susceptible to insect infestation. It was prepared with bamboo-split rack (locally known as *Bana*) which is capable of facilitating better air circulation from both sides and is placed on 2.5ft raised platform of bamboo frame having around 30kg drying capacity (Plates:3.1a-f).

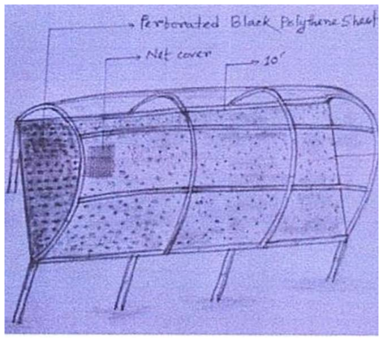


Plate 3.1a Schematic diagram of BPS method

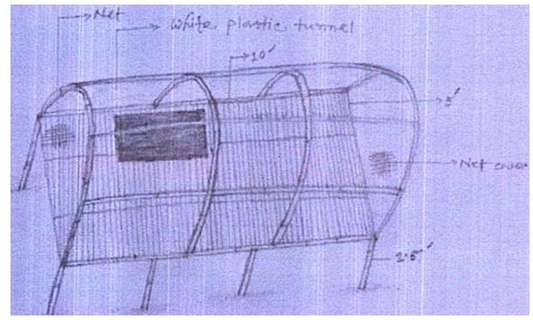


Plate 3.1b Schematic diagram of WPT method

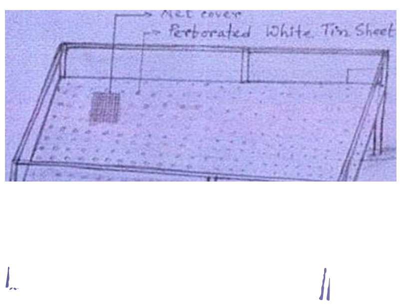


Plate 3.1c Schematic diagram of WTS method

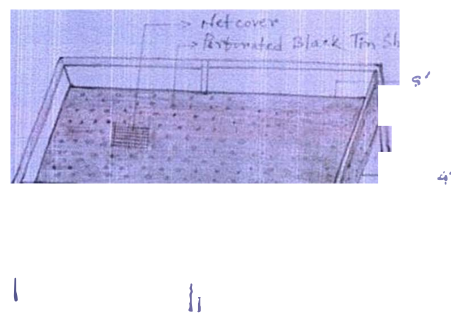


Plate 3.1d Schematic diagram of BTS method

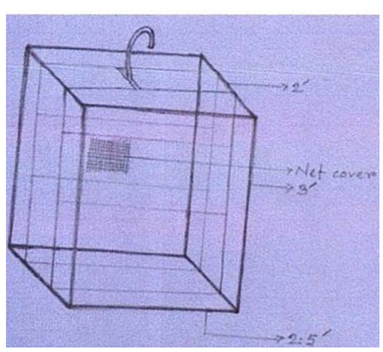


Plate 3.1e Schematic diagram of HB method

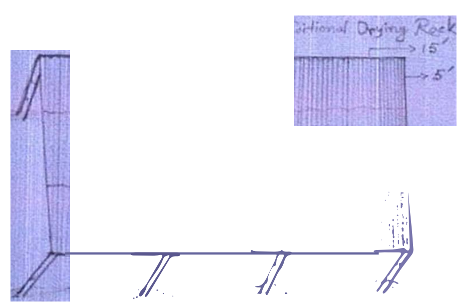


Plate 3.1f Schematic diagram of TRD method

Plate 3.1(a-f) Schematics diagram of different fish dryers

3.2.3. Raw fish preparation (sample) and method of drying

During the glut period, particularly in winter substantial amount of fishes are harvested in *Chalan Beel* area. As a result, price relatively decreases and various species captured from the *beel* are subjected to traditional sun drying. Along with few big species, different small species are abundantly dried in the study area (Table 3.1). However, among these common fish species, five most popular fishes (*Channa punctatus*, *Mystus vittatus*, *Channa striatus*, *Wallago attu* and *Puntius* sp.) having considerable acceptance with respect to commercial significance and taste were selected as sample species. The samples were purchased from adjacent wholesale fish market of the *beel* and washed, weighed, eviscerated and cleaned thoroughly using tube well water, and then 5% salt was mixed and kept overnight, then again washed to remove extra salt and finally spread for drying using different drying techniques (Figure 3.1, Plate: 3.2 and 3.3) Drying was conducted from 09:00 am to 5:00 pm and at night the fishes were kept in plastic bag until next morning and then again left for drying which continued till desired moisture content is obtained.

Table 3.1 Commonly used fish species for drying in *Chalan Beel* area

Sl. No.	Scientific name	Bangla name
	Puntius sp.	Punti
2	*Macrobrachium* sp.	Icha or small rawn
3	*Colisa* sp.	Colisa
4	*Chanda* sp.	Chanda
5	*Hypophthalmichthys molitrix*	Silver c
6	*Amblypharyngodon mola*	Moa
7	*Esomus danricus*	Darkina
8	*Channa punctata*	Taki
9	*Lepidocephalus guntea*	Gutum
	Xenentodon cancila	Kakila
11	*Mystus vittatus*	Ten a
12	*Mastacembelus pancalus*	Guchi
13	*Glossogobius giuris*	Bele
14	*Wallago attu*	Boal
15	*Channa striatus*	Shol
16	*Cirrhina reba*	Raikhor
17	*Gudusia cha ra*	Khoira/Cha ila

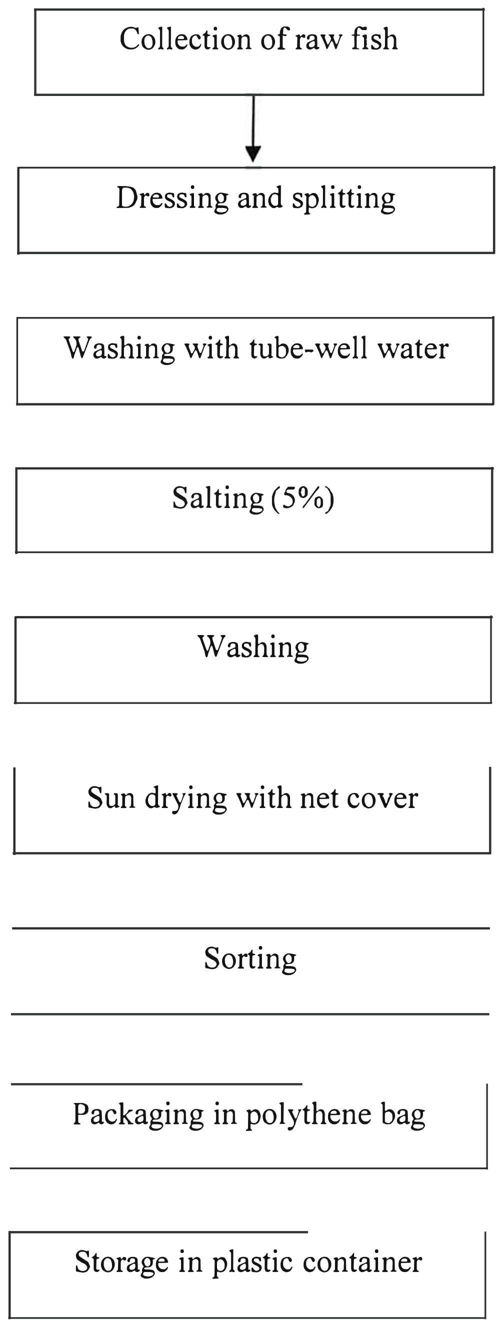


Fig. 3.1 Flow chart of experimental fish sample preparation

Plate 3.2 Fresh fish for dressing

Plate 3.3 Fish samples mixed with salt

3.2.4. Measurements

3.2.4.1. Temperature and relative humidity

After installation of improved drying approaches, studies were conducted to evaluate the ranges of ambient temperature and humidity inside the dryer and in atmosphere (Plate 3.4). These parameters were recorded at various locations within dryers and atmosphere using 'Hanna thermo-hygrometer' (Model: HI 9564) along with thermometers from 09:00 am to 5:00 pm during 1st to 15th January, 2017.

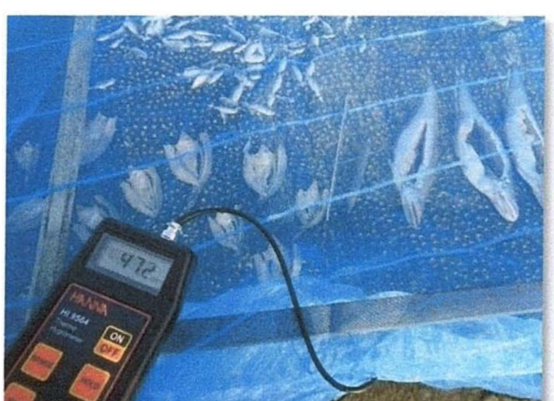


Plate 3.4 Measuring Temperature and Humidity

Plate 3.5 Weighing dried fish to measure moisture loss

3.2.4.2. Moisture content

Moisture and ultimately weight losses from each fish sample and dryer were measured daily using digital weighing balance until moisture content reached around 15% (wet basis) through moisture losses (Plate 3.5) The percentage moisture content of fish samples dried in different techniques was calculated according to Ranganna (1986) as follows:

$$\% \text{ Moisture Content, weight basis (w.b.)} = \frac{(W1-W2)}{W1} \times 100$$

Where, W1= wt of sample before drying

W2 = wt of sample after drying

3.2.4.3. Drying Rate (D.R.)

Drying rate is a fundamental parameter in the evaluation drying process. To calculate D.R. weight loss and required drying time were critically observed. Drying rate of fish sample was determined using the following formula (Sengar, 2009) with simple modificaton.

$$\text{Drying rate (D.R.)} = \frac{\Delta W}{\Delta T}$$

Where, ΔW= weight loss (g) in required time interval

ΔT= difference in time reading (h)

3.2.5. Statistical Analysis

The obtained results and differences between the mean values regarding drying time, temperature and relative humidity among the dryers were analyzed statistically using the one-way ANOVA (Analysis of Variance) and post-hoc analysis, the Tukey's test, when there were significant differences among the groups. All analyses were performed by SPSS (Statistical Package for Social Science) version 20 and the significance was defined at $P< 0.05$.

3.3. Results and observations

3.3.1. Temperature and Relative humidity

After installation of dryers, temperature and relative humidity in atmosphere and inside the dryer were recorded from 9 am to 5 pm. Drying times for different drying techniques were also measured. In traditional (TRD) or open method, normal atmospheric temperature or ambient temperature was recorded in the range of 22-29 °C from 9am to 5pm while in that time atmospheric ambient relative humidity varied in the range of 45-75%. With respect to different methods, temperature ranged as 23.5-34.5, 24.3-34, 24.8-37, 32-48.7 and 21.5-28 °C in BPS, WTS, BTS, WPT and HB method respectively, and relative humidity was recorded as 35-56.9, 39-56, 31-54.5, 18-53 and 48-78 % in BPS, WTS, BTS, WPT and HB method respectively (Appendix Table-IV and V). Maximum temperature was recorded around 49 °C in WPT at noon (1.00 pm) and minimum of 21.5 °C in HB at afternoon (5.00 pm) while maximum relative humidity was found 78% in HB at 5.00 pm and minimum of 18% in WPT at 1.00 pm. As a natural phenomenon in respect of all drying methods, temperature was considerably lower in the morning and afternoon with appreciably higher humidity whereas with the highest increase of temperature during 1.00-3.00 pm humidity normally decline at lower level (Fig.3.2 and 3.3).

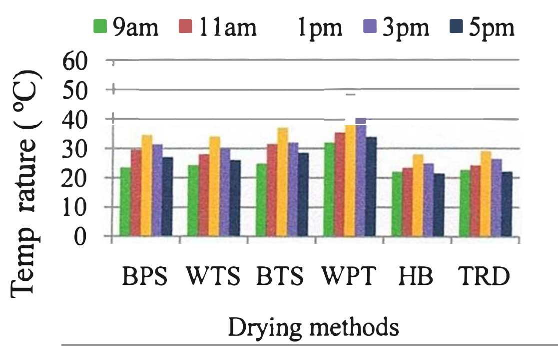


Fig.3.2 Method wise temperature at different time

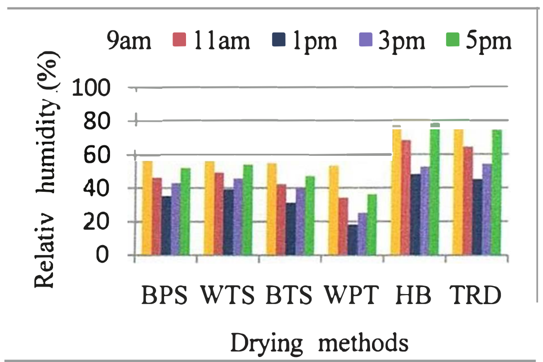


Fig.3.3 Method wise relative humidity at different time

In the present study, maximum average drying temperature obtained from WPT was 38.14 °C followed by BTS (30.76 °C), BPS (29.2 °C), WTS (28.46 °C), TRD (24.88 °C) and the lowest was 23.98 °C in HB method, while in case of relative humidity maximum average value was obtained as 64% in HB method followed by TRD (62.40%), WTS (48.70%) BPS (46.58%), BTS (42.90%) and WPT (33.20%) (Table 3.2 and Fig.3.4).

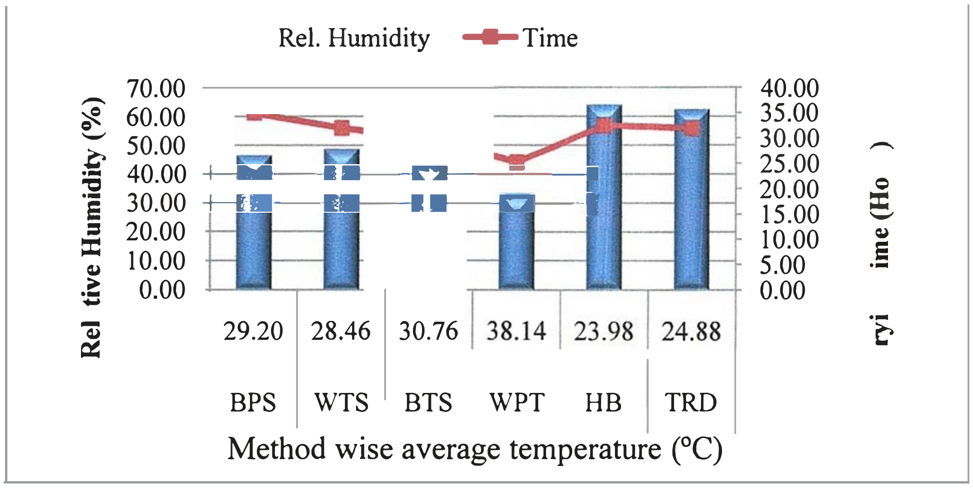


Fig.3.4 Method wise temperature, Relative humidity and drying time

Table 3.2 Method wise temperature, Relative humidity and drying time

Drying Method	Relative Humidity (%)	Temperature (°C)	Time (Hour)
BPS	46.58±1.82^{c}	29.20±1.35^{c}	35.00±7.34^{a}
WTS	48.70±1.33^{b}	28.46±1.15^{c}	32.00±6.44^{ab}
BTS	42.90±1.88^{d}	30.76±1.26^{b}	30.00±6.47^{ab}
WPT	33.20±1.24^{e}	38.14±1.10^{a}	25.20±5.86^{b}
HB	64.00±1.32^{a}	23.98±1.34^{d}	32.60±6.75^{ab}
TRD	62.40±1.29^{a}	24.88±1.14^{d}	32.00±9.09^{ab}

Values are shown as mean ± standard deviation; superscripts in each column with different letters are significantly different ($P< 0.05$).

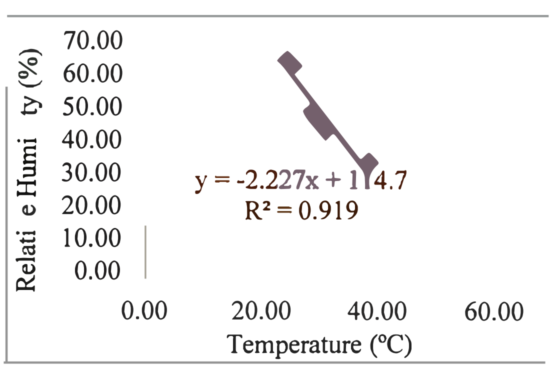


Fig.3.5 Relation between Humidity and Temperature

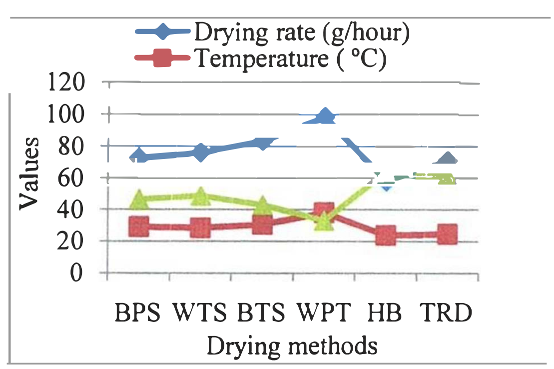


Fig.3.6 Method wise temperature, humidity and drying rate

With respect to all methods, average temperature variation was found to exist within small range throughout the drying period. Results indicate that negative correlation was noticed between temperature and relative humidity (Fig.3.5). As a result, inverse relationship was found as to where temperature increased with increasing intensity of sunshine, humidity became more likely to decrease and vice-versa as well.

3.3.2. Drying time

Drying time varied according to different drying methods. It is also likely to be influenced by airflow, temperature and humidity. Findings indicate that minimum average time required was 25.20h in WPT followed by BTS (30h), WTS (32h) and TRD (32h), HB (32.60h) and BPS (35h). (Table-3.2 and Fig. 3.4) Drying time exhibited negative correlation with temperature, however, with respect to relative humidity it was positively correlated (Fig.3.7 and 3.8).

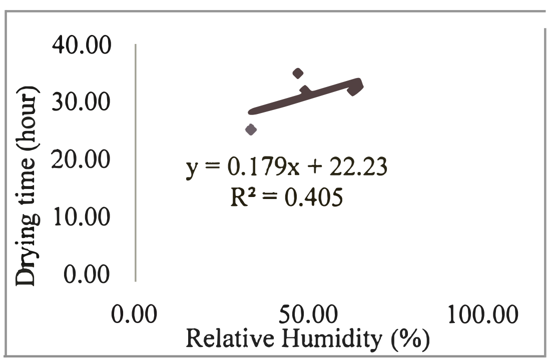


Fig.3.7 Relation between drying time and relative humidity

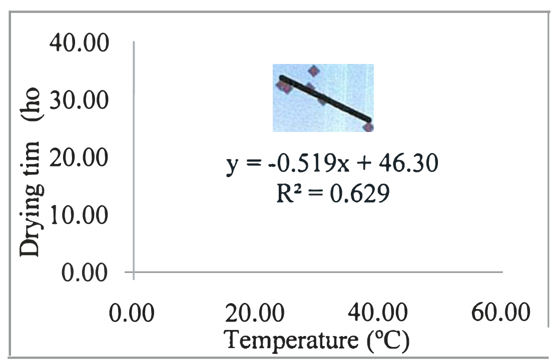
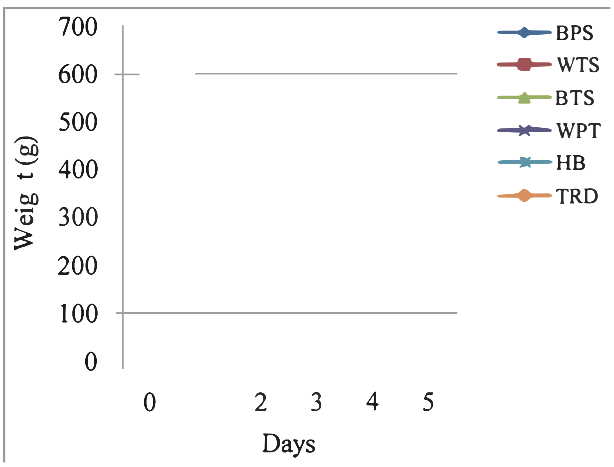


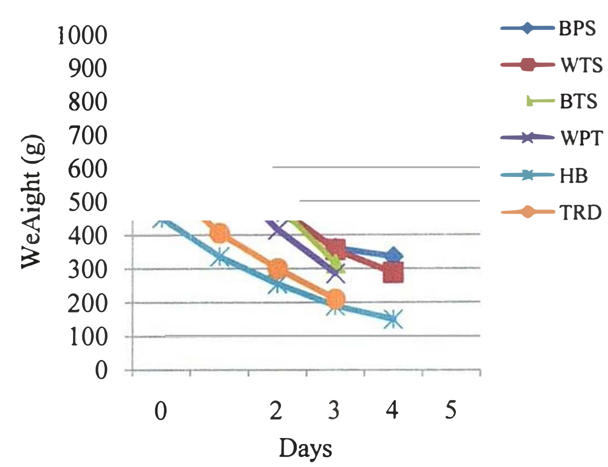
Fig.3.8 Relation between drying time and temperature

3.3.3. Drying rate and percent moisture loss

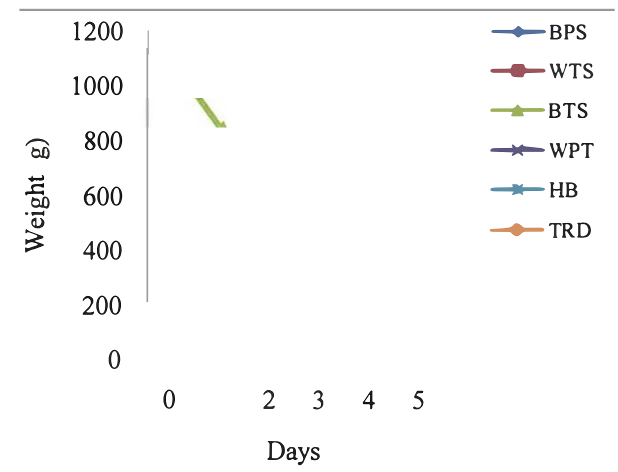
In case of all dryers fish showed greater moisture loss at initial stage of drying than that of the following stage (Fig. 3.9 a-e). As a result, loss of moisture content declined comparatively at higher rate in 1st and 2nd days and highest drying rate was observed as 98.61 g/hour in WPT followed by BTS (83.5 g/hour), WTS (76.03 g/hour), TRD (71.10 g/hour), BPS (72.71 g/hour) and HB (58.13 g/hour). Drying rate was likely to increase as air temperature became higher; however, in case of relative humidity it showed inverse relation (Fig.3.6).



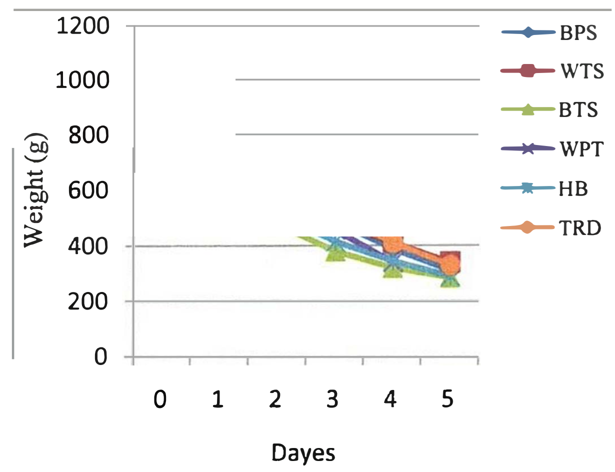
a. *Puntius sp.*



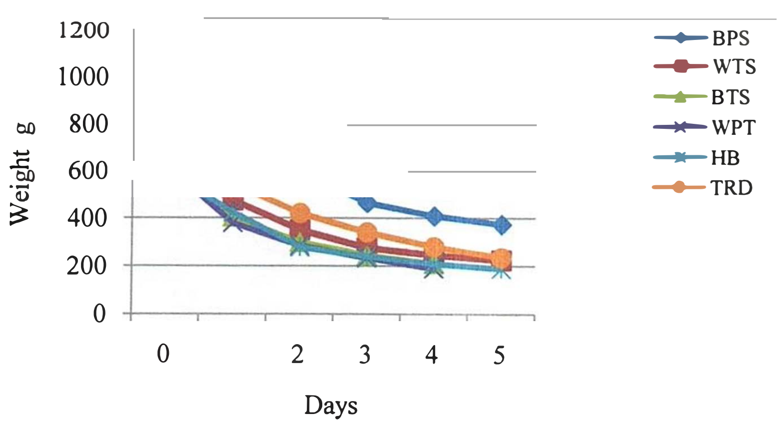
b. *Mystus vittaus*



c. *Channa striatus*



d. *Wallago attu*



e. *Channa punctatus*

Fig.3.9 (a-e) Variations in weight loss (moisture reduction) of different species in different dryers

Percent moisture loss was found to vary within small range in respect of different dryers and fish species. Results show that moisture loss was in the range of 69.40 (WPT) to 64.10% (BPS), 66.67 (WPT) to 58.38% (BPS), 66.24 (WPT) to 63.90% (BTS), 63.40 (WTS) to 67.00% (TRD), 65.23(WPT) to 60.10% (WTS) in *C. punctatus*, *M. vittatus*, *C. striatus*, *W. attu* and *Puntius sp.* respectively (Table 3.3).

Table 3.3 Percentage of moisture losses in different species dried with different methods

Drying method	*C. punctatus*	*M. vittatus*	*C. striatus*	*W. attu*	*Puntius* sp.
BPS	64.10	58.38	64.40	63.70	65.00
WTS	64.30	65.42	64.20	63.40	60.10
BTS	64.71	65.38	63.90	63.70	65.04
WPT	69.40	66.67	66.24	66.20	65.23
HB	68.10	66.60	65.20	63.50	62.00
TRD	66.40	63.20	65.40	67.00	64.62

Plate 3.6a Fish Drying in BPS

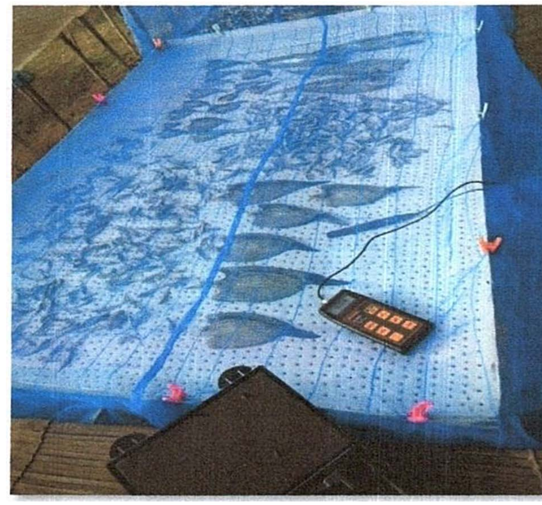


Plate 3.6b Fish Drying in WTS

Plate 3.6c Fish Drying in WPT

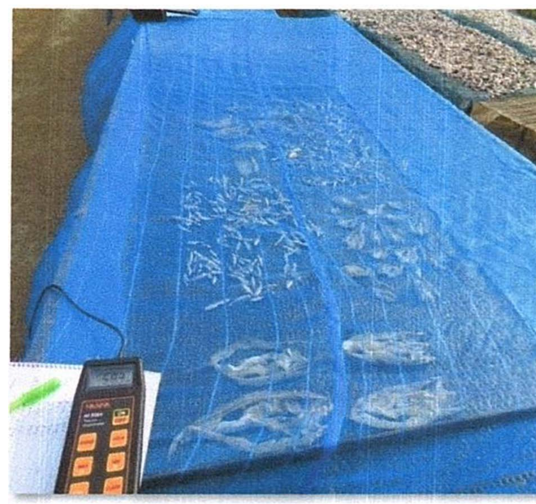


Plate 3.6d Fish Drying in BTS

Plate 3.6e Fish Drying in HB

Plate 3.6f Fish Drying in TRD

Plate 3.6 (a-f) Fish drying in different dryers

3.3.4. Cost comparison of different dryers

The total costs of different dryers were figured out to be 2500, 2212, 2212, 2930, 800 and 2100 BDT for BPS, WTS, BTS, WPT, HB and TRD respectively (Table 3.4). Except TRD and HB, the costs of all the dryers were not that much different if performance is taken into account. Though expense for WPT turned out to be slightly higher, its advantages could outweigh this drawback as far as efficiency and product quality are concerned. It was evident that products from WPT were less likely to be affected by dust and dirt and were also less susceptible to invasion by microbes and intrusion by liquid such as rain.

Table 3.4 Installation costs for different dryers

Drying method	Particulars of Costs	Specification	Quantity	Rate (BDT/Unit)	Costs (BDT)
BPS	Bamboo rack, tunnel and frame	10×5ft	Bamboo-3pcs	300/pcs	900
	Net	15×5ft	2pcs	8/ft	240
	Black polythene	0.05mm (10×5ft)	1pcs	16/ft	160
	Labor	-	4days	300/day	1200
	Total				**2500**
WTS	Bamboo frame	8×4ft	Bamboo-1pcs	300/pcs	300
	White coated tin sheet	0.4mm (8×4ft)	1pcs	35/sq.ft	1120
	Net	12×4ft	2pcs	8/ft	192
	Labor	-	2day	300/day	600
	Total				**2212**
BTS	Bamboo frame	8×4ft	Bamboo-1pcs	300	300
	Black coated tin sheet	0.4mm (8×4ft)	1pcs	35/sq.ft	1120
	Net	12×4ft	2pcs	8/ft	192
	Labor	-	2day	300/day	600
	Total				**2212**
WPT	Bamboo rack, tunnel and frame	10×5ft	Bamboo-3pcs	300/pcs	900
	Net	15×5ft	1pcs	8/ft	120
	White polythene	0.2mm (10×8ft)	1pcs	50/ft	500
	Labor	-	4days	300/day	1200
	Black tin sheet	3×2ft	1pcs	35/sq.ft	210
	Total				**2930**
HB	Iron bar	6mm (3×2.5×2 ft)	4kg	45/kg	180
	Net	-	15ft	8/ft	120
	Labor	-	1.5day	300/day	450
	Paint	-	Small pack	1pcs	50
	Total				**800**
TRD	Bamboo rack and frame	15×5ft	Bamboo-3pcs	300/pcs	900
	Labor	-	4days	300/day	1200
	Total				**2100**
Miscellaneous cost for each method		-	-	200	

3.4. Discussion

Six different dryers used in this work were found to dry the fish samples effectively by removing water showing various levels of performance and effectiveness in terms of producing heat and humidity along with efficiency of drying time reduction.

As far as temperature is concerned, with respect to different methods maximum value was found in WPT (48.7°C) at noon (1.00 pm) and minimum was in HB (21.5°C) in afternoon (5.00 pm). In case of efficiency with regards to temperature rise, WPT gave best performance and it is evident from highest average temperature which was statistically significant ($P<0.05$) as compared to other methods; and this may be attributed to efficient solar absorbance by black tin sheet contributing to elevate temperature and retain heat within tunnel for longer duration. However, WPT had shortcomings because of having insufficient insulation. As a result, internal heat of drying chamber was likely to get lost through the space between bamboo-splits of drying rack. In terms of other methods, BTS showed slightly better results with significantly different mean temperature. However, in BPS and WTS, and in TRD and HB obtained average temperature was not significantly different ($P>0.05$). Inability to effectively absorb and retain the solar temperature as the heat tends to diffuse out of net-covering may account for this shortfall. Similar findings were reported by Islam *et al.* (2006) who observed that drying temperature in three dryers varied from 31-57°C, and lower temperature was found as 29-33.5°C at 8.30-9.30am and 38-40°C at 15.30-15.30pm which reached around 50°C at 12.30pm. Sengar *et al.* (2009) also found maximum temperature at 1 pm as 57°C while 38.7°C at 10:54 am while maximum ambient temperature was 35.3°C at 12:54 pm. Kituu *et. al.* (2010) reported that in case of solar dryer, between 10 am and 4 pm, the temperatures were relatively high, and the relative humidity was low, which enhanced the drying process. Mujumdar (2006) stated that the hotter the air temperature the faster the moisture evaporation. In a study Chavan (2011a) observed that the optimum points for all sensory attributes evaluated were at the temperatures ranging from 40-46°C for 18-29h and also found that variation of the drying air temperature can save the dried fish from partial cooking due to excess temperature. Reza (2009) observed the dried products produced at 45-50 °C were found with organoleptically excellent quality.

Kamruzzaman (1992) also reported the higher temperature above 60 ℃ is likely to result in case hardening which takes place due to cooking of muscle and formation of gel which becomes elastic and hard after drying. In a research on hot-plate regulated drying tunnel, Rahman *et al.* (2012) found useful to install a table fan in order to blow hot air and maintain the desirable range (40-55 °C) of temperature.

With respect to relative humidity, maximum relative humidity was found in HB (78%) at 5.00 pm and minimum in WPT (18%) at 1.00 pm. Since relative humidity is regarded as one of the key factors for drying and it is well-known that the lower the relative humidity, the greater is the absorbing capacity of drying air.

In respect of humidity reduction efficiency, WPT showed best results compared to other methods which is statistically significant ($P<0.05$). The lowest mean humidity recorded in the dryer lends credence to this fact. Other methods like BTS, BPS and WTS produced significantly different results from each other. However, the obtained average humidity in HB and TRD method did exhibit significant difference ($P>0.05$). From this study, as a natural phenomenon, negative correlation was noticed between temperature and relative humidity. Present findings agree with results reported by Islam *et al*. (2006) where the relative humidity gradually decreased with the increasing temperature. Mujumdar and Devahastin (2000) reported that as temperature drops relative humidity rises resulting in the decreases of the moisture absorption potential of air. Present results corroborates the findings reported by Abraha *et al.* (2017) where the highest mean temperature in the solar tent dryer was found to be 45 ℃ with relative humidity 42%, in open sun rack drying was 35°C with relative humidity 47%. In this study relative humidity was considerably lower inside the WPT compared to outside or ambient relative humidity which accelerated drying rate. Sengar *et al.* (2009) found humidity to vary from 32.2 to 22.3% inside the solar dryer whereas outside humidity ranged from 43.02 to 29.35%. In a similar study Sultana *et al.* (2009) revealed that outside the tunnel temperature and humidity varied from 28-32.83 ℃ and 58.83-74% respectively, while it ranged from 31.33-47.78 ℃ and 33.83-68% inside the tunnel respectively, which is in agreement with the present study. Present findings are also identical to the observations reported by Hubackova *et al.* (2014).

In respect of different drying methods, studied fish samples required various time duration for drying which ranged from 25.2 hours (WPT) to 35.0 hours (BPS). Less drying time in WPT may be due to sufficient circulation of hot air within plastic tunnel facilitated by black tin sheet which elevated internal temperature and reduced drying time, whereas in case of BPS more time required because of accumulation of water on polythene and less air flow beneath the fish resulting in poor evaporation. The study reveals that positive correlation was found between drying time and relative humidity. Analysis also shows the drying methods have significant ($P<0.05$) impact on mean drying time in case of WPT and BPS; however, with respect to other methods there was no statistically significant difference. Present results resemble the findings regarding drying period observed by Islam *et al.* (2006) in which required drying time ranged from 28-38 hours and 24-34 hours while temperature varied in the range of 34-51 °C and 37-57 °C respectively. Curran and Trim (1985) observed that 3 days were required for fish drying in solar tent dryer. They also reported that fish dried on sloping rack-required 4 days for reducing moisture up to 20%. Relekar *et al.* (2014) found that solar tent dryer needed less time than other methods such as raised bamboo platform and black polythene sheet. Chavan (2011a) opined the initial moisture content of *Rastrilliger kangurta* was 71.60% which reached 16.09% within 27 h of drying time in the solar tunnel drying method due to higher air temperature compared to open sun drying, while open sun drying took 44 h to reach the same moisture content. Sultana *et al.* (2009) also mentioned that the reason of longer drying period is likely to be associated with thickness of skin and muscle as well as with fat content which obstruct the drying process.

Highest drying rate was observed in WPT (97.62 g/hour) while lowest was 59.51 g/hour (HB). This may be due to higher temperature and less humidity in WPT which resulted in greater amount of moisture reduction within less drying period. On the other hand, box required longer time as it was completely covered with net which slightly obstructed air flow allowing less moist air out of the box causing lower drying rate. In all drying methods, drying rate increased with the rise of temperature and declined when relative humidity was high. As shown in the figure weight loss pattern or drying rate was higher at initial stage because in this phase moisture gets removed directly from the fish surface and as time progresses rate of weight loss or drying gradually gets slower because in the following drying phase moisture from deeper portion of muscle are brought to the surface and then evaporated. This observations match with findings revealed by Sultana *et al.* (2009). Present study also supports the findings of Chavan *et al.* (2011a) who reported that in solar tunnel dryer, drying rate of mackerel is higher as compared to open sun drying method. He also opined relative humidity of drying air is a critical factor for controlling the drying rate of the product. Obtained results are akin to those observed by Joshi *et al*. (2014) which revealed that drying rate initially depends upon the rate of airflow over the fish as the moisture evaporates from the surface and is removed by the air. Waterman (1976) also stated that drying rate is dependent upon air temperature.

Percent moisture losses were found to vary in respect of different drying methods and fish species. Highest percent moisture loss was found in *C. punctatus* (69.40%) and the lowest was in *M.vittatus* (58.38%) for WPT and BPS respectively. This may be attributed to elevated temperature and reduced humidity obtained in WPT which contributes to removing water effectively resulting in significant loss of weight and moisture. Similar findings were observed by Mustapha *et al.* (2014) in which percent moisture loss was between 64.45 and 69.73. Clucas (1982) and Frazier & Westhoff (2008) reported that a fish with percentage moisture loss of between 66 and 75 will not be infected by microbes and the shelf-life of the fish will be increased.

Chapter 4

Nutritional Composition of Dried Fish

Chapter 4

Nutritional Composition of Dried Fish

4.1. Introduction

Huge number of people, notably children and women from under developed countries are more likely to suffer from nutritional deficiency. Severe nutritional deficiency often puts their lives at risk of different fatal diseases or even leads to death. In fact, malnutrition is still the number one killer and cause of suffering on earth, causing more deaths than HIV/AIDS, warfare, genocide, terrorism, particularly with developing countries; 23 children currently die every minute from under-nutrition (FAO, 2016). Similarly, in Bangladesh a large number of people suffer from malnutrition mostly caused by the deficiency of protein and different minerals or vitamins in the diet. However, a well balanced diet that includes a variety of fish or fish products can promote the growth of and development of population suffering from malnutrition. The importance of fish as a food is primarily because of its unmatched nutritional qualities. Throughout the world, it is well accepted that fishes are good sources of animal protein and other elements for the maintenance of healthy body (Andrew, 2001). In fish, the major constituents are water, protein, lipids and ash. Fish flesh contains up to 15-25% protein, 80% water, 1-2% mineral matter (CSIR, 1962). Nutritional studies have revealed that fish protein ranks in the same class as chicken protein and is superior to beef protein, milk and egg albumin in some respects (Srivastava, 1959).

In recent years, the importance of aquatic food from nutritional point of view has increased substantially because of scientifically recognized beneficial effects of eating aquatic food, fats and oils. Besides, fish and fish product contribute immensely to the supply of both macro and micronutrients in our diet. Dried fish is also an important source of high-quality and highly digestible protein and serves as a vital means of supplying essential minerals (Nettleton, 1992; Basu and Gupta, 2004).

Generally, dried fish represents a low cost source of high quality protein (Souness, 1988). Laureti (1998) reported that dried fishes often are an alternative to fresh fishes in many places of the world. In Bangladesh it serves as a good sources low-cost dietary protein and is used as a substitute for fresh fish at the time of scarcity of fish (Khan and Khan, 2002). In addition, in the perspective of the country like Bangladesh, dried fish is an important and potential source of protein, and it is relished by many people of coastal, central and North-eastern districts (Nowsad, 2007).

Almost all species of fish, freshwater or marine, can be sun dried and the nutritional quality remains intact even after drying. Dried fish retains higher nutritional value compared to raw fish. Dried fish and prawns are rich sources of protein, lipid, calcium, iron and zinc (Azam, 2002) However, the composition and total contents of nutrients tend to vary considerably from species to species in respect of age, sex, environment, feeding, time of the year and physical activity (Huss, 1995). Moreover, Balachandran (2001) also mentioned that large variations occurring in the proximate composition are influenced by several factors like the species of the fish, diet, fishing grounds, season, sex and sexual maturity, and spawning. Besides, the amounts of protein, fat and ash of ten fish species were different in respect of drying methods and varieties (Azam and Ali, 2004). Proximate composition is an important aspect of fish quality and influences both the keeping quality and technological characteristics of the fish. The proximate composition is an important aspect of fish and it influences the process of maintaining quality and characteristics of the fish products. The key chemical components of fish muscle namely moisture, protein, lipid and ash have the significant impact on the nutritive value, the functional properties, the sensory quality and the storage stability of fish meat. The other constituents, i.e. vitamins and minerals, exist in minor quantity also play notable role in biochemical process taking place in tissue during post-mortem (Flowra and Tumpa, 2012). As dried fish is one of the most valuable resources of high grade protein available to the man, the knowledge of its composition is essential for ensuring fullest use of it.

Now-a-days, being more conscious with respect to health and food, consumers are much aware of what they are consuming and whether the food ensures required nutrition. As a result, in recent years, the buyers have been showing concern about the quality and nutritional status of the dried fish products. Similar concern has also been voiced elsewhere in Bangladesh (Siddique and Aktar, 2011).

The study on proximate composition and minerals will provide information regarding nutritional quality of dried fish which has important implications for ensuring proper utilization of this product. Although a good number of works on biochemical composition of fishes has been conducted by many researchers viz. Rubbi *et al.* (1987), Mollah *et al.* (1998, 2000), Nurullah *et al.* (2003), Islam *et al.* (2003), Sultana *et al.* (2008) Flowra and Tumpa (2012), Flowra *et al.* (2012), Islam *et al.* (2013) Prashun *et al.*(2016), Abraha *et al.*(2017) etc. However, comparative study on freshwater fishes with regards to proximate composition along with minerals is scant in Bangladesh. Moreover, little attention has been paid on the study regarding mineral contents of dried fish. Therefore, the present study was intended with a view to making an assessment and comparison between traditionally and experimentally produced freshwater dried fish in terms of proximate composition and contents of some important minerals.

4.2. Materials and Methods

4.2.1. Sample collection and processing

Traditional Samples of five dried fish species (*Channa punctatus*, *Mystus vittatus*, *Channa striatus*, *Wallago attu* and *Puntius* sp.) were purchased from adjacent fish drying sites of *Chalan beel* area namely Tarash, Atrai and Vangura. In this sample, *Mystus vittatus*and *Puntius* sp. were not dressed and washed and other species such as *Channa punctatus, Channa striatus* and *Wallago attu* under went dressing and washing in the prevailing unhygienic environment of drying yard. In case of experimental sample, raw fish were bought from the nearby market of the water body, and all species of which were subjected to washing under tube well water and sun drying in hygienic environment after removal of non-edible parts like viscera, gills and scales. The dried samples were ground with a mortar and passed through a suitable mesh sieve. The fine powder sample was preserved in clean and dry plastic bottles for analysis. Finally, prepared samples were brought to the BCSIR (Bangladesh Council for Scientific and Industrial Research) laboratory, Rajshahi, Bangladesh and the Central science Laboratory, University of Rajshahi, Bangladesh for determination of biochemical composition and minerals.

4.2.2 Estimation of moisture

Moisture content was determined by standard International Union of Pure and Applied Chemistry (IUPAC) method (1977). 2 gm of sample were weighed in a porcelain crucible (which was previously cleaned, heated to 105^0 C cooled and weighed). The crucible with the sample was heated in an electrical oven for about six hours at 105^0C. It was then cooled in desiccators and weighed again. The percentage moisture in the oil cakes was calculated from the formula

Moisture = 100× (W1- W2)/W2 %,

Where,

W1 = Original weight of the sample before drying

W2 = Weight of the sample after drying.

4.2.3. Estimation of protein

Protein in the sample was determined by Micro-Kjeldahl distillation method (AOAC 1990). The samples were digested by heating with concentrated sulphuric acid (H_2SO_4) in the presence of digestion mixture, Potassium sulphate (K_2SO_4) and copper sulphate ($CuSO_4$). The mixture was then made alkaline with 40 % NaOH. Ammonium sulphate thus formed, released ammonia which was collected in 4% boric acid solution and titrated against standard HCl. The percent nitrogen content of the sample was calculated the formula given below. Total protein was calculated by multiplying the amount of percent nitrogen with appropriate factor (6.25).

$$\%N = \frac{Weight\ of\ sample\,(g)}{1.4 \times (ml\ HCl - ml\ blank) \times Concentration\ of\ HCl}$$

% Protein = % N ×Factor (6.25)

4.2.4. Estimation of Lipid

Lipid determination is one of the key analyses used for food labeling and quality control. Lipid content in the fish powder was determined by petroleum ether extraction followed by soxhelt apparatus (Jinadasa, 2010).

4.2.4.1. Procedure

For the present study 5 g of finely ground sample was taken in a motor and anhydrous sodium sulphate of twice the weight of the sample was added into it. Then the mixture was ground until a free flowing powder was obtained. Then the powder was transferred to a thimble and sealed the end. Extraction thimble with the sample was placed in the soxhelt apparatus and fixed a previously dried and weighed round bottom flask. 200 ml of extracting solvent (petroleum ether) was added to the flask containing pumice chips. Then the Flask and the condenser were connected to the soxhelt extractor. Sample was allowed to reflux for about five hours. After the extraction flask was removed from the apparatus and kept in the water bath and then in the oven. Then the flask was cooled and weight was taken.

4.2.4.2. Calculation

Percent crude lipid was calculated using the following formula.

% Crude lipid = (X-F) ×100/W

Where,

X=Weight of the flask with lipid and chips

F= Weight of the flask and chips

W=Weight of the sample

4.2.5. Estimation of ash

Ash content was determined as described by AOAC (1955).

4.2.5.1. Procedure

About 2 gm of fish powder samples were weighed in a porcelain crucible (which was previously cleaned, heated to about 100^0C, cooled and weighed). The crucible with its content was placed in a muffle furnace for about four hours at about 600^0C. It then cooled in desiccators and weighed. To ensure completion of ashing, the crucible was again heated in the muffle furnace for half an hour, cooled and weighed again. This was repeated till two consecutive weights were the same and the ash was almost white in colour.

4.2.5.2. Calculation

The percentage of ash content in the fish powder was calculated from the formula (g per 100g of experimented samples)

$$Ash = 100\times (W_1/W_2)$$

Where,

W_1 = Weight of the ash obtained

W_2 = Weight of the experimental sample

4.2.6. Estimation of Minerals

4.2.6.1. Digestion of sample for mineral estimation

A 0.5gm of oven dried and grind sample were taken in 30ml micro-Kjeldhal digestion flask with 7ml conc. nitric acid+3ml perchloric acid. The sample was digested on digestion until the content becomes clear. The acid extract was diluted with distilled water in 100ml volumetric flask. The acid extract was used for the estimation of mineral such as phosphorus, calcium, potassium and iron content of the samples.

4.2.6.2. Estimation of phosphorous

Determination of Phosphorus was performed by following the Vanadomolybdate yellow colour method (Bhargava and Raghupathi 2005). 10 ml aliquot of plant extract was pipetted out into 50 ml volumetric flask. Then 10ml vanadomolybdate reagent was added, dilute to 50 ml with DW, mix well and the intensity of the yellow colour was read at 470 nm on spectrometer. For the preparation of standard curve standard orthophosphate solution measuring 0, 0.5, 1.0, 1.5, 2.0, and 2.5 ml was taken separately in 50 ml volumetric flask, and it was followed by the addition of 10 ml of the ammonium molybdate-vanadate reagent. The content were diluted to 50 ml with distilled water and mixed well. The absorbance was measured after 30 min. at 470 nm on spectrophotometer and the graph was prepared. The amount of phosphorus was calculated from standard graph of phosphorous.

4.2.6.3. Estimation of Calcium

The calcium was measured by flame method by using atomic absorption spectrophotometric procedure (Perkin-Elmer, 1982).

4.2.6.3.1. Preparation of standard sample

The ash obtained as earlier was moisturized with a small amount of distilled water (0.5-1) and then 5ml of concentrated HCL was added to it. The mixture was evaporated to dryness on a boiling water bath. Another 5ml of concentrated HCL was added again to the precipitate and the solution was evaporated to dryness as before. Then 4ml of concentrated HCL and a few warmed on a boiling water bath. The warmed solution was then filtered into a 100ml volumetric flask using Whatman no-41 filter paper.

4.2.6.3.2. Procedure

After preparing the standard solution of appropriate concentration, 1 ml from 1000 ppm standard calcium (ca) solution is taken in 100 ml volumetric flask to prepare 10 ppm solution with deionized water. 10 ml from 10 ppm is pipetted in 100 ml volumetric flask to produce 1000 ppb solution. Then 5ml, 10ml, 20ml, have been taken from 1000 ppb solution in 100ml volumetric flask to prepare 0.5, 1 and 2 ppb solution respectively. Finally, the calcium content was measured by flame method by using atomic absorption spectrophotometric procedure (Perkin-Elmer, 1982) using atomic spectrophotometer (model: AA-6800, Shimadzu Corporation, Japan).

4.2.6.4. Estimation of Iron

The Iron was measured by flame method by using atomic absorption spectrophotometric procedure (Perkin-Elmer, 1982).

4.2.6.4.1. Preparation of $CaCl_2$ Solution

2.3 g $CaCl_2$ exactly was taken in a 100 mL volumetric flask and the volumeis made up to the mark with DI Water

4.2.6.4.2. Preparation of Fe Standard solution from 1000 ppm Standard solution of Fe

Preparation of 20 ppm Standard stock Solution of Fe is done from 1000 ppm Standard solution of Fe by taking 1 ml of 1000 ppm Std. solution in a 50 ml volumetric flask and making the volume up to the mark with De Ionized Water. To prepare 0.5 ppm, 1 ppm, 2 ppm and 4 ppm standard solution 1.25 ml, 2.5 mL, 5 mL and 10 ml Std. 20 ppm Stock solution was taken respectively in 50 ml volumetric flask, 2.5 ml Conc HNO_3 and 1.5 ml previously prepared $CaCl_2$ solution was added in each volumetric flask and make the volume up to the mark with DI water. To prepare the Blank2.5 ml Conc. HNO_3 and 1.5 ml $CaCl_2$ is taken in a 50 ml volumetric flask and the volume is made up to the mark with DI Water.

4.2.6.4.3. Preparation of Sample and procedure

100 ml aliquot of well-mixed sample is transferred to a beaker and 2 ml Conc. HNO_3 and 5 ml Conc. HCl is added. The sample is covered with a watch glass and heated on a steam bath or hot plate at 90^0 to 95^0 C until the volume reduced to 15-20 ml. The beaker is removed and allowed for cooling. The beaker walls and watch glass is washed down with DI water when necessary filter or centrifuge the sample to remove silicates or other insoluble material. The final volume is adjusted to 100 ml with DI water. Then2.5 ml Conc. HNO_3 and 1.5 ml $CaCl_2$ solution is taken in a 50 ml volumetric flask and volume is made up to the mark with Treated Water sample. Finally, the Iron content was estimated by flame method by using atomic absorption spectrophotometric procedure (Perkin-Elmer, 1982) using atomic spectrophotometer (model: AA-6800, Shimadzu Corporation, Japan).

4.2.6.5. Estimation of Potassium

The Potassium content was measured by flame method by using atomic absorption spectrophotometric procedure (Perkin-Elmer, 1982)

4.2.6.5.1. Preparation of CsCl Solution

1.0 g CsCl is taken exactly and dissolved in 100 mL with DI Water

4.2.6.5.2. Preparation of K Standard solution from 1000 ppm Standard solution of Potassium

Preparation of 10 ppm Standard stock Solution of K is done from 1000 ppm Standard solution of K by taking 1 ml of 1000 ppm std. solution in a100 ml volumetric flask and making the volume with De Ionized Water. To prepare 0.1 ppm, 0.2 ppm, 0.4 ppm and 0.8 ppm Standard solution 0.5 ml, 1 ml, 2 ml and 4 ml Std. 10 ppm Stock solution are taken respectively in 50 ml volumetric flask, 2.5 ml Conc. HNO_3 and 1.2 ml previously prepared CsCl solution is added in each volumetric flask and the volume is made up to the mark with DI water.To prepare the blank2.5 ml Conc. HNO_3 and 1.2 ml CsCl is added in a 50 ml volumetric flask and the volume is made up to the mark with DI water

4.2.6.5. 3. Preparation of Sample and procedure

100 ml aliquot of well-mixed sample is transferred to a beaker and 2 ml Conc. HNO_3 and 5 ml Conc. HCl is added. The sample is covered with a watch glass and heated on a steam bath or hot plate at 90 to 95^0 C until the volume reduced to 15-20 ml. The beaker is removed and allowed for cooling. The beaker walls and watch glass is washed down with DI water when necessary filter or centrifuge the sample to remove silicates or other insoluble material. The final volume is adjusted to 100 ml with DI water. Then 2.5 ml Conc. HNO_3 and 1.2 ml CsCl solution is taken in a 50 ml volumetric flask and volume is made up to the mark with Treated Water sample. Finally, the Potassium content was measured by flame method by using atomic absorption spectrophotometric procedure (Perkin-Elmer, 1982) using atomic spectrophotometer (model: AA-6800, Shimadzu Corporation, Japan).

4.2.7. Statistical Analysis

Data obtained from this study were subjected to analysis usıng SPSS software (Version 20). A one-way analysis of variance (ANOVA) was used to test the significance of difference in levels of various nutritional elements of traditional and experimental dried samples. The Tukey's post-hoc test (HSD) was used if the means of different groups under comparison were significantly different in the normally distributed data, and $P < 0.05$ was regarded as statistically significant.

4.3. Results and Observations

The proximate composition and mineral contents of traditionally and experimentally prepared dried fish were measured and all the results (dry weight basis) obtained are summarized in (Table 4.1 and 4.2; Fig. 4.1-4.8).

4.3.1. Proximate composition

The results regarding proximate composition of dried fish presented in Table 4.1 and Fig. 4.1-4.4 indicate that contents of different parameters varied in respect of sample species as well as drying techniques, which has been given in following findings.

4.3.1.1. Protein content

The values concerning protein given in Table 4.1 and Fig. 4.1 provide an indication that there were noticeable fluctuations in respect of different samples. As far as traditional sample is concerned, the highest protein content was 78.83 (*C. punctatus*) followed by 64.79 (*W. attu*), 64.57 (*M. vittatus*), 62.09 (*C. striatus*) and 50.33 % (*Puntius* sp.), while in terms of experimental sample it was 79.71(*C. striatus*), 74.92 (*C. punctatus*), 71.23 (*W. attu*), 59.88 (*M. vittatus*) and 59.3% (*Puntius* sp.).

4.3.1.2. Fat content

In most cases fat percent in traditional sample was slightly lower compared to the experimental one; however, the maximum level in terms of traditional sample was 14.99 (*Puntius* sp.) followed by 14.41(*M. vittatus*), 11.10 (*W. attu*), 3.72(*C. punctatus*) and 3.12 % (*C. striatus*) and in case of experimental sample fat content was 18.50 (*Puntius* sp.), 15.20(*M. vittatus*), 5.10 (*W. attu*),5.00 (*C. punctatus*)and 4.20% (*C. striatus*) (Table 4.1 and Fig. 4.2)

Table 4.1 Proximate composition of different dried fish samples

Species	Sample type	Protein (%)	Fat (%)	Moisture (%)	Ash (%)
C. punctatus	Traditional	78.83±0.45^{a}	3.72±0.23^{de}	12.40±0.43^{de}	14.97±0.35^{e}
	Experimental	74.92±1.48^{b}	5.00±0.35^{d}	11.80±0.18^{de}	19.87±0.08^{d}
M. vittatus	Traditional	64.57±0.86^{d}	14.41±1.13^{b}	12.60±0.24^{d}	15.48±0.61^{e}
	Experimental	59.88±1.12^{e}	15.20±0.95^{b}	9.97±0.17^{f}	22.31±0.98^{c}
C. striatus	Traditional	62.09±1.23^{de}	3.12±0.17^{e}	20.90±0.57^{a}	25.71±1.25^{bc}
	Experimental	79.71±0.25^{a}	4.20±0.23^{de}	14.70±0.17^{c}	15.14±0.86^{e}
W. attu	Traditional	64.79±1.69^{d}	11.10±0.33^{c}	19.50±0.63^{a}	20.87±0.98^{d}
	Experimental	71.23±1.86^{c}	5.10±0.22^{d}	15.30±0.87^{c}	16.44±0.56^{e}
Puntius sp.	Traditional	50.33±1.23^{f}	14.99±0.38^{b}	16.70±0.48^{b}	29.91±1.05^{a}
	Experimental	59.30±1.35^{e}	18.50±0.34^{a}	9.21±0.11^{f}	20.65±1.15^{d}

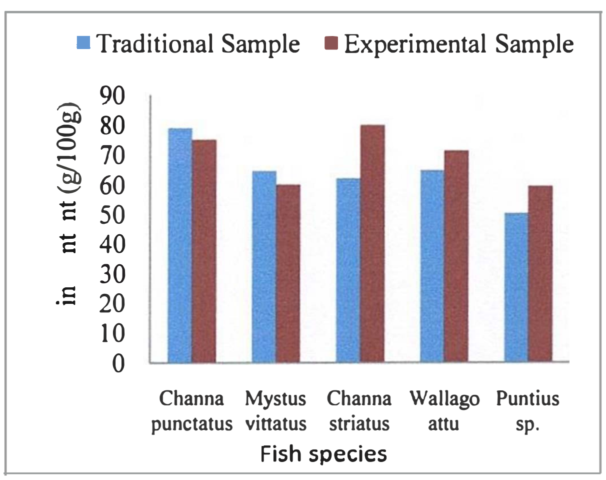


Fig. 4.1 Protein content in dried fish

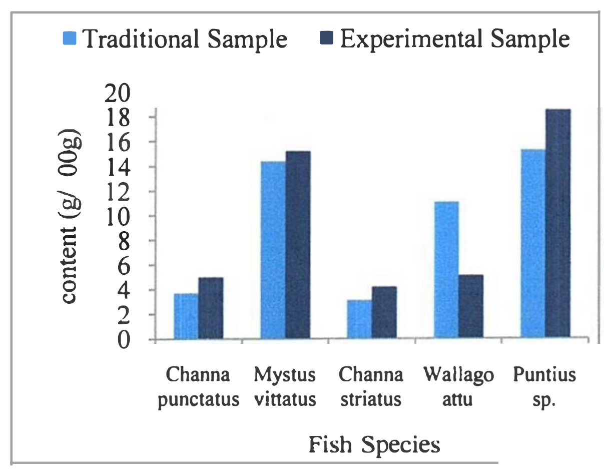


Fig.4.2 Fat content in dried fish

4.3.1.3. Moisture content

The initial moisture content is one of the most important factors influencing the quality of fish products. With respect to traditional samples, result for moisture level reveals that it was comparatively higher than that of experimental samples. According to Table 4.1 and Fig.4.3 moisture percents in traditional sample varied as 12.40, 12.60, 20.90, 19.50 and 16.70 %; and on the other hand, in experimental sample it was 11.80, 9.97, 14.70, 15.30 and 9.21% in *C. punctatus*, *M. vittatus*, *C. striatus*, *W. attu* and *Puntius* sp. respectively.

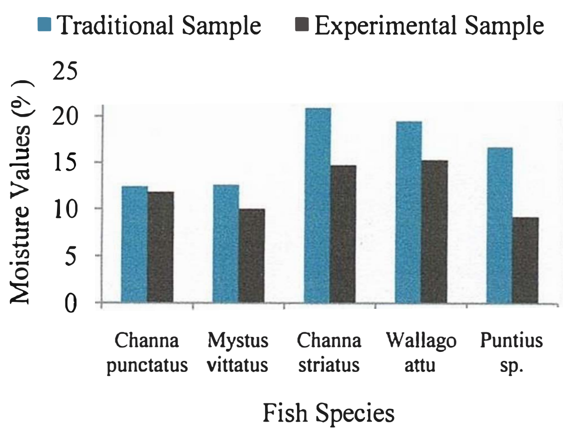


Fig.4.3 Moisture content in dried fish

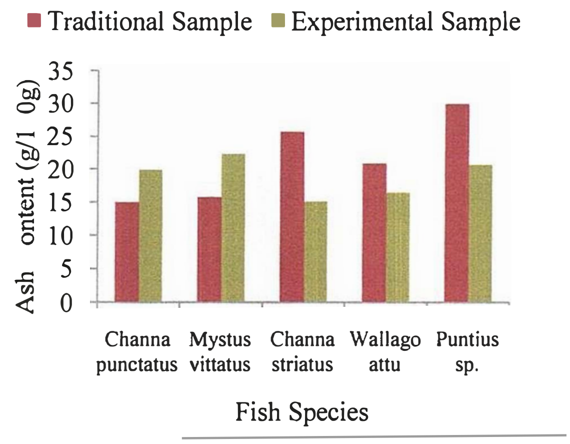


Fig.4.4 Ash content in dried fish

4.3.1.4. Ash content

The results shown in Table 4.1 and fig.4.4 reveal that the traditional sample contained maximum ash as 29.9 % (*Puntius* sp.) followed by 25.71(*C. striatus*), 20.87 (*W. attu*), 15.74 (*M. vittatus*) and 14.97% (*C. punctatus*); on the contrary, in experimental sample the ash content was 22.31(*M. vittatus*), 20.65 (*Puntius* sp.), 19.87 (*C. punctatus*), 15.14 (*C. striatus*) and 16.44% (*W. attu*).

4.3.2. Mineral contents

Dried fish is a good source of minerals which play a vital role to meet the requirements of human body. The concentration of different minerals estimated from the present investigation was recorded as follows-

4.3.2.1. Iron content

In case of traditional sample, the highest level of iron found was 14.65 (*W. attu*) followed by 14.41 (*M. vittatus*), 6.92 (*Puntius* sp.), 4.61(*C. punctatus*) and 3.88 mg/100g (*C. striatus*) whereas in experimental samples the values for iron were found as 15.2 (*M. vittatus*), 10.8 (*W. attu*), 5.1 (*Puntius* sp.), 4.36 (*C. punctatus*) and 3.57 mg/100g (*C. striatus*) (Table 4.2, Fig.4.6).

Table 4.2 Mineral contents of different dried fish samples

Species	Sample type	Iron (mg/100g)	Calcium (mg/100g)	Potassium (mg/100g)	Phosphorous (mg/100g)
C. punctatus	Traditional	4.61±0.01[g]	134.28±0.11[d]	90.19±0.10[b]	485.77±3.15[b]
	Experimental	4.35±0.07[h]	28.74±0.25[h]	90.18±0.00[b]	261.62±3.16[h]
M. vittatus	Traditional	14.41±0.06[c]	190.60±0.24[a]	90.14±0.20[b]	535.45±4.12[a]
	Experimental	15.20±0.05[a]	132.66±0.26[e]	90.03±0.10[c]	442.10±3.13[d]
C. striatus	Traditional	3.40±0.00[i]	94.56±1.16[f]	80.46±0.10[e]	229.78±2.13[i]
	Experimental	2.79±0.06[j]	20.83±0.04[i]	70.80±0.00[g]	336.35±1.21[g]
W. attu	Traditional	14.66±0.20[b]	184.29±0.56[b]	90.47±0.00[a]	413.97±3.26[e]
	Experimental	10.79±0.13[d]	93.61±0.35[f]	80.61±0.50[d]	374.08±2.14[f]
Puntius sp.	Traditional	6.89±0.06[e]	159.47±1.20[c]	90.01±1.10[c]	441.82±3.12[d]
	Experimental	5.07±0.18[f]	40.54±0.33[g]	80.31±0.00[f]	450.08±2.51[c]

4.3.2.2. Calcium content

According to the findings of the present study showed in table 4.2 and Fig. 4.5 reveals that the moisture contents in traditional sample were 134.28, 190.60, 94.56, 184.29and 159.47mg/100g; however, in experimental sample it was 28.74, 132.66, 20.83, 93.61and 40.54mg/100g in *C. punctatus*, *M. vittatus*, *C. striatus*, *W. attu* and *Puntius* sp. respectively.

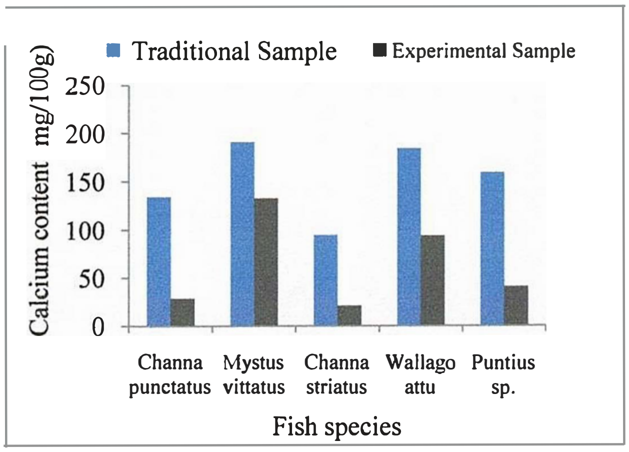


Fig. 4.5 Calcium content in dried fish

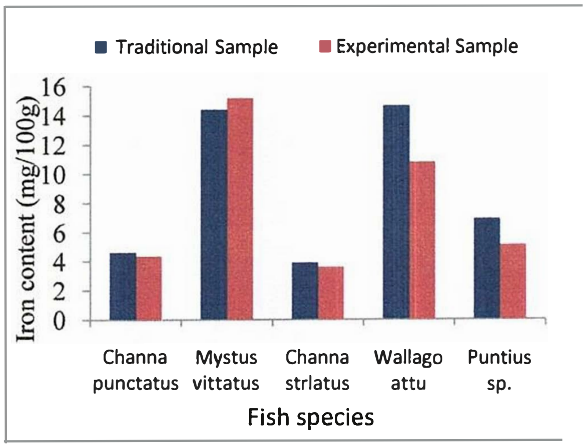


Fig. 4.6 Iron content in dried fish

4.3.2.3. Potassium content

With respect to potassium concentration, the result summarized in Table 4.2 and Fig.4.7 shows that in most cases the values are more or less equal both in traditional and experimental samples. The potassium content was found as 90.19, 90.14, 80.46, 90.47 and 90.01 mg/100g in traditional sample; on the other hand, in case of experimental sample it varied as 90.18, 90.03, 70.80, 80.61and 80.31 mg/100g in *C. punctatus*, *M. vittatus*, *C. striatus*, *W. attu* and *Puntius* sp. respectively.

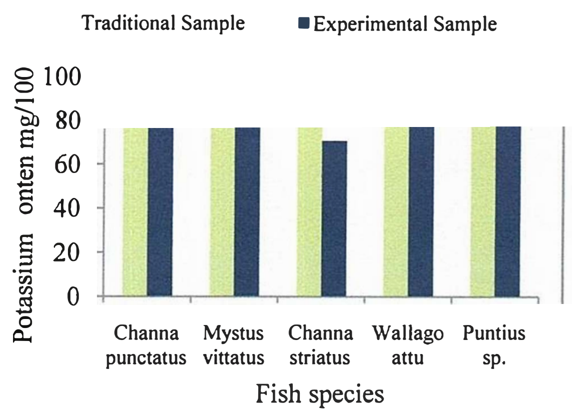


Fig.4.7 Potassium content in dried fish

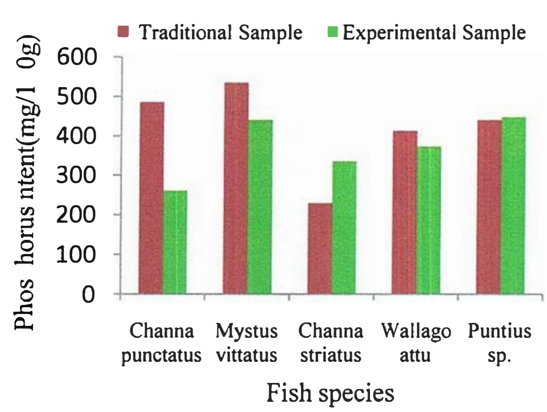


Fig.4.8 Phosphorous content in dried fish

4.3.2.4. Phosphorous content

In terms of traditional sample, highest phosphorous content was determined as 535.45 (*M. vittatus*) followed by 485.77 (*C. punctatus*), 441.82 (*Puntiussp*), 413.97 (*W. attu*) and 229.78mg/100g (*C. striatus*), while in case of experimental sample the highest concentration obtained was 450.08 (*Puntiussp*), 442.10 (*M. vittatus*), 374.08 (*W. attu*), 336.35 (*C. striatus*) and 261.62 mg/100g (*C. punctatus*) (Table 4.2 and Fig.4.8).

4.4. Discussion

4.4.1. Proximate composition

It is desirable to have a high percentage of protein in food products which is one of the important factors in case of quality analysis. In the present research, protein content (dry weight basis) in traditional sample varied from 50.32 (*Puntius* sp.) to 78.83% (*C. punctatus*), while in experimental sample its amount was slightly higher ranging from 59.3 (*Puntius* sp.) to 79.71% (*C. striatus*). Normally, it was observed that the sun-dried fishes contain 60 to 80% protein (Hoq, 2004). However, Hussain *et al.* (1992) reported that protein content varied widely from 17.2 to 78% in 23 different dried species. Flowra and Tumpa (2012) found the protein content of selected dried fishes varied from 28.20% *(Wallago attu)* to 51.19 % (*Palaemon* sp.), which is relatively lower than the present levels of protein. Another study of Flowra et al. (2012) also reveals the similar findings were protein content of five selected dried fish species was in the range of 53.45 to 76.39% on dry matter basis. The results also supports the findings of Sultana *et al*. (2011) in which protein content of dried fish varied from 52.65% (*C. ranga*) to 72.45% in mixed Small Indigenous Species (SIS). In a study concerning proximate composition of dried fatty fishes done by Keshava and Sen (1982) revealed that the mean values for protein was 75.3%. Besides, Islam (1982) studied the proximate composition of traditionally dried Rohu fish and found protein content as 73.26%. These results are also similar to those reported by Azam *et al.* (2003) where the values varied between 40.69 to 66.52% with regards to protein level in fourteen selected dried fish species. In addition, the present results are more or less similar to the findings of Mansur *et al.* (2013) who found the protein content ranging from 49.23 to 62.85% in three selected dried fish species. This difference in protein content may be attributed to the extent of removal of moisture depended on different samples and drying techniques. However, analysis indicated that for individual species difference in protein contentwas significant ($P<0.05$) with respect to various samples prepared by traditional and experimental method. Similarly, significant difference in protein content of different dried fish processed by various drying techniques has been reported by Aberoumand and Karimi (2015) and Gokoglu *et al.* (2004). Chavan *et al.* (2011b) observed that in terms of protein content, sample from solar tent drier showed relatively higher values (44.13%), while the dried fish procured from market had lower protein level (32.48%).

In terms of fat content, in traditional sample the maximum value was 14.99 % in *Puntius* sp. and minimum 3.12% in *C. striatus* whereas in experimental sample it was in the range of 4.2% (*C. striatus*) to 18.5% in (*Puntius* sp.). Similar finding was reported by Sultana *et al.* (2011) where fat content remained in the range from 12.66% to 23%. In addition, this result is also in agreement with the previous study conducted by Islam, *et al*. (2013) who stated that lipid content varied from 3.21 to 14.03% with the highest lipid content in *Amblypharyngodon mola* (Mola) and the lowest in *Channa punctatus.* Besides, the results are similar to the finding of Flowra and Tumpa (2012) in which lipid values lied within 5.38% (*Labeo bata)* to 15.86 % *(Wallago attu).* Hussain *et al.* (1992) also observed lipid content varying from 3.7 to 17.8% in 23 sun-dried fish species which matches with the present results. While working on dried fish Sultana *et al.* (2008) found lipid content ranging from 8.05 to 19.18% with highest value in silver jewfish and lowest in Bombay duck. The present investigation showed that *C. striatus*, *C. punctatus* and *W. attu* contained relatively less amount of fat; in contrast, these samples were observed to have comparatively higher level of protein. Similarly, an inverse relation between protein and fat was also markedly evident in the values recorded by Sultana *et al.* (2008). In addition, in all experimental samples fat content was found to be slightly higher compared to the traditional one, which might be the results of relatively more oxidative deterioration of traditional sample since these samples were more likely to be exposed in air before it was procured. During storage, a decrease in the level of crude protein and fat of small and large salted Bouri fish muscle (*Mugil cephalus*) was observed by El-Sebahy and Metwalli (1988). Chavan *et al.* (2011b) opined that crude fat content of ribbon fish dried by different methods fluctuated in accordance with moisture during storage. Moreover, as far as lipid content is concerned, the difference in samples also may be due to individual variation in natural composition. Analysis showed that for individual species in most cases drying method had no significant impacts ($P<0.05$) with respect to lipid content.

The initial moisture content is the most important factor affecting the ultimate quality and storage life of dried fish (Antony and Govindan, 1983). With respect to moisture content, traditional dried samples of the study ranged from 12.40to 20.90% with the lowest content in *C. punctatus* and the highest in *C. striatus* whereas in experimental sample it varied from 9.20 to 15.3 % with the lowest content in *Puntius* sp. and the highest in *W. attu.* These values remained within the range observed by Hoq (2004) who reported that normally sun-dried fishes contain an average of 10 to 20% moisture. In a similar investigation, Flowra and Tumpa (2012) worked on five selected freshwater dried fish and found the moisture content varying from 12.13

(*Puntius ticto*) to 18.18% (*Palaemon* sp.), which corroborates the present findings. However, this result was considerably higher than that of the findings of Islam, *et al*. (2013) who reported that moisture content of traditional sample was in the range of 29.25 to 34.43% with the highest value obtained from *Channa punctatus*(Taki) and lowest from *Amblypharyngodon mola* (Mola). In another investigation, Sultana *et al.* (2008) observed that in case of solar dried fish, moisture content was in the range of 14.05 to 19.71% which agrees with the present results. In case of *C. punctatus* and *W. attu*, moisture content was comparatively higher in both traditional and experimental sample; however, with respect to lipid content, the levels were noticeably lower in these samples. Similarly, an inverse relation was found between moisture and lipid content as reported by Stansby (1962). However, traditional sample of *Puntius* sp. showed an exception with high lipid content despite having relatively more moisture level, which might be due to excessive use of salt which is hygroscopic and promote moisture absorption from environment. Frazier and Westhoff (1978) stated that generally no microbe (bacteria, yeast and mold) can grow in dried products with moisture content below 15%. The present findings show that moisture content of traditionally dried C. *striatus*, *W.attu*, *Puntius* sp. was above the recommended limit whereas these values for most of the experimental samples fell within this suggested level. Analysis indicates that in most cases average moisture content of individual species varied significantly ($P< 0.05$) in respect of samples dried employing different technique. Chavan *et al.* (2011b) reported that the initial moisture content of dried ribbon fish procured from market was 30.6 %, while it was 17.85, 19.35 and 19.95% in the samples dried in solar tent drier, raised bamboo plat form and black polythene sheet respectively.

Ash content reflects fair degree of importance of a species as a source of minerals. Ash content in dried fish is higher than that of fresh fish as the inorganic content remain as ash after the organic matter is removed by incineration (Clucas and Ward, 1996). In present study, ash content in traditional sample varied from 14.97 (*C. punctatus*) to 29.91% (*Puntius* sp.), while in experimental sample it was from 15.14 (*C. striatus*) to 22.31% (*M. vittatus*), which supports the results of Islam, *et al*. (2013) who found that ash content was in the range of 20.14 -24.40 %. From a study, Flowra and Tumpa (2012) mentioned that the ash content was observed to range from 10.78

(*Labeo bata)* to 15.67% *(Palaemon* sp.). In another similar research on dried Bombay duck, Haque *et al.* (2013) found ash content lying within the range of 16.95 to 21.41%, which also agree with present results. Mansur *et al.* (2013) observed the ash content in the range of 11.11-18.89% in three dried fish species and present findings are in agreement with reported values. Chavan *et al.* (2011b) opined that ash content is likely to be influenced by the quantity of salt used during processing.

4.4.2. Mineral Contents

Depending on species, results (dry weight basis) showed a wide variation in minerals content. Windom *et al.* (1987) opined that such variation in concentrations of mineral elements from one species to another was due to the chemical forms of the elements and their concentrations in the local environment. Iron is an essential constituent of haemoglobin and myoglobin and most common derangement of iron metabolism is represented by anemia (Sen *et al*., 1961). In the present study, the highest amount (14.65 mg/100g) of iron found in traditional sample was in *W. attu* and the lowest (3.88 mg/100g) was in *C. striatus*, while it varied from 15.20 mg/100g (*M. vittatus*) to 3.57 mg/100g (*C. striatus*) in terms of experimental samples. This result supports the findings of Jahan *et al.* (2017) who reported that the highest iron content was in *C. mrigala* (18.4mg/100g) and lowest in *H. molitrix* and *P. sophore* (4.3mg/100g). Kabahenda *et al.* (2011) mentioned that *mukene*, a low value fish, contained 8.18–10.91 mg/100 g iron on dry basis. In another study, Sultana, *et al*. (2011) observed that maximum iron content (45.20 mg/100g) was found in mixed SIS species and the minimum (16.85 mg/100g) was in *O. bacaila*, which is more or less similar with the present findings. In a similar study, Nurullah *et al*. (2003) found the iron content remaining in the range from 14.50 to 42.20 mg/100 g of raw fish, and Chapila (*G. cahpra*) contained the highest amount of iron among the studied SIS fishes, moreover, *Esomus danricus*, *A. mola*, *G. chapra*, *M. vittatus*, etc. were found to be rich in iron. However, Roos *et al.* (2003) mentioned that SIS fishes normally present in the fish culture ponds of Bangladesh are low in iron and calcium content. The present findings reveal that average iron concentration varied significantly ($P<0.05$) in respect of different species. This discrepancy may be due to the factors affecting the iron content such as species, individual and sampling period (Yilmaz *et al.* 2010).

Calcium plays essential role in human body for the formation of bones muscle tone and nervous impulse (Mollah *et al*., 1998).In addition, calcium deficiency has been implicated in the development of rickets, which is gaining more attention than before (Hagan *et al.*, 2010). The results reveal that calcium was found to vary from 94.56 mg/100g (*C. striatus*) to 190.60 mg/100g (*M. vittatus*) in traditional samples whereas in experimental samples it was in the range from 20.83 mg/100g (*C. striatus*) to 132.66mg/100g (*M. vittatus*). This result is supported by the findings of Jahan*et al.* (2017) who found the highest (254mg/100g) calcium content in small prawns and the lowest (248mg/100g) in *L. rohita*. However, the present values are lower than the findings of Islam *et al*. (2003) who reported that *Cirrhina reba* contains 822 mg calcium/100g of fish. Another study reveals that (Small Indigenous Species) SIS species like *Gudusia chapra*, *Channa punctatus* and *A. mola* contained good amount of Ca with the concentration of 1063, 1093and 1171 mg /100g respectively; this could be due to the fact that SIS fishes are consumed totally along with bones and there is no wastage of calcium from these fishes (Roos *et al*., 2003). Present results are considerably lower than those findings regarding SIS species, and this variation may be attributed to removal of scales, skull bone and fins before drying. In terms of experimental samples, complete dressing was done for all species. However, with respect to traditional sample, only partial dressing (fins and some bones are not removed) was limited to large species where head is partially removed leaving some hard bones in case of *C. striatus, C. punctatus*, while head is totally not removed in *W. attu*, which may be the cause of having higher calcium levels in traditional samples compared to the experimental one. Analysis also indicates that the mean values of calcium varied significantly ($P<0.05$) in respect of different fish samples prepared in traditional and experimental method.

Potassium is one of the predominant electrolytes distributed in bio-fluids of a living system (Sen *et al.*, 1961). Results revealed that in most of the samples variations in potassium content were comparatively lower. With respect to traditional samples, potassium content was found to vary from 80.46 mg/100g (*C. striatus*) to 90.47 mg/100g (*W. attu*), while in experimental sample it was in the range from 70.80 mg/100g (*C. striatus*) to 90.18 mg/100g (*C. punctatus*). In raw fish, typical values for potassium range within 19-502 mg/100g (Clucas and Ward, 1996). In another study on 55 fishes of Bangladesh, Bogard *et al.* (2015) found potassium content to vary from 58– 350 mg/100 g raw fish. When compared with those results (wet basis), the present values (dry weight basis) normally seem to be more or less similar.

Phosphorous is another essential trace element having high nutritional significance, and maximum amount of which was 535.45 mg/100g (*M. vittatus*) and lowest was 229.78mg/100g (*C. striatus*) in traditional samples whereas in case of experimental samples it was in the range from 450.08 mg/100g (*Puntius* sp.) to 261.62 mg/100g (*C. punctatus*). Present result is more or less similar to the findings reported by Jahan *et al.* (2017) where maximum (191 mg/100g) phosphorus content was found in experimentally dried *P. sophore* and minimum (94mg/100g) in *L. rohita.* The results also agree with another similar study conducted by Abbey (2017) who reported that phosphorus content in dried Burrito fish and Tuna trimmings were 93.71 and 600.9 mg/100g. In a study regarding mineral contents of SIS (Small Indigenous Species) dried fishes, Sultana *et al*. (2011) observed that highest amount of phosphorus was found in *C. ranga* (2.90%) and the lowest was in *C. soborna* (1.72%), which is considerably higher than the present results, and this may be due to removal of some parts rich in phosphorous and calcium like scales, fins and head. Similar opinion was also mentioned by Jahan *et al.* (2017). In addition, Bogard *et al.* (2015) observed that phosphorus content ranged from 110 to 1000 mg/100g raw fish, having higher composition in fish species with bones included in edible parts. In this study results show that in most cases average phosphorous content of individual species differed significantly ($P<0.05$) in respect of various samples.

Chapter-5

Safety Aspects of Dried Fish

Chapter-5

Safety Aspects of Dried Fish

5.1. Introduction

Food safety is a major global concern at present which is more prevalent in under-developed or developing countries. Foods are adulterated or contaminated in different ways and most of these take place due to natural or anthropogenic causes which bring about many threats to food safety. In many cases food safety is disturbed from the nature because of unconscious ventures, ignorance and negligence of stakeholders in various steps of handling, preservation, processing, storage, transportation and marketing; however, deliberative abuse of hazardous chemicals, pesticides and antibiotics is also evidently responsible for undermining food safety. Bangladesh is the one of the notable countries which is desperately struggling with persisting problems posed by unsafe food. Consumption of unsafe food is a serious threat to public health in Bangladesh for last couple of decades (Ali, 2013). Fish is good for health; however, it may further impose serious risks to human being when it is subjected to various types of contamination resulted from bacteria, fungus, sewage toxicants, chemicals, pesticides and antibiotics (Nowsad, 2016). Therefore, ensuring quality and safety should necessarily form an integral part of any food processing activity, and more so in the fish processing activity because of the highly perishable nature of fish and the probability of many hazards, particularly pathogenic bacteria, pesticide and heavy metals residues etc. (Balachandran, 2001).

Heavy metal residue is treated as an important chemical hazard to consumer health. Anthropogenic activities like draining of sewerage, mining, industrial processing, use of large quantities of agrochemicals such as metal-based pesticides and fertilizers play major role in the pollution of environment and the contamination of foodstuffs by heavy metals (Loutfy *et al.*, 2012; Pourang and Noori, 2012). Excess amounts of heavy metals from anthropogenic sources that enter into the ecosystem may lead to geo-accumulation and bioaccumulation, which in turn pollute the environment and also affect the food chain and ultimately pose serious human health risks

(Weldegebriel *et al*., 2012). Some elements like mercury, cadmium and lead show no known essential function in life and are toxic even at low concentration when ingested over a long period; therefore many consumers regard any presence of these elements in fish as a hazard to health (Bremner, 2002).

Heavy metals cannot be degraded; they are deposited, assimilated or incorporated in water, sediment and aquatic animals (Linnik and Zubenko, 2000). As fishes are constantly exposed to pollutants in contaminated water, they could be used as excellent biological markers of heavy metals in aquatic ecosystem (Nsikak *et al*., 2007). Fish and other aquatic animals take up heavy metals from their food and also from the water they pass through their gills. The uptake of meals is often dependent on the amount of ingested and on the heavy metal content of the food or prey (Phillips, 1995). Accumulation takes a long time and results in high concentrations in aged and big fish. Some species, mainly predatory fish, which are relatively long lived, are known for storing higher amounts of heavy metals in different organs. The main organs, which are used in fish for storage and detoxification of heavy metals, are the liver, kidney, bones, scales, spleen and gills (Bremner, 2002).

High level of As, Lead (Pb), Copper (Cu), and Iron (Fe) have been found to cause rapid physiological changes in fish (Tarrio, 1991). Cd is a known teratogen and carcinogen, probable mutagen and has been implicated as the cause of serious deleterious effect on fish. Trace metals can be accumulated by fish through both the food chain and water (Hadson, 1988). Pollution from any metal or element may also cause unsuspected hazards to man. The effects of the elements of most concern are cumulative poisons that cause harm to health through progressive and irreversible accumulation in the body as a result of ingestion of repeated small amounts. Mercury (Hg), Cd, Cr, Pb and Selenium (Se) are known to be potentially harmful pollutants which contaminate fish; particularly Hg has been implicated in disease to consumers caused by eating fish (Connell, 1975; Connell, 1980)

Chalan Beel, which contributes to substantial amount of freshwater dried fish production and located in north-west region of Bangladesh, is one of the largest *beel* (In rainy season: 375 square kilometers and in dry season : 52-78 square kilometers) of the country producing huge amount of freshwater fishes every year (Hossain *et al*., 2009). The water quality of this *beel* has been deteriorating since last few decades as during dry season, huge amount of agricultural activities like paddy and winter crops cultivation take place where enormous amount of pesticides and inorganic fertilizers are applied regardless of recommended dose. Concentration of Cd, Cu, Ag and Zn in fish liver increased in the agricultural areas in the River Basin, U.S.A. (Heing and Tate, 1997). Elevated lead content in fish muscle tissue was reported only from areas with intensive industrial and agricultural activities Wong *et al.* (2001). Some water bodies located in pollution prone area of Rajshahi city were likely to suffer from heavy metal contamination (Flowra *et al.*, 2012). Many countries are now taking voluntary or mandatory action to reduce pollution of the aquatic environment with heavy metal for the food safety of aquatic food particularly fish. Considering the affect of heavy metal on fish quality and safety, the food regulatory and health authorities in some developed countries have taken serious view and adopted maximum allowable limit of harmful metals and elements. The concentration of harmful metal and element is much higher in the processed fish as moisture percentage gets reduced considerably. As a result, the concentration of pollutants in per unit weight/mass increases remarkably (Mansur, 2013), which may pose serious risk for human health. Keeping in view of this hazardous impact of heavy metals, its contents or residues have been determined.

Before processing, raw fish can contain anthropogenic contaminates like pesticides and in most cases this occurs due to unawareness or even deliberative abuse of various hazardous pesticides which may pose a serious threat to public health (Nowsad, 2016). Pesticide residue is considered as one of the crucial chemical hazards, particularly prevails in dried fish. Dried fish is more likely to suffer from insect infestation during various stages of processing and marketing. One of the major problems associated with the sun-drying of fish is the infestation by the blowfly and beetle larvae. Insect infestation is an important cause of economic and physical losses in the cured fish industries of developing countries (Poulter *et al.* 1988). Under warm and humid condition, sun-dried fish are subjected to infestation by blowfly larvae (Kordyl 1976). During rough weather like foggy or rainy day fish are likely to suffer from blow fly and insect infestations. Larger fish are at higher risk from gravid female blowflies during the raw material preparation and early stages of sun-drying when moisture content is high (Nowsad, 2007). However, salt treatment can reduce the rate of blowfly infestation in cloudy or foggy day (Nowsad, 2014). Extent of damage due to infestation is likely to increase up to 25-30% under very humid condition in Bangladesh where sufficient salt is not applied (Doe, 1977 and Ahmed, 1978).

On the other hand, when drying is over, dried fish products are generally stored in a dump warehouse. Heavy damage takes place due to bettle infestations mainly during storage and distribution. Various pesticides are normally used to control blowfly and bettle infestations. During drying, Nogos, Nuvacron, Endrin, Malathion, Dimacron etc. are commonly used, while in the storage, DDT, Basudin and Malathion etc. are preferably applied. However, the degree of pesticide use is sharply reduced in sunny and dry weather. Most of the pesticides of first category and the DDT of second category are banned for any use in Bangladesh (Nowsad, 2014).

Walker (1987) also reported cheap domestic and agricultural insecticides like DDT and dichlorvos, both of which are dangerous to consumer health, are employed during fish drying in Bangladesh. Studies on the conservation of dry fish showed that a mixture of organochlorine (DDT and heptachlor) is used in dry fish in Bangladesh (Bhuiyan *et al.*, 2008). In Bangladesh, all Persistent Organic Pollutants (POPs) like DDT and heptachlor import and production have been banned but at least five POPs pesticides including DDT are still in use under different names or labels (ESDO, 2005). DDT, which has been implicated to results in various chronic health problems, can transfer from generation to generation through breast milk (Solomon and Weiss, 2001). The organochlorine insecticides like DDT are extremely lipophilic in nature and resistance to biodegradation, which results in their accumulation and concentration in fatty tissues and their extreme persistence in environment (Tannenbaum, 1979). Besides, people exposed to pesticides for prolonged duration are more likely to suffer from immediate and long term effects on health (Khan, 2002b). Thus, it goes without saying that pesticide results in detrimental impact on consumer health as well as on the people involved in drying, which ultimately contributes to undermining the endeavor of enhancing food safety.

Like other food items, dried fish is also vulnerable to biological hazard like pathogenic microorganisms, and its presence exceeding the prescribed limit makes dried fish unsafe. The presence of pathogenic loads in dried fish is gaining importance in view of the safety and quality aspects. That is why, microbiological quality assessment is necessary to ensure safe dried fish production and guard consumer's health and hygiene (Lilabati *et al*., 1999). Fish become contaminated in various ways. However, the type of microorganism associated with a particular fish depends on the water bodies it was found (Clucas and Ward, 1996). Besides, fish is also contaminated with microorganisms during post-harvest activities such as poor standards of hygiene and sanitation, inadequate processing, unhygienic condition of market etc. The chances of this contamination are very high unless a high degree of sanitation is maintained throughout various phases. Nowadays, the microbial safety of fish products is an important concern of consumers as the major share of the outbreaks related to consumption of fish are caused by bacteria such as *C. botulinum*, *E. coli, Salmonell and Vibrio sp* etc. (Fleming, 2000). Most of these bacteria are of human origin. However, the occurrence of Coliforms and *E. coli* is the indicative of fecal contamination, and the presence of few members of these bacteria is permissible up to a certain limit in fish and fishery products whereas presence of others like *Salmonella* and *Vibrio* is not permitted to any extent. (Balachandran, 2001). Therefore, bacteriological test is of great significance for determining the level of hygienic handling and processing and also for monitoring wholesomeness and microbial safety of dried fish.

Given the fact that dried fish is more likely to be adversely affected by many hazards, the present investigation is a small endeavor to evaluate the present status from food safety point of view. Research on nutritive value of freshwater dried fish is available and already established. However, less attention has been given to assess prevailing state of food safety in freshwater dried fish. Therefore, in view of the potential contamination from various sources, present research is intended to assess the safety aspects of dried fish of *Chalan Beel* area in respect of heavy metal contamination, pathogenic bacterial count and pesticide residue.

5.2. Materials and Methods

5.2.1. Heavy Metals Residue

5.2.1.1. Sample collection and processing

Traditional Samples of five dried fish species (*Channa punctatus*, *Mystus vittatus*, *Channa striatus*, *Wallago attu* and *Puntius* sp.) were purchased from adjacent fish drying sites of Chalan *beel* area namely Tarash, Atrai and Vangura. In this sample *Mystus vittatu s*and *Puntius* sp. were not dressed and washed and other species such as *Channa punctatus, Channa striatus* and *Wallago attu* underwent dressing and washing in the prevailing unhygienic environment of drying yard. In case of experimental sample, raw fish were bought from the nearby market of the water body, and all species of which were subjected to washing under tube well water and sun drying in hygienic environment after removal of non-edible parts like viscera, gills and scales according to common household practices. Then only edible portions including mainly muscle and some bones were chopped into small pieces and dried in an oven at 80° C until a constant weight was obtained. The dried samples were ground with a mortar and passed through a suitable mesh sieve. The fine powder was preserved in clean and dry plastic bottles in the dark until digestion.

5.2.1.2. Digestion of samples

A known quantity of dried fish powder of each sample was weighed by an electronic balance and 5 ml of diacid mixture (5 ml conc. HNO_3; 3 ml 60% $HClO_4$) was added to each sample. The content was mixed for overnight. Samples were then digested initially at 80°C temperature and later at 150°C for 2 h. The completion of digestion was indicated by almost colorless appearance of the solution. The samples were separately filtered by using an ash less filter paper (Whatman No. 42). Final volume was made up to 150 ml with 0.5% HNO_3 (Eboh, 2006).

5.2.1.3. Analysis of heavy metals

Concentrations of Pb, Cr and Cd ın the filtrate of digested fish samples were estimated in Central Science Laboratory, University of Rajshahi employing furnace method and Cu in flame using an atomic absorption spectrophotometer (model: AA-6800, Shimadzu Corporation, Japan). Standard stock solutions of 1,000 ppm for all the metals were obtained from Kanto Chemical Co. Inc., Tokyo, Japan. These solutions were diluted for desired concentrations to calibrate the instrument. All samples were collected and analyzed in triplicate, and the average results were used to represent the data. The absorption wavelengths were 217.0 nm for Pb, 228.8 nm for Cd, 357.87 nm for Cr and 324.75 nm for Cu. The results were expressed as micrograms per gram (µg/g) in dry weight basis.

5.2.1.4. Health Risk Assessment

Estimated Daily Intake (EDI): was calculated using the following equation, which is recommended by the USEPA (1997).

$$\text{EDI} = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

Where EDI is the average daily intake or dose through ingestion (mg/kg bw/day); C is the heavy metal concentration in the exposure medium (mg/L or mg/kg); IR is the mean ingestion rate (0.0312 kg/day) for normal adult; EF is the exposure frequency (365 days/year); ED is the exposure duration (60 years for Bangladeshi population; Uddin *et al.* 2010); BW is the body weight (average adult body weight was taken as 60 kg; Wang *et al.* 2005) and AT is the time period over which the dose is averaged (365 days/year × number of exposure duration, as considered to be 60 years in this study).

5.2.1.5. Target Hazard Quotient (THQ)

The human health risk posed by contaminant exposure are usually characterized by the Target Hazard Quotient (THQ) (USEPA, 1997), the ratio of the average Estimated Daily Intake (EDI) resulting from exposure compared to the Reference Dose (RfD) for an individual pathway and chemical. The oral Reference Doses (RfD) for Cu, Pb, and Cd suggested by FAO/WHO (2006) was 0.14, 0.00357 and 0.001 mg/kg/day, respectively. The THQ based on non-cancer toxic risk was determined by

$$\text{THQ} = \frac{EDI}{RfD}$$

A THQ below 1 means the exposed population is unlikely to experience obvious adverse effects whereas THQ value above 1 indicates there may be concerns for potential health risks with an increasing probability as the value gets elevated.

5.2.2. Pathogenic microbial assessment

All laboratory works on pathogenic microbial assessments were accomplished in the Department of Microbiology, University of Dhaka.

5.2.2.1. Preparation of sample solutions

Sterile blender was used to prepare powder from dried fish samples. For serial decimal dilution 10g of fish powder for all samples was weighed on an electric balance, blended and suspended in 100 ml sterile water to make a stock suspension. The content of the stock was homogenized with vortex apparatus for 60 seconds. Then 1ml was transferred from the stock by pippetting to 9ml diluents of sterile water. This process was repeated for three other test tubes to obtain 10^{-4} dilution. Finally, this dilution of all samples was used for bacteriological analyses.

5.2.2.2. Enumeration of total and fecal Coliforms

For enumeration of total coliforms, 1 ml of each dilution of the samples was pour-plated on MacConkey Agar in duplicates. Plates were aerobically incubated in inverted positions at 37°C. The colonies with pink color appearance were considered as total coliform, and counted after 24 hours and 48 hours of incubation. On the other hand, in case of fecal coliform detection, the colonies that appeared pink on MacConkey agar were isolated and inoculated aseptically on Eosine Methylene Blue (EMB) agar plate through streaking method. Then the plates were incubated at 44.5°C for 48 hours and observed for dark red colonies with green metallic sheen. Finally, colonies were counted and calculated by multiplying with the appropriate dilution factor as colony forming units per gram (cfu/g) of fish sample (APHA, 2005).

5.2.2.3. Detection of *Salmonella*

The presence of *Salmonella* spp. was detected by homogenizing a 5 g of dry fish and dissolved in 50 ml (pH 7.5) sterile buffered peptone water aseptically and incubated for 24-48 hour at 37°c. After incubation 1 ml sample was pipette out to duplicate tubes of Tetrathionate (9 ml) and Selenite Cysteine Broth (9 ml); then it was incubated for 24 hours at 37°c and sub-cultured into Xylose Lysine Deoxycholate (XLD) and Brilliant Green Agar (BGA). After incubation for 24 hr at 37°c, characteristics colonies (on XLD- black centered, colony, convex, entries, glossy and on BGA-pink, red, convex, entree glossy colonies surrounded by brilliant red zones in the agar) were streaked with sterile platinum wise loop incubated at 37°c for 6 hrs. After incubation characteristics change may determine regarding the presence or absence of *Salmonella*. H_2S gas was not found which indicate that *Salmonella* was absent in the sample (USFDA, 1984).

5.2.2.4. Detection of *Vibrio cholerae*

For detecting *V. cholera*, 5 g of dry fish powder was dissolved in 50 ml sterile alkaline peptone water aseptically and incubated at 37°c for 24 hrs. Loopful alkaline peptone water was streaked on the surface of separate plates of Thiosulfate Citrate Bile Salts (TCBS) agar in such a manner to obtain individual colony and incubated at 37°c for 24 hrs. After incubation, *V. cholerae* colony was tested. The colony of *V. cholerae* was plain, yellow color and very big size (generally 2-3 mm). From TCBS the selected colony was transferred to the butt of Triple Sugar Iron Agar (TSIA) Slant with streaking. Then TSIA tubes were incubated at 37°C for 24 hrs. Black color gas was observed in TSIA which indicated that *V. cholerae* was absent (USFDA, 1984).

5.2.3. Pesticide residue detection

5.2.3.1. Sample Collection

Traditional dried fish products were collected from different drying spots of *Chalan Beel* area. The Five most popular dried fish samples namely Puti (*Puntious* sp.), Tengra (*Mystus vittatus*), Boal (*Wallago attu*), Taki (*Channa punctatus*) and Shol (*Channa striatus*) were collected from different drying yards of *Chalan Beel* area. The samples were packed tightly species wise in polyethylene bags and taken to the DRiCM laboratory, BCSIR, Dhaka for laboratory analysis. Samples of each species were preserved in a separate container at room temperature during study period.

5.2.3.2. Apparatus and Reagents

Soxhlet extractor, separatory funnels (500 ml & 200 ml), Chromatographic tube (20 mm i.d. 50 cm long), sample concentrator (Techne dry block DB.3), round bottomed flask (500 ml & 100ml), volumetric flask (50 ml & 10 ml), Gas Chromatograph (GCMS-TQ8040, Shimadzu), syringe(0.45 um). 15ml 1% acetic acid in acetonitrile (MeCN), 1.5g anhydrous sodium acetate (NaAc), 6g anh. MgSO4, Centrifuge>1500rcf for 1 min,150mg anh.MgSO4,50mg primary secondary amine (PSA) and 1-8ml MeCN extract(upper layer).

5.2.3.3. Sample preparation

Pesticide residues in foods sample was extracted by Acetonitrile Extraction location no: AOAC 10.1.04 and method no: AOAC 2007.01. Taking about 200g fish sample to be extracted and chop or grind the sample with vertical cutter or grinder respectively. Then blend the sample to homogenize with blender. After that transfer about 5g subsample to 50ml Teflon tube and add 15ml 1% acetic acid in acetonitrile (MeCN)+1.5g anhydrous sodium acetate (NaAc) +6 ganh MgSO4.Then shake vigorously/vortex for 1min and Centrifuge>1500rcf for 1min. Then take 150mg anhydrade MgSO4+50mg primary secondary amine (PSA) per ml extract in a tube and transfer 1-8ml MeCN extract (upper layer) to the tube. Again shake/vortex was done for 30 sec. After that transfer about 1-1.5ml extract to GC vial by filtering through 0.45um syringe filter. Finally analyze by GC/MS (model no. GCMS-TQ 8040 Shimadzu).

5.2.3.4. Sample analyses

The pesticide residues were analyzed by GCMS (model no. GCMS-TQ 8040 Shimadzu, 2010) with an Electron Capture Detector (an auto injector) and GC solution software.

5.2.4. Statistical Analysis

All experiments were replicated in triplicates and the mean was calculated from the results. Obtained data were subjected to the analysis using SPSS version 20. The independent samples t-test was carried out to determine whether significant differences of means exist between traditional and experimental sun dried fish products. Trends were considered significant when the means of compared sets differed at $P < 0.05$ and statistical significance is indicated with appropriate letters on the data table.

5.3. Results and Observations

5.3.1. Heavy Metals

Trace metal contents obtained in dried fish are expressed in Table5.1and Fig.5.1-5.4 after analysis and the results (dry weight basis) reveal whether there is any impact on heavy metal concentration in terms of experimental and traditional samples.

5.3.1.1. Lead Content

The values regarding lead content given in Table 5.1 and Fig.5.1 indicate that all the traditional samples showed higher lead concentration compared to the experimental samples. As far as traditional sample is concerned, the highest led content was 1.595 (*Puntius* sp.) followed by 1.289 (*C. punctatus*), 0.919 (*C. striatus*), 0.617 (*W. attu*), 0.609 µg/g (*M. vittatus*), while in terms of experimental sample it was 0.995 (*Puntius* sp.), 0.242 (*C. striatus*), 0.24 (*M. vittatus*), 0.179 (*C. punctatus*) and 0.164 µg/g (*W. attu*).

Table 5.1 Concentration of heavy metals in traditional and experimental samples of dried fish of *Chalan Beel* (µg/g, dry weight basis)

Species	Sample type	Pb	Cd	Cr	Cu
C. punctatus	Experimental	$0.179±0.001^a$	$0.015±0.00^a$	$1.025±0.021^a$	$6.503±0.110^a$
	Traditional	$1.289±0.004^b$	$0.020±0.001^b$	$0.914±0.016^b$	$3.093±0.110^b$
M. vittatus	Experimental	$0.240± 0.001^a$	$0.009±0.00^a$	$0.655±0.013^a$	$27.523±0.555^a$
	Traditional	$0.609±0.023^b$	$0.016±0.00^b$	$0.729±0.007^b$	$23.683 ±0.755^b$
C. striatus	Experimental	$0.242±0.000^a$	$0.012±0.00^a$	$1.089±0.048^a$	$6.301±0.002^a$
	Traditional	$0.919±0.023^b$	$0.018±0.00^b$	$0.995±0.017^a$	$6.683±0.275^a$
W. attu	Experimental	$0.164 ±0.000^a$	$0.018±0.001^a$	$0.448±0.018^a$	$23.510±0.612^a$
	Traditional	$0.617±0.002^b$	$0.014±0.00^b$	$0.636±0.009^b$	$28.067±0.682^b$
Puntius sp.	Experimental	$0.995±0.026^a$	$0.012±0.00^a$	$1.277±0.038^a$	$7.081±1.140^a$
	Traditional	$1.595±0.034^b$	$0.015±0.001^b$	$1.472±0.025^b$	$6.030±0.121^a$

Means with different superscript letters (a and b) for each species within a column are significantly different ($P<0.05$).

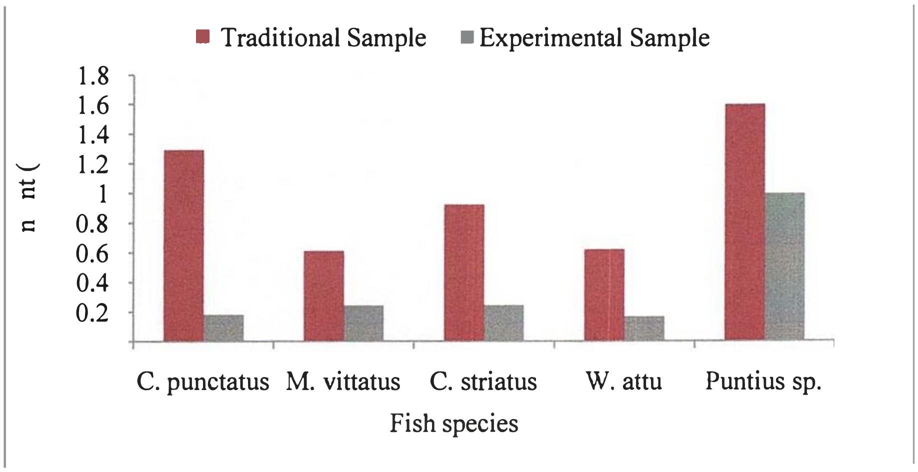


Fig.5.1 Lead content in different fishes

5.3.1.2. Cadmium content

In most cases, except *W. attu*, cadmium content in traditional sample was relatively higher compared to other one; however, the maximum level in terms of traditional sample was 0.02(*C. punctatus*) followed by 0.018 (*C. striatus*), .016 (*M. vittatus*), 0.015 (*Puntius* sp.) and 0.014 µg/g (*W. attu*), and in case of experimental sample cadmium concentration was 0.018(*W. attu*), 0.015 (*C. punctatus*), 0.012 (*Puntius* sp.), 0.012 (*C. striatus*) and 0.009 µg/g (*M. vittatus*) (Table 5.1 and Fig.5.2).

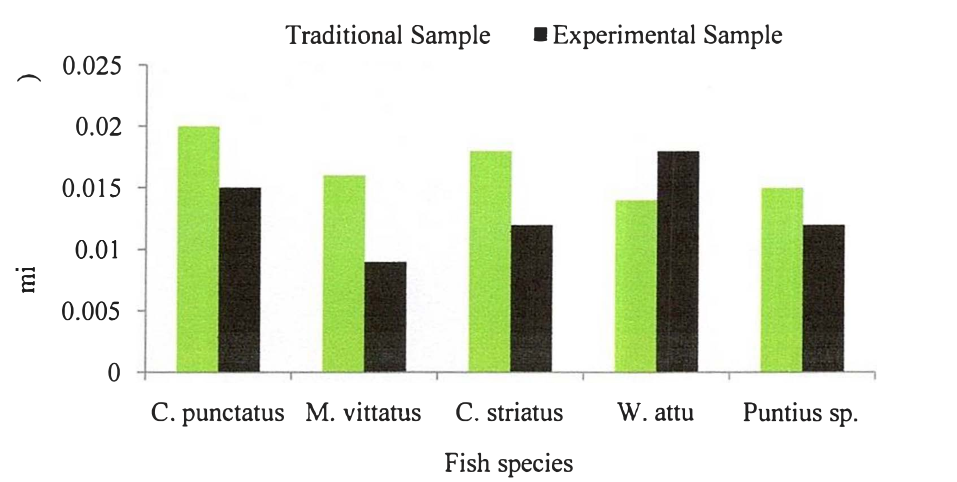


Fig.5.2 Cadmium content in different fishes

5.3.1.3. Chromium content

With respect to chromium concentration, the results summarized in Table 5.1 and Fig.5.3 reveal that in most cases the values were more or less similar both in traditional and experimental samples. The chromium content was found as 0.914, 0.729, 0.995, 0.636 and 1.472 µg/g in traditional sample; on the other hand, in case of experimental sample it varied as 1.025, 0.655, 1.089, 0.448 and 1.277 µg/g in *C. punctatus*, *M. vittatus*, *C. striatus*, *W. attu* and *Puntius* sp. respectively.

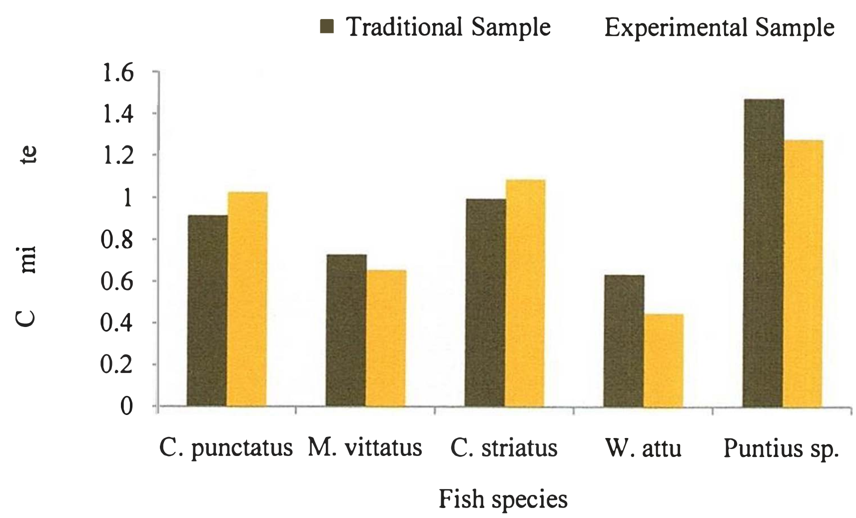


Fig.5.3 Chromium content in different fishes

5.3.1.4. Copper content

According to the findings presented in table 5.1 and Fig.5.4 reveal that the copper content in traditional sample was 3.093, 23.683, 6.683, 28.067 and 6.03 µg/g; however, in experimental sample it was 6.503, 27.523, 6.301, 23.51, and 7.081 µg/g in *C. punctatus*, *M. vittatus*, *C. striatus*, *W. attu* and *Puntius* sp. respectively.

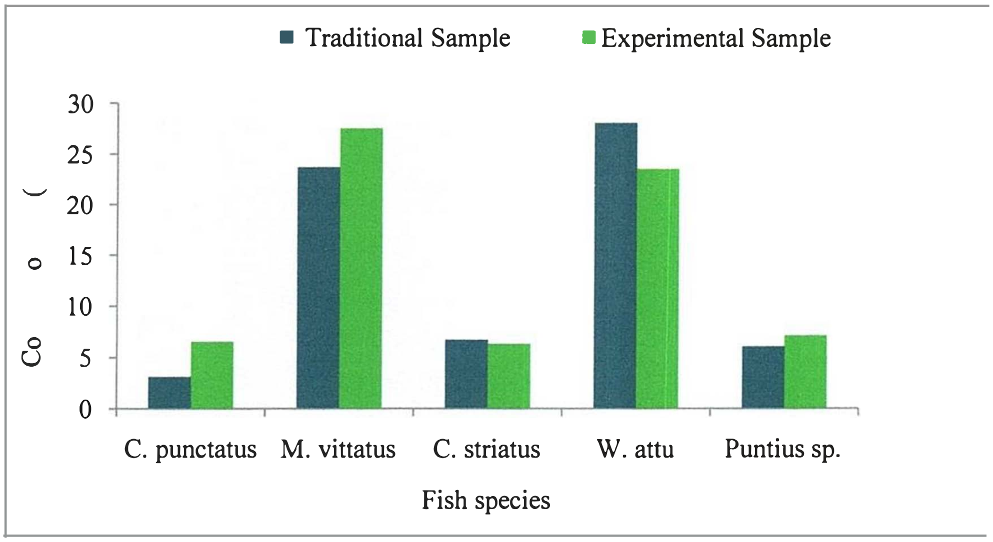


Fig.5.4 Copper content in different fishes

5.3.1.5. Estimated Daily Intake (EDI)

According to the dried fish consumption, the EDI values for heavy metals are given in Table 5.2. The highest (1.46×10^{-2} mg/kg bw/day) EDI was obtained from traditional sample of *W. attu* in terms of Cu and the lowest (4.60×10^{-6} mg/kg bw/day) from experimental sample of *M. vittatus* in case of Cd.

Table 5.2 Comparison of health risk assessments of heavy metals between experimental and traditional dried fish samples.

Species	Methods	Pb		Cd		Cr		Cu	
		EDI	***THQ***	***EDI***	***THQ***	***EDI***	***THQ***	***EDI***	***THQ***
C. punctatus	Exp.	9.30×10^{-5}	0.026	7.80×10^{-6}	0.008	5.33×10^{-4}	0.0004	3.38×10^{-3}	0.024
	Trd.	6.70×10^{-4}	0.187	1.00×10^{-5}	0.010	4.75×10^{-4}	0.0003	1.60×10^{-3}	0.011
M. vittatus	Exp.	1.23×10^{-4}	0.035	4.60×10^{-6}	0.005	3.40×10^{-4}	0.0003	1.43×10^{-2}	0.102
	Trd.	3.10×10^{-4}	0.088	8.30×10^{-6}	0.008	3.70×10^{-4}	0.0003	1.23×10^{-2}	0.088
C. striatus	Exp.	1.25×10^{-4}	0.035	6.20×10^{-6}	0.006	5.66×10^{-4}	0.0004	3.27×10^{-3}	0.023
	Trd.	4.77×10^{-4}	0.134	9.36×10^{-6}	0.009	5.17×10^{-4}	0.0003	3.47×10^{-3}	0.025
W. attu	Exp.	8.50×10^{-5}	0.023	9.36×10^{-6}	0.007	2.30×10^{-4}	0.0002	1.22×10^{-2}	0.087
	Trd.	3.20×10^{-4}	0.089	7.28×10^{-6}	0.007	3.30×10^{-4}	0.0002	1.46×10^{-2}	0.104
Puntius sp.	Exp.	5.10×10^{-4}	0.145	6.20×10^{-6}	0.006	6.64×10^{-4}	0.0004	3.68×10^{-3}	0.026
	Trd.	8.30×10^{-4}	0.232	7.80×10^{-6}	0.008	7.65×10^{-4}	0.0005	3.13×10^{-3}	0.022

Note: Exp. = Experimental sample, Trd. = Traditional sample, *EDI* = Estimated Daily Intake (mg/kg bw/day) and *THQ* = Target Hazard Quotient.

5.3.1.6. Target Hazard Quotient (THQ)

Table 5.2 show the THQs of individual heavy metal through dried fish consumption where the highest (0.232) value was observed in traditional sample of *Puntius* sp. for Pb, while the lowest (0.0002) was in both traditional and experimental sample of *W. attu* for Cr. In all cases the values were noticeably lower than 1.

5.3.2. Hygiene indicator and pathogenic bacteria in dried fish

With respect to traditional dried fish, total coliform bacteria were found in all samples with the highest value of 4.5×10^3 cfu/g in *Puntius* sp. and lowest as 5.1×10^2 cfu/g in *C· punctatus* whereas in case of experimental sample, total coliforms were detected only in *W. attu* (1×10^2) and *C· striatus* (1×10^2 cfu/g). However, no fecal coliforms were detected in experimentally dried samples. On the other hand, fecal coliform organisms were observed in *C. striatus* (1.5×10^2), *W. attu* (2×10^2) and *Puntius* sp. (2.5×10^2 cfu/g) in case of traditional sample (Table 5.3 and Plate 5.1, 5.2). In addition, both the traditional and experimental dried fish samples were free from pathogenic bacteria like *V. cholerae* and *Salmonella.*

Plate 5.1 Pink colonies of total coliforms in *C. striatus* of traditional sample

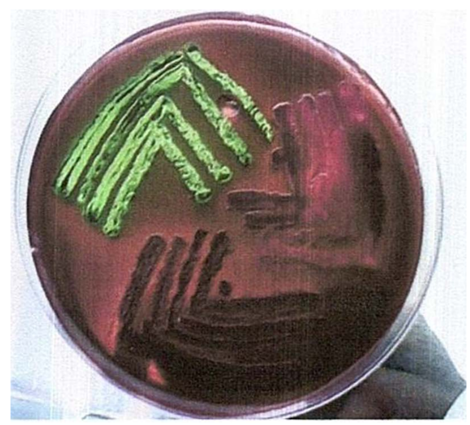


Plate 5.2 Colonies with green metallic sheen for fecal coliforms in W. attu of traditional sample

Table 5.3 Comparative mean microbial count between experimental and traditional dried fish samples

Species	Drying Methods	Total Coliform (cfu/)	Fecal Coliform (cfu/ ;)	*V. cholerae* (cfu/)	*Salmonella* cfu/)
C. punctatus	Ex erimental	0	0	0	0
	Traditional	5.1×10	0	0	0
M. vittatus	Ex erimental	0	0	0	0
	Traditional		0	0	0
C. striatus	Ex erimental		0	0	0
	Traditional		1.5×10	0	0
W. attu	Ex erimental		0	0	0
	Traditional		2×10	0	0
Puntius sp.	Ex erimental		0	0	0
	Traditional	4.5×10	2.5×10	0	0

5.3.3. Pesticide Residue detection

The results obtained from screening of dried fish samples revealed that out of five species collected from traditional drying sites adjacent to *Chaln Beel* area Boal (*Wallago attu*), Taki (*Channa punctatus*) and Shol (*Channa striatus*) contained Chlorpyrifos, chromatograms of which are shown in Fig.5.5-5.9.

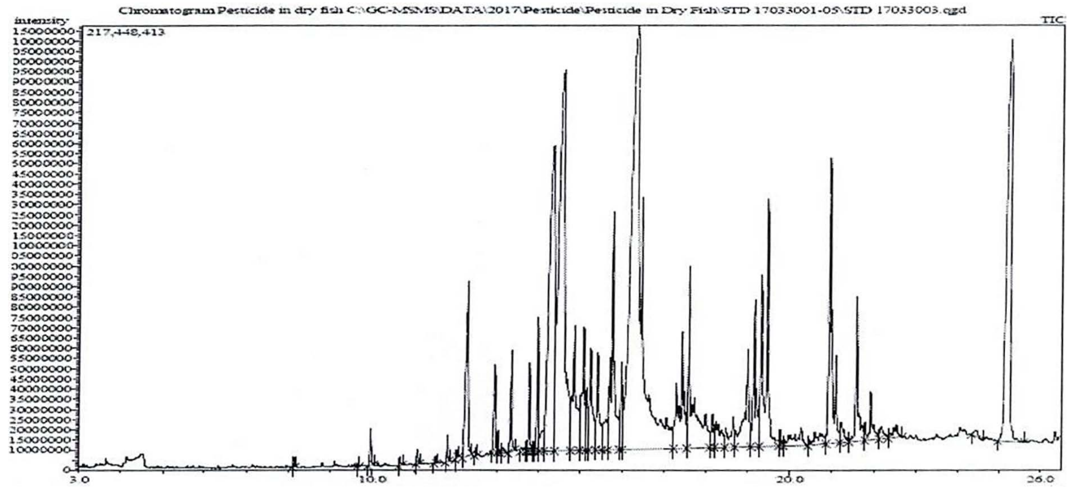


Fig.5.5 Chromatogram of pesticide residue detection for C. *punctatus*

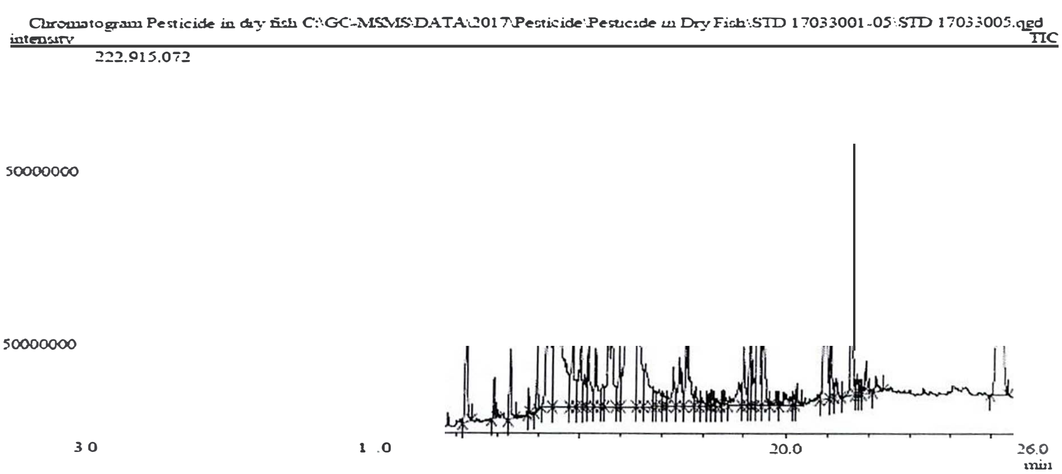


Fig.5.6 Chromatogram of pesticide residue detection for *W. attu*

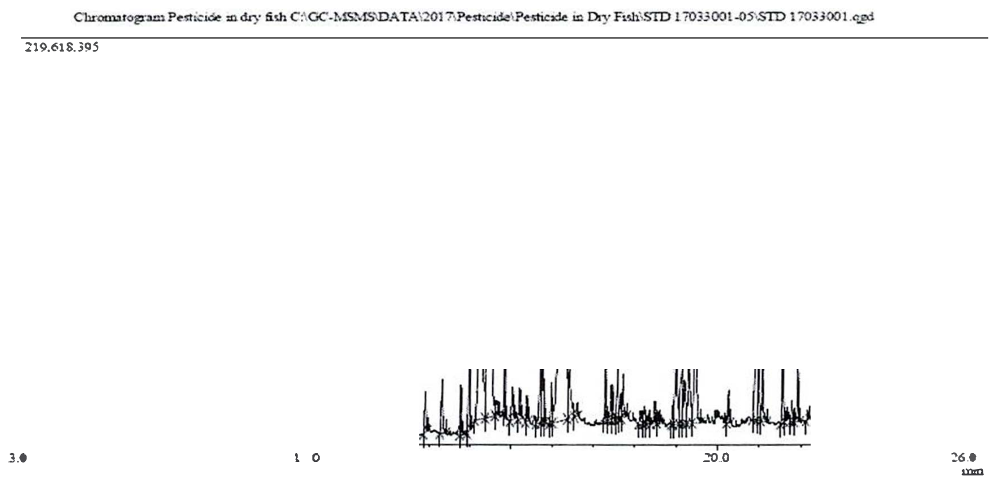


Fig.5.7 Chromatogram of pesticide residue detection for C. *striatus*

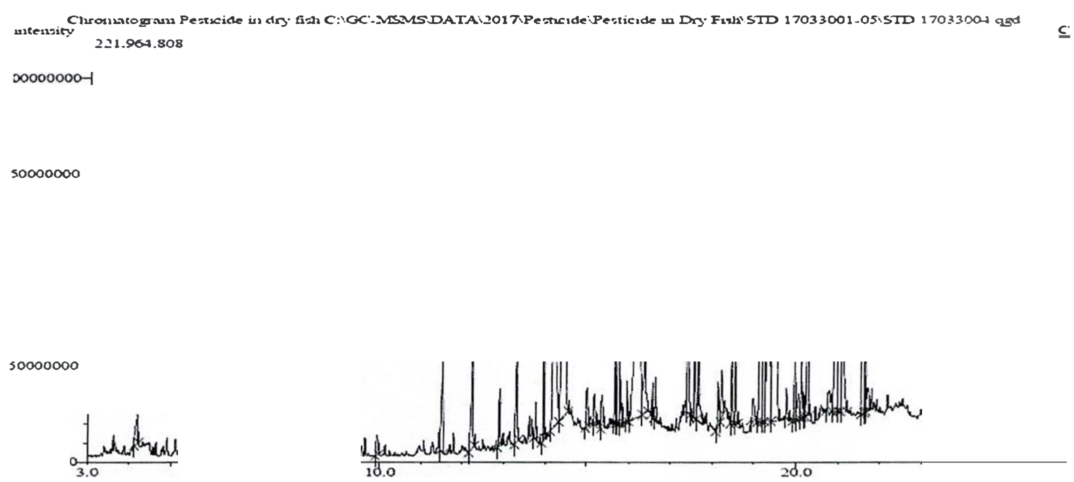


Fig.5.8 Chromatogram of pesticide residue detection for *Puntius* sp.

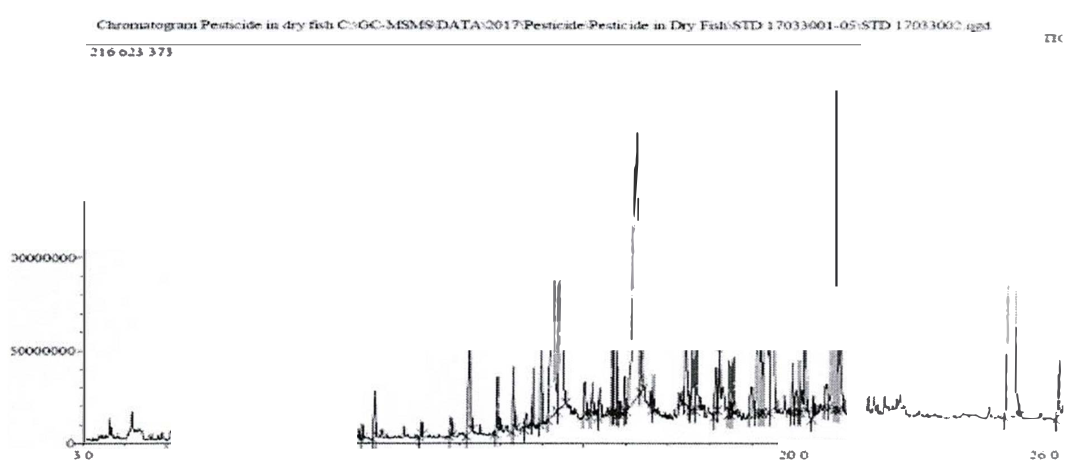


Fig.5.9 Chromatogram of pesticide residue detection for *M. vittatus*

5.4. Discussion

5.4.1. Heavy Metals and its hazard

Fish deposit lead mainly in bones, while soft tissue like heart, gonads and gastrointestinal organs do not show elevated quantities of lead (Bremner, 2002). In the present study, concentration (dry weight basis) of lead was observed to vary from 0.609 (*Mystus vittatus*) to1.595µg/g (*Puntius* sp.) and from 0.164 (*Wallago attu*) to 0.995 µg/g (*Puntius* sp.) in traditional and experimental sample respectively. This finding was considerably lower than the results (1.44 mg/kg in Mozambique tilapia and 23.993 mg/kg in *Catla*) reported by Saha and Zaman (2013); and which also remained within the sprescribed limit where the maximum permitted concentration of Pb for fish proposed by the Australian National Health and Medical Research Council (ANHMRC) is 9.6 mg/kg dry weight (Bebbington *et al.*, 1977; Plaskett and Potter, 1979). This may be attributed to the complete dressing of samples removing gill, viscera, kidney and scales except edible portion as gills and liver is the major sites for accumulation of Pb and kidney is for Cr (Malik *et al.*, 2010). The present results indicate that the method of processing had significant ($P<0.05$) effect on average lead concentration. This variation may be partially attributable to complete removal of scales, skull bone and fins before drying of all experimental samples. However, with respect to traditional sample, only partial dressing (fins and some bones are not removed) was limited to large species where head is partially removed leaving some hard bones in case of *C. striatus, C. punctatus*, while head is totally not removed in *W. attu*, which may be the cause of having relatively higher Pb levels in traditional samples compared to the experimental one. In addition, the observed value were fairly comparable with the mean Pb concentration (2.08 µg/g) recorded in the muscle tissues of the three species of fish from the freshwater Dhanmondi Lake, Bangladesh (Begum *et al.*, 2005), and also with the Pb concentration (0.393 µg/g in muscles of *L. rohita*) observed by Malik *et al.* (2010). Pb content of the present study lied within recommended limit (4 µg/g dry weight) of FAO (FAO, 1983). However, lead content in most of the traditional samples were higher than the legal limit (0.30 mg/kg) set by EU (2008); hence there is a potential risk of Pb poisoning or toxicity when traditional dried fish of these species are consumed for prolonged period.

Cadmium (Cd) is one of the most toxic heavy metals for human beings and its content in the edible part of fish (muscle tissue) is generally very low; fish deposit it in the organs like kidney and liver (Bremner, 2002). Cd was listed as endocrine-disturbing substance and may lead to the development of prostate cancer and breast cancer (Pan *et al.*, 2010). In the present study, Cd level was found to fall within the range from 0.009 (*M. vittatus*) to 0.018 µg/g (*W attu*) in experimental sample, while in traditional sample it belonged in the range of 0.014 – 0.02 µg/g in *W. attu* and *C. punctatus* respectively. In a similar study conducted by Saha and Zaman (2013) revealed that Cadmium concentration was from 0.0223mg/kg in *Catla* to 2.11 mg/kg in *Wallago* (dry weight basis). These values were consistent with the findings of Heing and Tate (1997) who observed Cd content as 0.053 µg/g in *L. rohita* and 0.097 µg/g in *W. attu*. Besides, present results were comparable with the findings (0.0004 µg/g) reported by Amirah *et al.* (2013). Similarly, Olatunde *et al.* (2013) observed that the highest Cd concentration was 0.081mg/Kg in smoked *Chrysichthys nigrodigitatus*. According to the ANHMRC (Bebbington *et al.*, 1977) and Western Australian Food and Drug Regulation (Plaskett and Potter, 1979), maximum limit of cadmium in fish is 2.0 and 5.5 mg/kg fresh weight, respectively. In addition, average concentration of Cd in this study was lower than the prescribed limits (0.1µg/g.) of European Union (EU) standard (2008). A possible explanation to this could be due to the fact that Cd is easier to leach from fish muscle (Hanamaka, 1981). Moreover, with respect to Cd content for individual species, mean values were observed to vary significantly ($P<0.05$) in case traditional and experimental samples.

Cr plays an important role in glucose metabolism. With respect to experimental samples, Chromium concentration was recorded from 0.448 (*W. attu*) to 1.277 µg/g (*Puntius* sp.), while in traditional sample it ranged from 0.636 (*W. attu*) to 1.472µg/g (*Puntius* sp.) which conformed to the findings of Saha and Zaman (2013) where Cr content was 0.422 mg/kg in *L. rohita* and 1.225 mg/kg in *Catla*. Chromium concentration in the muscles of different fresh frozen fish of Korea was recorded between 0.10 and 1.03 mg/kg and in canned fish between 0.09 and 1.32 mg/kg (Islam, *et al.*, 2010), which agree well with the present result. Recorded Cr concentration values of the study were in agreement with the observations made by Malik *et al.* (2010) who reported Cr concentration as 0.218µg/g in muscle of *L. rohita* and also observed that its level considerably varied in respect of different organs (kidney was the major site for Cr accumulation followed by liver, gills and muscles) serving as a site for accumulation. In a similar study on smoked dried fish by Edosomwan *et al.* (2016), Cr concentration was 0.11 and 0.26 mg/kg in *Claria gariepinus* and *C. obscura* respectively, which was lower than the present values. However, the results of this study regarding Cr were below the threshold values (2 μg/g dry weight) set in FAO standard (FAO, 1983). Apart from *C. striatus*, mean values of Cr content for individual species were observed to differ significantly ($P<0.05$) in case traditional and experimental samples.

Copper is not toxic for humans in low concentrations and is an essential element for the human being (Linder and Hazegh-Azam, 1996). Cu is an essential part of several enzymes and is necessary for the synthesis of haemoglobin; however, very high intake of Cu is likely to cause adverse impact to health (Sivaperumal et al., 2007). In traditional sample, Copper concentration belonged in the range from 3.093 (*C. punctatus*) to 28.067 μg/g (*W. attu*), whereas in case of experimental sample it varied from 6.301 (*C. striatus*) to 27.523 μg/g (*M. vittatus*), which are comparable with the values (3.36 - 6.34mg/kg) observed by Ahmad *et al.* (2010). Another study (Zingde *et al.*, 1979) reported that the Cu concentration ranged between 2.80 and 12.40 ppm in different fish species and other study (Khan *et al.*, 1987) observed that Cu varied between 0.65 and 58.1 mg/kg on a (dry weight basis) for five different species of fish in the Bay of Bengal region of Bangladesh coast, in addition, results of one research (Amin *et al.*, 2011) reveals that Cu content remained from 1.48 to 21.30 μg/g, all of which agree well with the present results. This finding was also comparable with another research conducted in urban pond of Rajshahi (Ahmed, 2014). Bremner (2002) reported that the concentration of copper in fish muscle is at an average 0.2-0.5mg/kg (wet basis) while excessive copper is stored mainly in the liver followed by scales, spleen, kidney and gills. However, present results revealed that Cu concentration in *W. attu* and *M. vittatus* was higher than the threshold values (10 μg/g dry weight) set by FAO (FAO, 1983).

The Estimated Daily Intake (EDIs) of four individual heavy metals from dried fish samples were considerably below the Reference Doses (RfD) values recommended by the international regulatory bodies. The oral Reference Doses (RfD) for Cu, Pb, and Cd suggested by FAO/WHO (2006) was 0.14, 0.00357 and 0.001 mg/kg bw/day, respectively; and for Cr the prescribed dose is 1.5 mg/kg bw/day (USEPA, 2009). The RfDs represent an estimate of the daily exposure to which the human population may be continually exposed over a lifetime without an appreciable risk of deleterious effects (Saha and Zaman, 2013).

The result indicates that there are no THQ values above one (1) suggesting that consumer would not experience significant health risks regarding non-carcinogenic toxic effect if they only ingest individual heavy metal through the dried fish of *Chalan Beel* area. In a similar study on dried fish, Edosomwan *et al.* (2016) reported that the EDIs were quite low and below the recommended standard for metals in fish and the THQ were all below one (1) which suggests no potential risk.

5.4.2. Hygiene indicator and pathogenic bacteria

Coliform bacteria are commonly used as indicators of sanitary quality of food and water. They do not normally cause serious illness. Normally coliforms are normal flora of human and animal intestine (Kakatkar, 2010). In fact, presence of coliforms can act as an indicator for other fecal origin pathogenic organisms (Sivashanthini *et al.*, 2012). In case of dried fish, the presence of coliforms indicates that fish is handled and processed or dried under unhygienic condition. However, good manufacturing practices significantly contribute to reducing the occurrence of coliforms (Relekar *et al.*, 2014). In the present study, the fish dried employing experimental methods were free from total coliforms except *C striatus* (1×10^2) and *W. attu* (1×10^2 cfu/g), whereas with respect to traditionally dried fish, total coliform organisms were found at comparatively elevated level with the highest value of 4.5×10^3 cfu/g in *Puntius* sp. and lowest as 5.1×10^2 cfu/g in *C. punctatus.* However, no fecal coliforms were detected in experimental samples. On the contrary, it was present in *C striatus* (1.5×10^2), *W. attu* (2×10^2) and *Puntius* sp. (2.5×10^2 cfu/g) in terms of traditional sample. This may be attributed to use of clean potable water for washing of fish and maintaining totally hygienic conditions during experimental drying. In contrast, the cause of relatively higher content of coliforms in traditionally prepared sample may be poor handling and processing, unhygienic drying conditions and use of *beel* water for washing which is usually subjected to various types of contaminations during flood. In a similar study, the total coliforms varied from 0 to 3.8×10^3cfu/g in dried fish of traditional market, which is comparable with the present results. Besides, he also reported that in most cases market sample exceeded accepted limit of total coliform counts (1×10^4 cfu/g) set by Ghana Standard Authority (Francis and Kombat (2013). However, standard value suggested by ICMSF (1982) for total coliform and fecal coliform are 10^2 and 10, cfu/g respectively, while *V. cholera*, *Salmonella* should not present. In the present study, total coliforms count for all traditional samples were beyond the prescribed limit, while most of the experimental samples were devoid of total coliforms other than *C striatus and W. atttu* having counts close to threshold value. This finding also agreed with the observations made by Basu *et al.* (1989) and Silva *et al.* (2002).

Fecal coliform counts of the observed in traditional samples were found to exceed the standard value. The presence of fecal coli- form organisms indicates recent and possibly hazardous fecal pollution. The most common fecal coliform species is *E. coli* (Kabler and Clark, 1960). Sinduja *et al.* (2011) observed that the MPN readings for fecal indicators varied with the seasons. In a Similar study Flowra *et al.* (2017) reported that market sample of dried fish had fecal coliforms like *E. coli* whereas experimentally prepared dried samples were free from this type of contamination, which supports the present findings in respect of fecal contamination since presence of *E. coli* is considered as an indicator of fecal contamination. This finding was also consistent with the observations of Patterson and Ranjitha (2009) who reported that total plate count and *E.coli* counts were higher in commercially sun dried fish in Tuticorin local market than that of experimentally sun dried, and attributed the fact to unhygienic method of processing. Balachandran (2011) also opined in this connection that avoiding fishing in contaminated water, maintenance of proper hygiene, sanitation and disinfection of handling or other equipments etc. are the preventive measures to be adopted. In a previous study Kombat *et al.* (2013) reported coliform organisms were not detected in raw fish used to produce dried fish as this sample was devoid of coliform contamination from earlier and also suggested that just drying is not enough to get rid of some bacteria like *B. cereus* from an already contaminated raw materials and therefore, the use of high quality fresh fish and hygienic processing approach is necessary to produce quality processed fish products. The results from this study, however, may have been because the raw materials were likely to get contaminated with coliforms after its arrival at the processing site either before or after it had been dried. Besides, Obodai *et al.* (2011) recorded higher coliforms loads in the dried fish of retail markets than those from the processing house, which also might have been the case in terms of present findings. They also attributed their observation to poor handling, packaging, transporting and storage conditions of processed fish.

Present investigation revealed that both the traditional and experimental samples were devoid of *V. cholerae* and *Salmonella.* This observation regarding absence of the spoilage organisms *Vibrio* sp. and *Salmonella* sp. in the dried fish samples coincided with the findings of Azam *et al.* (2003), Yousuf *et al.* (2007) and Saritha *et al.* (2012). However, Sinduja *et al.* (2011) observed the presence of *Vibrio* and *Salmonella* is influenced in respect of season. In a similar study, in post monsoon season *Salmonella* contamination was detected in few samples and *Vibrio* was observed in most of the samples. Contamination of fish and fishery products with *Salmonella* and *Vibrio* has also been reported by many researchers in different parts of India (Bandekar *et al.*, 1995; Iyer and Shrivastava, 1989). Incidence of pathogens in the samples of dried fish market may be attributed to external contamination and poor handling at ambient temperature (Jedah *et al.*, 1998).

5.4.3. Pesticides residue

Presence of pesticides in dried fish is one of the important issues contributing to undermining food safety and quality of fisheries products. According to the results of the present study out five species Chlorpyrifos residue was detected in Boal (*W. attu*), Taki (*C. punctatus*) and Shol (*C. striatus*) which were collected from traditional fish drying sites adjacent to *Chaln Beel* area. In a similar study, Bhuiyan *et al.*, (2009) found residues of organochlorine pesticides like DDT and Heptachlor in six dried fish of Bangladesh. It is known that Chlorpyrifos is a broad-spectrum, chlorinated organophosphate (OP) non-systemic insecticide which kills insects upon contact by affecting the normal function of the nervous system by inhibiting the breakdown of acetylcholine (ACh), a neurotransmitter (Smegal, 2000). Moreover, Chlorpyrifos is metabolized in the human liver to the active metabolite, chlorpyrifos oxon, which produces neurotoxicity by inhibiting esterases in the peripheral and central nervous system (Richardson, 1995). However, some experimental studies have detected chlorpyrifos-induced mutagenicity also (Waters, *et al.*, 1980; Patnaik and Tripathy, 1992). Present results indicated that as large and fleshy fish are more likely to be attacked by insects, probable occurrence of pesticidal residue is more in those species. Nowsad (2007) mentioned that as most of the hazardous pesticides inevitably results in detrimental effects, the uncontrolled use of such insecticides in dried fish could cause serious consequences for consumers and dried fish processor.

Chapter 6

Assessment of Shelf-life of Dried Fish

Chapter 6

Assessment of Shelf-life of Dried Fish

6.1. Introduction

Improving food quality along with extended shelf-life is one of the major issues for food processing activities, particularly for fish processing entrepreneurs. The fish are most likely to get spoiled within shorter period after harvest and because of having highly perishable nature compared to other animal protein sources it becomes susceptible to autolysis, oxidation and hydrolysis of fats and microbial spoilage (Frazier and Westhoff, 2008). In order to prevent spoilage and preserve fish for longer period, different preservation technique is employed and among those drying is simplest and ancient method which has been traditionally practiced in many developed countries, and it has still significant importance in the less developed regions of the world (Waterman, 1976).

During monsoon when relative humidity is comparatively higher complete drying with expected moisture level is not obtained in traditional methods which facilitates microbial growth and contributes to reducing shelf-life of dried fish (Azam, 2002). In addition to that, the quality of dried fish as well as its shelf-life is adversely affected by the onset of microbial proliferation accompanying chemical changes including hydrolysis of carbohydrates, proteins and fats to simpler forms, which are ultimately utilized by bacteria and other microorganisms (Frazier and Westhoff, 2008). Moreover, metabolic activity of microorganisms also results in the spoilage of food through undesirable enzymatic changes affecting the quality of the foods, which include the formation of products developing off-flavors and affecting the organoleptic and textural quality leading to decline in Shelf-life (Sivasankar, 2010).

Generally, the deterioration of fish or fish products is known to take place mainly because of bacterial activity, which brings about very noticeable changes in the texture, flavor, odor and general appearance of the product resulting in shorter shelf-life. This microorganisms present in fish include those bacteria associated with the raw materials acquired during harvesting, handling and processing (Huss, 2003;

Abraham, 2011). Besides, following the death, several biochemical changes also take place in fish muscle constituents contributing to changes in texture and flavor producing odoriferous compounds as indicators of spoilage or shelf-life (Balachandran, 2001).

The quality and shelf-life of dried fish products depends upon the quality of environment of processing and storage. In order to obtain safe and healthy products, assessment with regards to quality and shelf-life of dried fisheries products is of great importance. During spoilage enzymes resulted from microorganisms can metabolize the amino acids of the fish muscle producing a wide variety of volatile compounds resulting off-flavors or odors. Total Volatile Base Nitrogen (TVB-N) is commonly used as an index for estimation of spoilage. For determining the degree of freshness or extent of spoilage of the fish and fisheries products, the assessment of indicators for spoilage or shelf-life concerned with lipid oxidation, ATP breakdown and the formation of biogenic amines and volatile compounds is done employing sensory methods, microbial methods or by chemical methods such as measuring Total Viable Count (TVC), Total Volatile Base Nitrogen (TVB-N), Peroxide Value (PV) etc. In some cases bio-chemical methods are conducted as complementary in relation to sensory methods (Gulsun *et al.*, 2009; Bremner, 2002). However, according to Azam *et al.* (2003), microbiological and biochemical assessment is necessary for the food safety any processed products; and therefore, like other food products shelf-life assessment of dried fish has appeared to be pre-requisite to ensure the safety and attain consumers' confidence.

In Bangladesh due to lack of necessary attention regarding quality and safety of dried fish, in recent years it is difficult to get quality dried fish products having desired flavor, taste, texture and other nutritional attributes. Saha (2003) reported that in Bangladesh most of the market samples become slightly odorless and some exceed shelf-life where rancid and bitter tastes are developed. Given the problems prevailing throughout the value chain of dried fish products, estimation of shelf-life is significant in respect of ensuring quality products and attaining consumer's satisfaction. Considerable number of researches is available regarding the nutritional quality aspects of different types of dried fishery products found in market, but the scarcity of investigation particularly focusing on measuring quality attributes and determining shelf-life of freshwater dried fish is evident from literature review. Therefore, this study is attempted with an aim to assess the changes of quality indicators for examining shelf-life during storage period.

6.2. Materials and Methods

6.2.1. Sample collection and preparation

Traditional Samples of five dried fish species (*Channa punctatus*, *Mystus vittatus*, *Channa striatus*, *Wallago attu* and *Puntius* sp.) were purchased from adjacent fish drying sites of *Chalan Beel* area namely Tarash, Atrai and Vangura. In traditional sample, *Mystus vittatus* and *Puntius* sp. were not dressed and washed; however, other species such as *Channa punctatus, Channa striatus* and *Wallago attu* under went dressing and washing in the prevailing unhygienic environment of drying yard.

As far as experimental sample is concerned, raw fish were bought from the nearby market of the water body, and all species of which were subjected to washing under tube well water and sun drying in hygienic environment after removal of non-edible parts like viscera, gills, fins and scales. Dressed fish were treated with 5% salt before drying and kept for few hours or until it penetrates and dissolves into fish muscle. Then the samples were subjected to drying in different techniques until the desired moisture level (around 15%) is obtained.

Before making powder samples, collected traditional and experimental dried fish samples were kept in different bucket shaped plastic containers for further biochemical test. Every time during laboratory analysis for shelf life assessment, those samples stored as whole fish were ground with an electric blender and passed through a suitable mesh sieve, and then, the fine powder sample was prepared and kept in separate airtight clean and dry small plastic container at room temperature (27-32°C). Finally, prepared samples were brought to the BCSIR (Bangladesh Council for Scientific and Industrial Research) laboratory, Rajshahi for quality and shelf-life study.

6.2.2. Sensory evaluation

Comparative organoleptic assessment between traditional and experimental dried fish samples was carried out employing hedonic scale grading based on the methods proposed by Peryan and Pilgrim (1957) with slight modification in order to appropriately fit with organoleptic attributes of dried fish namely odour/smell, texture and colour (Appendix table- XIV). A three-member experienced test panel judged the acceptability of dried samples using the scales having following points (Table 6.1). The quality score of 5 was considered as the limit of acceptability.

Table 6.1 Sensory evaluation score (Peryan and Pilgrim, 1957)

Criteria	Range
Like Extremely (LE)	9-10
Like Very Much (LVM)	8-8.9
Like Moderately (LM)	7-7.9
Like Slightly (LS)	6-6.9
Neither Like Nor Dislike (NLND)	5-5.9
Dislike Slightly (DS)	4-4.9
Dislike Moderately (DM)	3-3.9
Dislike Very Much (DVM)	2-2.9
Dislike Extremely (DE)	1-1.9

6.2.3. Determination of TVB-N

Determination of TVB-N by the official method TVB-N was determined based on an adaptation of the current official European steam-distillation method (Official Journal, 1995). The method is based on the extraction of TVB using alkaline solution and the titration of the recovered ammonia as follows: 100gof flesh of homogenized fresh fish sample was weighed and blended with 200 ml of 7.5%tricholoroacetic acid in 2 minutes. The blend was then filtered through Whatman no 1 filter paper to obtain clear extract. Then 25 ml of the extract was pipette into the distillation tube and placed in the distillation flask of semi auto distillation apertures (model UDK-6, Milan, Italy). Then program was started and 30 ml of 10% NaOH and 100 ml of distilled water were added, the apparatus sealed and the end of the steam distillate collected in a flask containing 25 ml of 4% boric acid and few drops of mixed indicator (methyl red/methylene blue 2:1). The steam distillation procedure was continued until 100ml of distillate had been collected. The obtained basic solution was titrated against 0.025 N H_2SO_4 to the end point indicated by a green to pink colour change. The TVB-N content was determined after blank correction that has been determined by the steam distillation of with 25 ml of distilled water sample. The recovery of method was calculated using the spiking of 4 hrs dried (105°C), $(NH4)_2SO_4$ to recovery calculation.

$$\text{TVB} - \text{N (mg/100g)} = \frac{14mg/mol \times a \times b \times 300}{25ml}$$

a = ml of Sulfuric acids

b = Normality of Sulfuric acid

6.2.4. Determination of Peroxide Value (PV)

The method for the determination of per oxide value was described by Egan *et al.* (1981) and adopted from Wood and Aurand (1977). 1g sample oil was weighed accurately into a stopper 250ml conical flask and 20ml of chloroform was then added to dissolve the lipid. The flask was then shaken for 30 seconds. A volume of 50ml of a mixture of acetic acid and chloroform in the ratio of 3:2 was added. One ml saturated aqueous potassium iodide was added and the flask was swirled for about 20 seconds and kept in the dark for 30 minutes. After that period, 100ml of distilled water and 4-6 drops of starch indicator were added and liberated iodine filtrated against 0.002M $Na_2S_2O_3\,5H_2O$. Freshly prepared 1% starch solution was used as an indicator. The per-oxide value was calculated as follows:

Per-oxide value = 2(S-B)/W, mEq/kg of oil

Where, S is sample titre, B is blank titre and W is weight of sample oil in g

6.2.5. Estimation of pH

The pH values were measured taking 1 g sample of the fish flesh which was homogenized in 10 ml of distilled water and the mixture was filtered. The pH of the filtrate was measured using a pH meter (Lovibond, Senso Direct, p^H110) (Vynke, 1981).

6.2.6. Enumeration of Total Viable Count/ Standard Plate Count (SPC)

The Standard plate count (SPC) was used to enumeration the total visible count sample using plate count agar according to the Standard methods of (AOAC, 1995).0.1ml amount of each dilution (10^1, 10^2, 10^3, 10^4,10^5) were transferred into 3 Petri dishes, of prepared standard plate agar plate, (Dried at 50˚C for 30 minutes), spread thoroughly to give a uniform dispersion of the microbial cell. The plates were incubated in an inverted position at 37˚C for 48 hours, plates with 30 < X > 300 colonies were counted, and the average was multiplied by the relevant dilution factor to give the number of colony-forming units (cfu/g) of original sample.

6.2.7. Statistical Analysis

Data obtained from this study were subjected to analysis using SPSS software (Version 20). A one-way analysis of variance (ANOVA) was used to test the significance of difference in biochemical and sensory attributes of traditional and experimental dried samples throughout the storage period on 1st, 4th and 8th month. The Duncan's Multiple Range Test (DMRT) was used if the means of different groups under comparison were significantly different in the normally distributed data and $P<0.05$ was regarded as statistically significant.

6.3. Results and Observations

The shelf-life of dried fish stored in normal plastic container at room temperature was measured through determination of different indicators of spoilage for storage period up to 1st, 4th and 8th month and the results obtained from this study are summarized in Table 6.2-6.6 and Fig.6.1-6.5.

6.3.1. Sensory evaluation

The results presented in Table 6.2-6.6 and Fig.6.1 from organoleptic evaluation during storage of dried fish samples indicate that there were gradual decline in overall quality characteristics namely odour, flavor, toughness and appearance. This qualitative evaluation reveals that experimental samples obtained comparatively higher acceptability score than that of traditional one. At the beginning of storage on 1st month, the initial average acceptability scores for traditional samples were 8, 8.5, 7.67, 6.50 and 8.25 while for experimental samples these were 9, 9.50, 8.50, 8.33 and 8.83 in *C. striatus*, *C. punctatus*, *W. attu*, *Puntius* sp. and *M. vittatus* respectively. After 4th month of storage sensory scores were recorded with a gradual descending trend and consequently at the end of 8th month this score of traditional sample was likely to drop touching the level of 4.0, 5.42, 3.0, 1.88 and 4.83 whereas in case of experimental samples the score reached to 6.0, 7.25, 5.5, 4.5 and 5.83 for *C. striatus*, *C. punctatus*, *W. attu*, *Puntius* sp. and *M. vittatus* respectively.

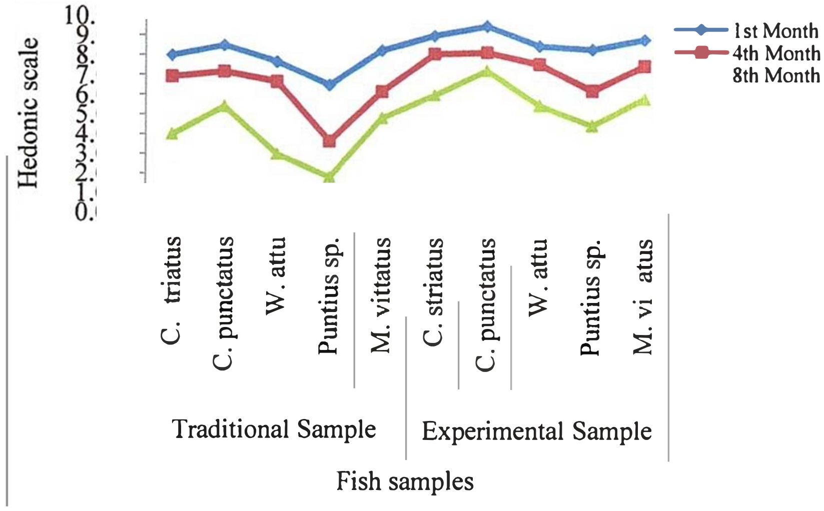


Fig.6.1 Changes in sensory evaluation score in different storage period

6.3.2. Total Volatile Base Nitrogen Content (TVB-N)

The values concerning TVB-N given in Table 6.2-6.6 and Fig.6.2 provide the impression that there were fluctuations and gradual upward tendency in respect of different storage periods. On 1st month, the maximum TVB-N content of traditional samples was 25.20 mg/100g in *C. striatus* followed by 24.3, 22.1, 19.7 and 16.5 mg/100g in *C. punctatus*, *W. attu*, *Puntius* sp. and *M. vittatus* respectively while in experimental samples it was 23.7, 18.8, 20.5, 13.2 and 16.3 mg/100g in *C. striatus*, in *C. punctatus*, *W. attu*, *Puntius* sp. and *M vittatus* respectively. However, in most cases these values were likely to rise gradually in respect of storage period.

Table 6.2 Biochemical parameters for *C. striatus* in different storage period.

Samples	Storage period	TVB-N (mg/100g)	PV (mEq/kg)	SPC (LogCFU/g)	pH	Hedonic scale score 1-10
C. striatus (Trd.)	1st month	25.20±1.25^{e}	17.47±0.66^{d}	3.50±.07^{e}	6.42±0.15^{cd}	8.00±0.50^{b}
	4 month	76.40±1.15^{c}	24.00±1.20^{c}	4.03±0.11^{d}	7.59±0.09^{b}	6.91±0.38c
	8 month	115.40±1.55^{a}	45.50±1.30^{a}	6.19±0.01^{a}	8.05±0.06^{a}	4.00±0.50^{e}
C. striatus (Exp.)	1st month	23.70±1.30^{e}	12.80±0.90^{e}	3.61±0.04^{e}	6.30±0.05^{d}	9.00±0.50^{a}
	4 month	53.50±1.35^{d}	18.20±0.60^{d}	4.19±0.06^{c}	6.55±0.03^{c}	8.08±0.52^{b}
	8 month	89.50±1.10^{b}	38.20±0.70^{b}	5.98±0.01^{b}	7.90±0.07^{a}	6.00±0.50^{d}

After 4th month of storage, in traditional samples TVB-N values remained within 76.4 (*C. striatus*) to 40.7 mg/100g (*M vittatus*) whereas in experimental samples these values ranged from 53.5 (*C. striatus*) to 29.5 mg/100g (*M vittatus*).

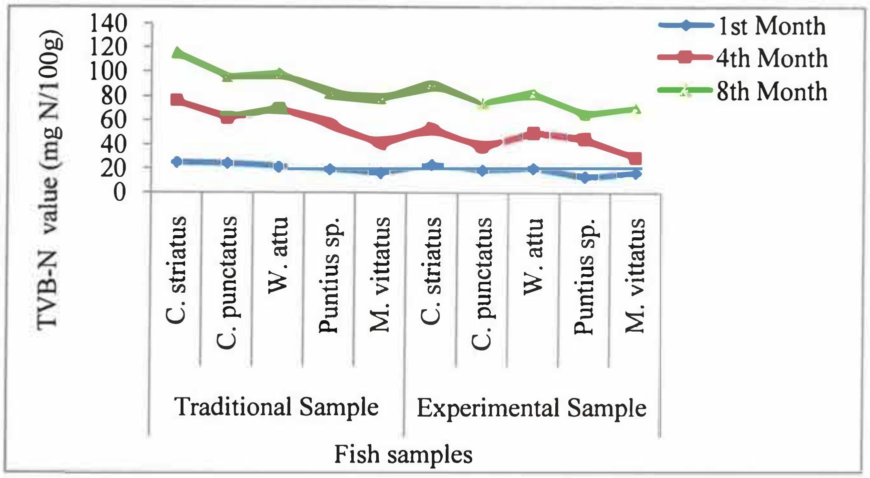


Fig.6.2 Changes in TVB-N contents in different storage period

After 8th month storage of traditional samples, TVB-N values showed steadily upward tendency and rose to 115.5 (*C. striatus*), 95.8 (*C. punctatus*), 98.3(*W. attu*) 82.5(*Puntius* sp.) and 78.2 mg/100g (*M. vittatus*). On the other hand, in terms of experimental sample the values were found to reachas 89.5 (*C. striatus*), 74.5(*C. punctatus*), 82.3 (*W. attu*) 65.45 (*Puntius* sp.) and 70.8 mg/100g (*M. vittatus*) (Table 6.2-6.6).

Table 6.3 Biochemical parameters for *C. puctatus* in different storage period

Samples	Storage period	TVB-N (mg/100g)	PV (mEq/kg)	SPC (LogCFU/g)	pH	Hedonic scale score (1-10)
C. puctatus (Trd.)	1st month	24.30±1.65^e	15.90±0.80^d	3.27±0.09^c	6.45±0.12^d	8.50±0.50^b
	4th month	61.90±1.45^c	21.60±1.15^c	3.87±0.18^b	7.05±0.08^c	7.16±0.28^c
	8th month	95.80±2.30^a	31.60±0.40^a	4.83±0.05^a	7.71±0.09^a	5.41±0.52^d
C. puctatus (Exp.)	1st month	18.80±1.65^f	12.30±0.40^e	3.07±0.01^d	6.20±0.10^d	9.50±0.50^a
	4th month	38.00±1.20^d	20.00±0.60^c	3.97±0.05^b	6.44±0.09^d	8.16±0.28^b
	8th month	74.50±1.30^b	28.25±0.33^b	4.93±0.04^a	7.38±0.01^b	7.25±0.25^c

Table 6.4 Biochemical parameters for *W. attu* in different storage period

Samples	Storage period	TVB-N (mg/100g)	PV (mEq/kg)	SPC (Log CFU/g)	pH	Hedonic scale score (1-10)
W. attu (Trd.)	1st month	22.10±1.85e	13.80±0.95d	4.82±0.08d	6.32±0.08c	7.66±0.57b
	4th month	69.59±1.14c	19.50±0.60c	5.04±0.04c	6.69±0.03b	6.66±0.28c
	8th month	98.30±1.25a	29.50±1.20a	6.36±0.01a	7.39±0.05a	3.00±0.50e
W. attu (Exp.)	1st month	20.50±1.60e	9.20±1.10e	4.38±0.11e	6.02±0.08d	8.50±0.50a
	4th month	49.90±1.40d	16.30±1.20d	4.83±0.07d	6.34±0.05c	7.58±0.38b
	8th month	82.30±1.40b	25.50±0.90b	5.95±0.01b	7.22±0.08a	5.50±0.50d

6.3.3 Peroxide Value (PV)

In the present study, the obtained results summarized in Table 6.2-6.6 and Fig.6.3 illustrates that with various storage period PV values were observed to grow slow but steadily. During the storage of 1st month, in traditional dried fish samples highest PV content was observed as17.47 mEq/kg in *C. striatus* followed by 15.9, 13.8, 9.6 and 8.1 mEq/kg in *C. punctatus*, *W. attu*, *Puntius* sp. and *M. vittatus* respectively while in experimental samples these values recorded were 12.8, 12.3, 9.2, 8.7 and 7.4 mEq/kgin *C. striatus*, *C. punctatus*, *W. attu*, *Puntius* sp. and *M. vittatus* respectively.

Table 6.5 Biochemical parameters for *Puntius* sp. in different storage period.

Samples	Storage period	TVB-N (mg/100g)	PV (mEq/kg)	SPC (Logcfu/g)	pH	Hedonic scale score (1-10)
Puntius sp. (Trd.)	1st month	19.70±1.65e	9.60±2.60c	4.51±0.05b	5.86±0.04bc	6.50±0.50b
	4th month	56.70±1.15c	18.10±1.40b	4.97±0.02b	6.80±0.05a	3.66±0.28d
	8th month	82.50±1.30a	35.40±1.90a	5.72±0.58a	5.75±0.05c	1.83±0.28e
Puntius sp. (Exp.)	1st month	13.20±0.90f	8.70±0.30c	2.93±0.19d	5.44±0.65d	8.33±0.57a
	4th month	44.80±1.45d	15.25±0.90b	3.67±0.06c	5.92±0.03b	6.25±0.25b
	8th month	65.45±1.20b	32.25±0.60a	4.87±0.05b	6.85±0.05a	4.50±0.50c

PV values were found to show slow but gradual upward trend in respect of storage time. After completion of 4th month storage, in case of traditional and experimental samplesthe values reached to 24, 21.6, 19.5, 18.1, 12.2 mEq/kg and 18.2, 20, 16.3, 15.25, 10.7 mEq/k for *C. striatus*, *C. punctatus*, *W. attu*, *Puntius* sp. and *M vittatus* respectively.

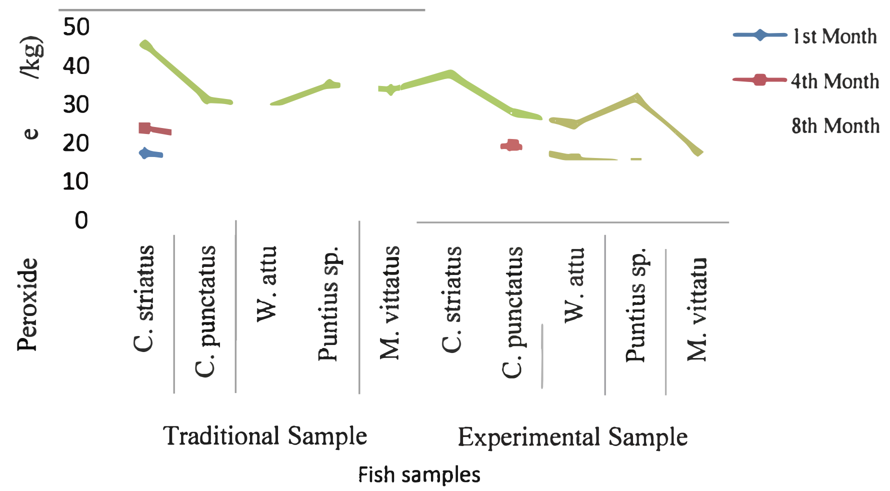


Fig.6.3 Changes in Peroxide Value (PV) in different storage period

At the end of 8th month in traditional sample maximum PV value climbed up to 45.5mEq/kg in *C. striatus*, while minimum value was recorded as 29.5 mEq/kg in *W. attu* whereas with respect to experimental sample it ranged from 38.2 (*C. striatus*) to 18.5 mEq/kg (*M. vittatus*) in that storage period (Table 6.2-6.6).

Table 6.6 Biochemical parameters for *M. vittatus* in different storage period.

Samples	Storage period	TVB-N (mg/100g)	PV (mEq/kg)	SPC (LogCFU/g)	pH	Hedonic scale score 1-10
M. vittatus (Trd.)	1st month	16.50±1.20e	8.10±1.30d	4.65±0.06c	5.49±0.02e	8.25±0.25a
	4tl month	40.70±0.90c	12.20±0.90c	4.99±0.02b	7.21±0.09b	6.16±0.28c
	8 month	78.20±1.30a	34.20±0.80a	5.26±0.03a	7.88±0.08a	4.83±0.25d
M. vittatus (Exp.)	1st month	16.30±1.10e	7.40±1.20d	2.87±0.08e	6.13±0.07d	8.83±0.28a
	4t month	29.50±1.30d	10.70±0.40c	3.86±0.04d	5.97±0.03d	7.50±0.50b
	8 month	70.80±1.40b	18.50±0.30b	4.71±0.03c	6.53±0.15c	5.83±0.24c

6.3.4. Changes in p^H values

The results showed in Table 6.2-6.6 and Fig.6.4 present that in respect of storage duration there was steady rise in pH values for all species except *Puntius* sp. With respect to traditional dried fish samples on 1st month of storage, highest p^H recorded was 6.45 (*C. punctatus*) and lowest was 5.49 (*M. vittatus*), while in experimental samples it was in the range from 6.3 (*C. striatus*) to 5.45 (*Puntius* sp.). In case of all samples slow upward tendency was noticed on 4th month as well.

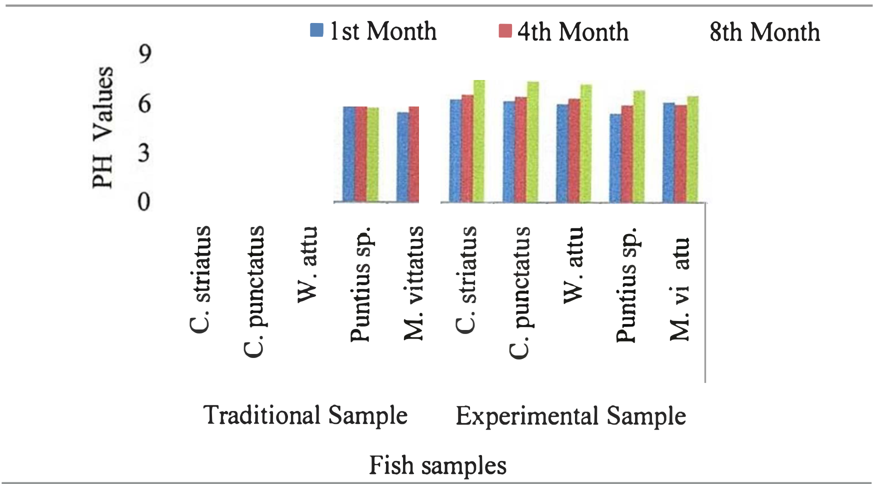


Fig.6.4 Changes in pH values in different storage period

Finally, on completion of 8th month pH in traditional samples varied from 5.75 in *Pintius* sp. to 8.05 in *C. striatus* while in experimental sample it was in the rage from 6.53 (*M. vittatus*) to 7.9 (*C. striatus*) (Table 6.2-6.6).

6.3.5. Standard Plate Count (SPC)

The findings presented in Table 6.2-6.6 and Fig.6.5 describes that bacterial content was found to exhibit rising tendency in terms of storage period. With respect to traditional samples, SPC values on 1st month were 3.50, 3.27, 4.82, 4.51 and 4.65LogCFU/g while in experimental sample these values were 3.6, 3.07, 4.38, 2.93 and 2.87 LogCFU/g in *C. striatus*, *C. punctatus*, *W. attu*, *Puntius* sp. and *M. vittatus* respectively. SPC values were observed to grow with a gradual upward trend in relation to storage duration. Consequently, on 4th month SPC showed steady rise in all samples.

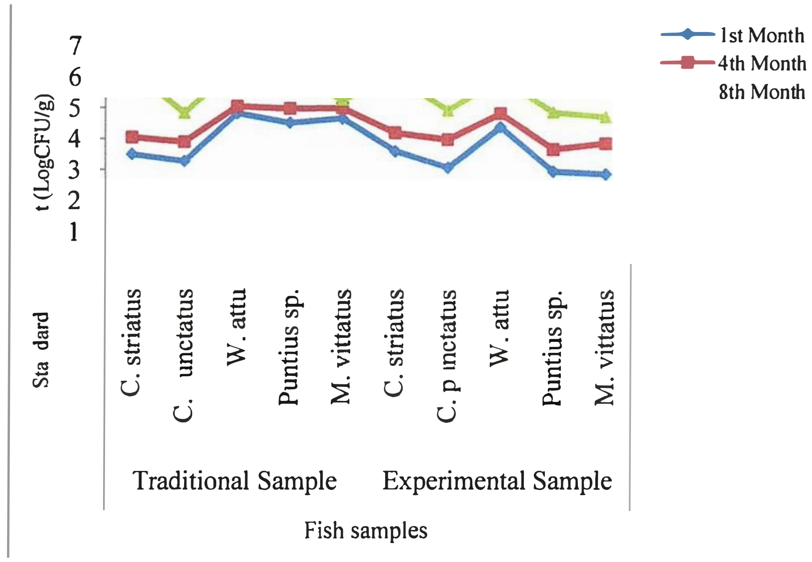


Fig.6.5 Changes in Standard Plate Count (SPC) in different storage period

On 8th month of storage, traditional samples showed higher values than that of previous observation which were 6.19, 4.83, 6.36, 5.72 and 5.26 LogCFU/g, while in case of experimental sample these were 5.98, 4.93, 5.95, 4.87 and 4.71 LogCFU/g in *C. striatus*, *C. punctatus*, *W. attu*, *Puntius* sp. and *M. vittatus* respectively.

6.4. Discussion

In the present study shelf-life of dried fish samples stored in normal plastic container at room temperature was assessed through estimating spoilage indicators like Total Volatile Base Nitrogen Content (TVB-N), Per-oxide Value (PV) and Standard Plate Count (SPC) along with examining p^H and sensory attributes after 1st, 4th and 8th of storage duration. The obtained values of different shelf-life indicators were observed to vary in respect of storage period and species.

Organoleptic evaluation or sensory evaluation of fish and fish products assessed by means of sense organs is very important in determining the consumer acceptability. In this study the evaluation was done by experienced test panel based on some sensory attributes which include odour, flavor, toughness and appearance. There were noticeable changes in organoleptic properties of prepared samples subjected to traditional and experimental drying. Tables for different species show that on 1st month, the initial highest average score in traditional samples was awarded as 8.5 (*C. punctatus*) with 'like very much' rank and lowest as 6.50 (*Puntius* sp.) 'like slightly' rank, while in experimental samples, the highest score was 9.50 (*C. punctatus*) with 'like extremely' rating and the lowest was 8.33 (*Puntius* sp.) with 'like very much' rating whereas after 8th month score of traditional sample was more likely to drop having the highest value 5.42 (*C. punctatus*) with 'neither like nor dislike' remark and the lowest value 1.88 (*Puntius* sp.) with remark of 'dislike extremely', while in experimental samples, with the highest score rated as 'like moderately' was 7.25(*C. punctatus*) and the lowest rated as 'dislike slightly' was 4.5 (*Puntius* sp.). Findings indicate that all the scores with regards to sensory attribute declined steadily throughout the storage period. Same findings have been reported by Joshi *et al.* (2014); Abraha *et.al.* (2017) and Nair *et al.* (1994). With respect to traditional samples, after 8th month of storage, all the samples had mean score below the limit of acceptability except *C. punctatus*; however, in all experimental samples only *Puntius* sp. had the score which was below the preference level. The results of analysis indicated that storage period had significant effect on the sensory properties. As a result, though in appearance some samples appeared with little changes, nevertheless, in respect of panel's preference, there was significant difference ($P<0.05$) in average score of sensory evaluation. This results support the findings of Farid *et al.* (2014c); Chavan *et al.* (2011a). At the end of storage duration most of the traditional samples appeared with yellow brownish colour, less firm texture and objectionable rancid or unpleasant odour, which is an indication of deteriorated quality. The changes of colour and odur possibly take place due to lipid oxidation during storage. However, reaction for appearance is not known, it can be assumed that excessive microbial and enzymatic proteolysis of the tissue causing tissue disintegration (Khuntia *et al.*, 1990). In this investigation sensory evaluation apparently reveals that experimental samples scored comparatively higher acceptability remark throughout the storage time than that of traditional one, which may be due to comparatively lower moisture and salt content of experimental sample. This observation agrees with the sensory evaluation done fish dried in open-sun drying and low-cost solar dryers by Sengar *et al.* (2009) and Rahman *et al.* (2012). Hence, fish dried through improved method following hygienic approach has more acceptability in respect of organoleptic properties and ensuring extended shelf-life.

TVB-N is a universally accepted spoilage indicator having correlation with bacterial growth and its measurement indicates the extent of breakdown of protein due to bacterial and enzymatic action leading to volatile amine production which is responsible for deterioration of odor and flavor in fish (Immaculate *et al*., 2013; Kalakowski, 1986). The present results disclose that at the beginning of 1st month of storage of traditional samples, maximum average value of TVB-N was observed in *C. striatus* (25.20 mg/100g) and minimum in *M. vittatus* (16.5 mg/100g) whereas in experimental sample, the highest TVB-N was in *C. striatus* (23.70 mg/100g) and the lowest in *Puntius* sp. (13.20 mg/100g). However, after 8th month these values for traditional samples were found to belong in the range from 78.2 (*M. vittatus*) to115.5 mg/100g (*C. striatus*), while it varied from 65.45(*Puntius* sp.) to 89.5 mg/100g (*C. striatus*) in experimental samples. This result evidently matches with the findings narrated by Joshi *et al.* (2014) in which TVB-N values for ribbon fish dried in experimental method ranged from 30.5 to 73.23 and 46 to 82.2 mg/100g while, it was from 70.6 to 211.56 mg/100g for dried ribbon fish procured from market at the end of 120 days storage. Thefindings are alsomore or less similar with theresults found in theresearches of Relekar *et al.* (2014) and Flowra (2017). Similar observations regarding TVB-N level of fish in retail market were obtained by other researchers also in which the TVB-N level of fish in retail market was high as 98 mg / 100 g (Iyer *et al*., 1986). Its level of *S. fimbriata* stored at 20°C for 24 hours was 23.9 mg / 100 g and increased to 53.6 mg / 100 g during 4 days of storage (Yamanaka *et al*., 1986); however, normally TVB-N value increased during storage at ambient temperature (Estrada *et al*., 1985).The present results also appeared to be much higher than the levels suggested by Ghaly (2010) where a value of 35mg/100g of TVB-N has been recommended as border line for fish and fish products. However, the values obtained from this research are lower than the prescribed value (100-200 mg/100g) for salted and dried fish products (Connell, 1995; Nowsad, 2007). Besides, while observing the gradual rising pattern, it was noticed that in all samples TVB-N value grows in relation to storage duration. This may be due to the fact that during storage of fish in normal plastic container at ambient temperature, the surface of the dried fish became slightly damp showing that the samples were likely to contain extra moisture. This can be resulted from the breakdown of fish muscles releasing moisture and also moisture uptake from the surroundings (Giyatmi, 1992). And this moisture is also known to support the growth of microorganisms leading to spoilage ultimately resulting in the rise of TVB-N level (Lakshmanan, 2002). The trends of growing TVB-N levels of the present findings are in close association with the research where TVB-N values of the products stored at ambient temperature showed linearly increasing pattern throughout the storage period (Chavan *et al.*, 2011a; Farid *et al.*, 2014b and Srikar *et al.*, 1993). The results also revealed that with respect to storage period, TVB-N value exhibited steadily upward tendency indicating increasing rate of spoilage, which had been evident from the results narrated by Muslemuddin (1970). In addition, analyses reveals that in most cases with respect to fish species, average TVB-N contents for traditionally and experimentally dried fish samples were significantly different ($P<0.05$) in terms of various storage periods. Such trend resembles with the findings reported by Flowra *et al.* (2017).

The Peroxide Value (PV) is a measure of the first stage of oxidative rancidity, and fish lipid being highly unsaturated, is highly susceptible to both autolytic as well as oxidative rancidity (Balachandran, 2001). However, PV sometimes does not necessarily correlate well with the sensory assessment of rancidity (Islam *et al.*, 2005). On the 1st month of storage, in traditional samples the highest per-oxide value (PV)measured was 17.47 mEq/kg in *C. striatus* and the lowest was 8.1 mEq/kg in *M. vittatus* while in experimental samples these values ranged from7.4 (*M. vittatus*) to 12.8 mEq/kg (*C. striatus*). And at the end of 8th month, in traditional sample the maximum PV reached up to 45.5mEq/kg in *C. striatus* and minimum value was recorded as 29.5mEq/kg in *W. attu* whereas with respect to experimental sample it ranged from 18.5 (*M. vittatus*) to 38.2mEq/kg (*C. striatus*). The obtained result reveals that PV was slightly higher in traditional samples compared to experimental one. This may be attributed to comparatively low moisture content of experimental sample which is likely to reduce activity of enzymes and microorganisms. This result is in agreement with the findings of previous study (Immaculate *et al.*, 2012).The present values are similar to the findings reported by Islam *et al.* (2005) who found PV to grow up to 28.2 mEq/kg during 90 days storage. In another research conducted by Haque *et al.* (2013), PV value was observed to reach 39.22 m Eq/kg in traditionally dried fish which is identical to the present results. From the beginning these values showed slow but gradual rising trend however, in the end of 8^{th} month in some samples the values were above the threshold value (20mEq/kg) reported by Connell (1976). Results also exhibited that in most samples PV value was significantly influenced ($P<0.05$) in respect of storage period. This may be due to the storage of samples in non-airtight plastic container at room temperature. Since, the fish oil unexpectedly gets oxidized in the presence of atmospheric oxygen; degree of unsaturation and rise of temperature are influencing factors for enhancing rate of lipid oxidation (Tuschiya, 1961). Also the cause of such lipid oxidation may be the pro-oxidant effect of sodium chloride (Rao and Bandyopadhay, 1983).

Though pH does not serve as a direct index to estimate shelf-life, it acts as an indicator of the extent of microbial spoilage and degree of freshness in fish. Some proteolytic microbes produce acid after decomposition, thereby increasing the acid level of the medium (Eyo, 1993). In the study, the highest p^H for traditional samples recorded was 6.45 (*C. punctatus*) and the lowest was 5.49 (*M. vittatus*) on 1^{st} month, while in experimental samples it was in the range from 6.3 (*C. striatus*) to 5.45 (*Puntius* sp); however, after 8^{th} month in traditional samples it varied from 5.75 (*Pintius* sp.) to 8.05 (*C. striatu*), while in experimental sample it ranged from 6.53 (*M. vittatus*) to 7.9 (*C. striatus*). This result is more or less same with the observations made by (Agab and Shafie, 1989). Similar findings have also been reported by Azam *et al.* (2003a). The fish products remain acceptable up to a pH of 6.8 and are considered to be unsuitable above 7.0 of pH (Huss, 1988; Erkan *et al.*, 2011). At the beginning of storage, initial pH values were similar to the findings of other researchers; however, in the end recorded pH values were comparatively higher. This variation may be attributed to the difference in fish species as well as in amount of salting. Present results regarding pH value showed a gradual but slow growing trend for all species throughout the storage period; however, in case of traditionally prepared *Puntius* sp. slight declining tendency was observed on 8^{th} month. This might be due to excessive use of salt which is responsible for increase of acidic compounds. As *Puntius* sp. is exclusively used for making fermented products (locally known as '*Chapa Sutki*'), traditional processors apply comparatively more salt for this species. This result supports the findings of Farid *et al.* (2014b). In present study, storage period showed significant impact ($P<0.05$) on changing average value of pH, which also agrees with the findings observed by Farid *et al.* (2014a) where pH varied from 6.3 (0 day) to 8.2 (180 days) in *C. striatus*. Continuous rise in pH values both in traditional and experimental samples may be due to the decomposition of nitrogenous compounds leading to an increase in pH of the fish flesh (Shenderyuk and Bykowski, 1989). Generally, the increase in pH indicates the loss of quality. Though, it was also reported that a determination of pH is sometimes unreliable for most species of fish because the end products of spoilage of both alkalineand acidic nature tend to neutralize each other (Stansby, 1963).

The amount of bacterial load in food serves as a spoilage as well as hygiene indicator. In the present study, in case of traditional sample, Standard Plate Count (SPC) on 1st month ranged from3.27 (1.9×10^3cfu/gin *C. punctatus*) to 4.82LogCFU/g (6.7×10^4cfu/g in *W. attu*), while in experimental sample from 2.87(7.6×10^2cfu/g in *M. vittatus*) to4.38LogCFU/g (2.5×10^4cfu/g in *W. attu*). However, at the end of 8th month, traditional samples had SPC from 4.83 (6.83×10^4in*C. punctatus*) to 6.36 LogCFU/g (1.83×10^5cfu/g in *W. attu*) and in experimental sample it rose from 4.71(5.25×10^4cfu/g in *M. vittatus*) to 5.98LogCFU/g (9.63×10^5cfu/g in *C. striatus*). Total plate count showed gradual growing tendency throughout the storage period. This may be because of the fact that during storage in normal plastic container at room temperature, the dried samples were likely to absorb extra moisture due to the hygroscopic nature of salt used in samples. A similar trend was observed by Giyatmi *et al.* (1992) who reported that the breakdown of fish muscles releasing moisture and the moisture uptake from the surroundings promote microbial growth. The rising pattern of bacterial load in present study supports the findings reported by Flowra *et al.* (2017) where total plate count of dried samples increased up to 7.8×10^5after 6th month of storage at room temperature. Mansur *et al.* (1989) reported that the total bacterial count of some traditionally dried Small Indigenous Species (SIS) ranged from 1.0×10^5 to1.5×10^6cfu/g, which are also supported by the present results. It is evident from the statistical analysis that bacterial count is influenced with storage duration and in most cases mean values of which are significantly (P<0.05) different in respect of storage time. The study reveals that bacterial count in experimental samples were lower than that of traditional one which may be attributed to the employment of improved drying techniques along with hygienic environment for preparing experimental samples. This result also supports the findings of Sivashanthini *et al.* (2012) in which total bacterial count recorded was up to 4.67×10^9cfu/g in terms of market samples and 6.42×10^4cfu/g for experimental samples. Number of total bacteria is one of the main factors affecting the quality and shelf-life of perishable food like fish. According to Indian Standard (IS, 2001):14950, the limit for Total Plate Count (TPC) is 1×10^5cfu/g in the dried products. Besides, Surendran *et al.* (2006) reported that at 37°C in fresh fish the acceptable limit is 5×10^5cfu/g but for cooked or dried fish the permissible limit is 1×10^5cfu/g. In this study, at the end of 8th month all samples exceeded the permissible limit except experimental sample of *Puntius* sp. *M. vittatus* and *C. punctatus*. And only traditional sample of *C. punctatus* had bacterial load count within recommended limit after 8th month storage. All the samples had a bacterial count lower than the prescribed acceptable microbial load ($<10^5$cfu/g) given by the International Commission on Microbial Specification for Foods (ICMSF, 1988) and appeared to be of good quality for consumption till the end of 4th; however, only in traditional sample of *W. attu* bacterial count touched the threshold value even after 4th month indicating the poor quality.

Chapter 7

Acceptability and Promotion of Dried Fish products in Different Packaging techniques

Chapter 7

Acceptability and Promotion of Dried Fish Products in Different Packaging Techniques

7.1. Introduction

Dried fish is considered to be a pleasing and appealing food item for a large number of consumers who enjoy it as a delicacy. High quality and safe dried fish products with desired sensory and physical properties are in good demand. However, consumers often express concern regarding the quality of dried fish when it's processing, storage and marketing activities do not meet required standard from food safety and hygiene perspectives. Now-a-days, in Bangladesh like many other countries, impressions and preferences aspects in terms of dried fish consumption are gradually changing due to increase in awareness among large group of consumers, and they are more likely to attach emphasis on quality instead of price and desire that the product should be acceptable in respect of both quality and safety (Islam *et al*., 2005). In recent years, consumers, retailers and producers have demanded improvements in the marketing, storage and handling of fish and fish products (Clucas and Ward, 1996). Regardless of the fish's shelf-life, the consumers are likely to use his or her own standards to evaluate the fish products. In addition, an important factor in consumer acceptance is the nature of the packaging used (Regenstein and Regenstein, 1997). A well dried fish product will go bad if it is not well packaged because of the hygroscopic nature and easy ability of fish to lose oil when exposed to the atmosphere. Appropriate packaging is necessary to maintain the quality of fishery products and customer satisfaction (Folorunsho, 2015). An effective fish packaging material should be able to reduce oxidation and dehydration, provide less bacterial and chemical spoilage, prevent odor permeation and protect the product from physical damage (UNCTAD, 2006).

It is well emphasized that packaging is a very powerful marketing tool, especially in the retail sector. It is used to display information and attract the consumers' attention as well as to protect the quality of the product (Clucas and Ward, 1996). Moisture and oxygen are principally responsible for spoilage of dried fish. They are subject to insect attack and are also likely to suffer from oxidative rancidity when it remains exposed to oxygen resulting in flavor changes. If not packed properly, moisture absorption from air also lead to accelerated spoilage due to bacterial action. Therefore, packaging material of dried fish should be inert in nature, resistant to mechanical abrasion and puncture, and also should prevent gain or loss of moisture, act as a barrier against oxygen (Balachandran, 2001).

The shelf-life of perishable foods as fish is limited in the presence of normal air by two principal factors-the chemical effect of atmospheric oxygen and the growth of aerobic spoilage micro organisms. These factors both individually or in association with one another bring about changes in odour, flavour, colour and texture leading to an overall deterioration in quality. In this case Modified Atmosphere Technique (MAP) is considered effective, in which the replacement of air in a pack with a single gas or mixture of gases is introduced (Church, 1994). Currently, the successful commercial application of MAP for inhibiting spoilage and extending shelf-life of fish products is associated with a number of interrelated factors, such as developments on new food packaging materials including vacuum packaging and gas packaging as a response to consumer demands for products with fresh characteristics, consumer concerns about preservation additives in such products, and favorable consumer perception of MAP technology (Ashie *et al.,* 1996). The vacuum-packaging method represents a static form of hypobaric storage widely used in food industries because of its effectiveness in reducing oxidative reactions in the product at relatively low cost (Gopal *et al*., 1999). Vacuum packaging is used for long-term storage of dry foods and the shelf-life extension of seafood. The product is packed in a vacuum package, which has good barrier properties towards oxygen and water and can be easily sealed. Air is removed under vacuum and the package is sealed. Gas packaging is commonly used for processing and preserving fresh fish and shellfish. MAP has proven to extend the shelf-life and retard the deterioration of seafood under refrigeration (Payap, 2011).

In modified atmosphere technique, the first concern is the gas used and the first choice is to simply remove all the air, which is known as vacuum packaging and it requires gas barrier packaging films or polyester (Regenstein JM and Regenstein CE., 1997). In this case, the removal of oxygen reduces aerobic bacterial spoilage, fat oxidation and rancidity, and therefore extends the shelf-life. In modified atmosphere packaging, the products are treated with the mixture of gases like carbon dioxide, oxygen and nitrogen. The composition of gas mixture varies depending upon the composition of fish- whether the fish in the pack is lean or oily. Naturally, oxygen sustains basic metabolism and minimize the possibility of aerobic spoilage; carbon dioxide inhibits bacterial and mold activity; and nitrogen is chemically inert and prevents rancidity, mould growth and insect attack by displacing oxygen (Nowsad, 2007). Nitrogen is an inert tasteless gas, which displays little or no antimicrobial activity on its own. In addition, N_2, by displacing O_2 in the pack, can delay oxidative rancidity and also inhibit the growth of aerobic micro organisms. Nitrogen can also indirectly influence the micro organisms in perishable foods by retarding the growth of aerobic spoilage organisms (Farber, 1991). Besides, packing of fish in special mixtures of gases may extend shelf-life by up to 30%, provided that the temperature is kept below +2° C (Clucas and Ward, 1996).

In this study, organoleptic or sensory method has been employed which is generally used to assess the degree of freshness or quality attributes based on some orgaoleptic characteristics such as odor, colour, consistency of flesh, general appearance, eyes, slime etc. However, with respect to dried fish, all of these characteristics are not applicable. Usually, these characteristics are judged by panel members and the changes in quality of fish are assessed with certain interval during storage. In such sensory methods, subjective judgments are made by individuals. In this sensory assessment method, numerical scoring or ranking systems have been developed in order to evaluate the judgment (Nowsad, 2007).

In traditional storage and marketing the dried fish is kept in improper and unsanitary ways. It is usually stored in gunny sacs made of jute or plastic or in bamboo made baskets; sometimes it is kept on raised bamboo rack under a tent for short time storage before marketing, which makes the dried products vulnerable to rancidity, moisture absorption, infestation and contamination. Besides, proper packaging is not practiced both in wholesale and retail marketing of dried fish. As a result, the products become more likely to be infested by beetles and mites which results in quality deterioration. To avoid such infestation processors sometimes commit deliberative abuse of hazardous pesticide posing threat to public health. Therefore, proper packaging is of immense importance for ensuring quality and safety of dried products.

Proper packaging can not only protect dried fish from contamination and insect infestation during storage, transportation, handling and marketing, but also contributes to enhancing consumer preference and keeping products quality intact. Various researches focusing on different aspects like nutritional qualities, processing techniques of dried fish have already been attempted; however, very scant attention has been paid on the packaging of dried fish. Therefore, in order to promote the storage and marketing of dried fish with various packaging approaches, the present research was intended to evaluating the performance of different packaging techniques such as vacuum, nitrogen and normal sealed air packaging by determining organoleptic or sensory attributes.

7.2. Materials and Methods

Experimentally prepared sun-dried fish (treated with 5% salt) samples of five species were subjected to different packaging techniques such as vacuum, nitrogen and normal sealed air packing and open pack without sealing, which were stored in room temperature. However, before packing all the surface bones and sharp spines were carefully removed in order to avoid puncture and prevent damage through mechanical abrasion. The pack had thickness of 0.20 mm having three layers (Polyethelene/Polyvenyle/Polyethelene) and impermeable in nature with the size of 12×8 inch. Vacuum and nitrogen packaging were done by Multivac packaging machine (Multivac-87787 Wolfertschwenden, Germany). This packaged dried fish underwent organoleptic assessment after certain interval (Plate 7.1 and 7.2 a-d).

Plate 7.1 Vacuum and N_2 packaging by Multivac packaging machine

7.2.1. Organoleptic assessment

Sensory analysis is the most used traditional method for fish quality judgment. In this study, organoleptic assessment of dried fish samples was carried out on 1st, 4th and 8th month employing hedonic scale grading based on the methods proposed by Peryan and Pilgrim (1957) with slight modification in order to appropriately fit with organoleptic attributes or sensory characteristics of dried fish such as odour/smell, texture and colour (Appendix Table-XIV). A ten-member assessors/consumers from different segments of the society comprising teacher, student, housewife, chef, doctors, engineer, banker, businessman, shopkeeper, day laborer judged the acceptability of dried fish samples using the scales having following points (Table 7.1). A sensory score of 5 was considered as the acceptability borderline.

Table 7.1 Sensory evaluation score (Peryan and Pilgrim, 1957)

Criteria	Range
Like Extremely (LE)	9-10
Like Very Much (LVM)	8-8.9
Like Moderately (LM)	7-7.9
Like Slightly (LS)	6-6.9
Neither Like Nor Dislike (NLND)	5-5.9
Dislike Slightly (DS)	4-4.9
Dislike Moderately (DM)	3-3.9
Dislike Very Much (DVM)	2-2.9
Dislike Extremely (DE)	1-1.9

8.3. Results and Observations

During present study, experimentally prepared high quality sun-dried fish with excellent sensory and physical properties were stored in different packaging methods at ambient temperature in order to assess the overall changes in sensory scores. There were noticeable changes in color, odor and texture in different dried fish samples which were subjected to various packaging techniques. Results summarized in the table showed that with the lapse of 8 month storage time most of the samples stored in air sealed and open pack produced faded fishy and rancid odor with faded whitish and yellowish color having relatively soft, semi-elastic and less-firm texture. Fungal attack was observed in open, air sealed and nitrogen pack; however, in vacuum pack no fungus was noticed. In addition, in some samples, particularly in open pack of *C. striatus* and *W. attu* were observed to suffer from beetle infestation to a little extent (Table 7.2, Plate 7.2 a-d and 7.3).

Table 7.2 Sensory attributes observed in dried fish in different packaging after eight months storage.

Species	Packaging method	Smell/ Odor	Colour	Texture
Puntius sp.	Vacuum	Moderately salty and fishy odor	White and light yellowish with glazing oily surface	Slightly soft and moderate flexible
	N_2 pack	Slightly faded fishy odor	Off-white with slight fungus attack	Slightly soft and semi-firm
	Air pack	Distinctive fishy and prominent rancid odor	Whitish with fungus	Semi-firm and moderately soft
	Open	Dominant rancid and off odor	Slight yellowish and faded brown with moderate fungus	Comparatively soft and fragile
M. vittatus	Vacuum	Characteristic fishy odor	Light brownish with slight glazing oily	Slightly tough and semi-elastic
	N_2 pack	Slight fishy odor	Whitish and fade yellow	Slightly soft and semi-firm
	Air pack	Slight fishy and rancid odor	Whitish yellow	Slight soft and less flexible
	Open	Slightly off and rancid odor	Yellowish brown	Relatively soft and less firm but brittle
C. punctatus	Vacuum	Flavorful fishy and characteristic salty odor	Whitish with slight glazing	Firm and slight elastic or flexible
	N_2 pack	Slight fishy odor	Whitish with slight fungus	Firm and not flexible
	Air pack	Slightly Faded fishy odor	Fade whitish with moderate fungus	Nearly firm and flexible
	Open	Slight rancid and faded odor	Fade with more fungus	Comparatively soft and slight flexible
C. striatus	Vacuum	Distinctive fishy and salty odor	Whitish with slight reddish	Slightly tougher, shrunken and semi-flexible
	N_2 pack	Slight fishy odor	Yellowish white with slight fungus	Slightly soft, shrunken and semi elastic
	Air pack	Moderate fish odor	Yellowish brown with fungus	Slightly soft, shrunken and semi-flexible
	Open	Faded fishy odor	Faded reddish white with more fungus and very few beetle attack	Comparatively soft, shrunken and semi-elastic
W. attu	Vacuum	Slight salty and fishy odor	Whitish with slight glazing	Comparatively tougher, shrunken and elastic
	N_2 pack	Slightly faded fishy odor	Whitish brown with slight fungus	Slightly tougher, shrunken and elastic
	Air pack	Slightly faded and rancid odor	Faded whitish or yellowish light brown with more fungus	Slightly tougher, shrunken and elastic
	Open	Slightly off odor and distinctive rancid odor	Faded off-white and yellowish light brown with huge fungus and few beetle infestations	Less tougher, shrunken and semi-elastic

During storage, sensory evaluation based on hedonic scale score revealed that on 1^{st} month sensory scores were same in all packing for individual species, while on 4^{th} month highest score (8.20±0.35) was observed in terms of vacuum pack in *C. punctatus* by 8.08±0.47, 7.45±0.44, 7.15±0.34 and 7.05±0.28 in *M. vittatus*, *C. striatus*, *W. attu* and *Puntius* sp. respectively whereas on 8^{th} month of storage vacuum pack demonstrated comparatively satisfactory performance with the sensory score of 7.10±0.57, 6.05±0.80, 5.40±0.52, 5.23±0.45 and4.80±0.42in *C. punctatus*, *C. striatus*, *M. vittatus*, *Puntius* sp. and *W. attu* respectively (Table 7.3 and Fig.7.1).

a. Vacuum package

b. Nitrogen package

c. Air package with normal sealing

d. Open package without sealing

Plate 7.2 (a-d) Dried fish in Different packaging techniques

Table 7.3 Sensory evaluation based on hedonic scale score of dried fish in different packaging and storage duration.

Species	Packaging method	Hedonic scale score on 1st month	Hedonic scale score on 4th month	Hedonic scale score on 8th month
Puntius sp.	Vacuum	8.40±0.39	7.05±0.28	5.23±0.45
	N_2 pack	8.40±0.39	6.45±0.44	3.95±0.55
	Air pack	8.40±0.39	6.30±0.35	3.70±0.63
	Open	8.40±0.39	6.10±0.46	2.88±0.43
M. vittatus	Vacuum	8.85±0.24	8.08±0.47	5.40±0.52
	N_2 pack	8.85±0.24	6.55±0.44	4.10±0.46
	Air pack	8.85±0.24	6.50±0.41	3.80±0.59
	Open	8.85±0.24	6.30±0.35	2.90±0.46
C. punctatus	Vacuum	9.48±0.32	8.20±0.35	7.10±0.57
	N_2 pack	9.48±0.32	7.15±0.24	4.95±0.50
	Air pack	9.48±0.32	7.10±0.32	4.80±0.54
	Open	9.48±0.32	6.90±0.57	3.95±0.55
C. striatus	Vacuum	9.05±0.51	7.45±0.44	6.05±0.80
	N_2 pack	9.05±0.51	6.93±0.53	3.95±0.44
	Air pack	9.05±0.51	7.18±0.24	4.28±0.61
	Open	9.05±0.51	6.60±0.38	3.83±0.60
W. attu	Vacuum	8.78±0.53	7.15±0.34	4.80±0.42
	N_2 pack	8.78±0.53	6.65±0.41	4.28±0.45
	Air pack	8.78±0.53	6.50±0.41	3.93±0.41
	Open	8.78±0.53	6.23±0.42	2.95±0.37

In case of other packing techniques, on 4th month storage all the samples exhibited moderate results which lied above the borderline of acceptability; however, after 8 month of storage, samples of other packaging methods obtained relatively poor scores and all of which were below the expected level (sensory score 5) set for suitable products based on hedonic scale score. In addition, with respect to performance, nitrogen and air sealed pack samples demonstrated more or less identical results in most cases where the sensory score in nitrogen pack ranged from 6.45±0.44 (*Puntius* sp.) to 7.15±0.24 (*C. punctatus*) and 3.95±0.44 (*C. striatus*) to 4.95±0.50 (*C. punctatus*) on 4th and 8th month respectively. Likewise, with respect to air pack, this score varied from 6.30±0.35 (*Puntius* sp.) to 7.18±0.24 (*C. striatus*) and 3.70±0.63 (*Puntius* sp.) to 4.80±0.54 (*C. punctatus*) on 4th and 8th month respectively. However, after 8 month of storage, the dried fish samples stored in open pack had considerably low scores with the highest value as 3.95±0.55 (*C. punctatus*) and the lowest as 2.88±0.43 (*Puntius* sp.) (Table 7.3 and Fig.7.1).

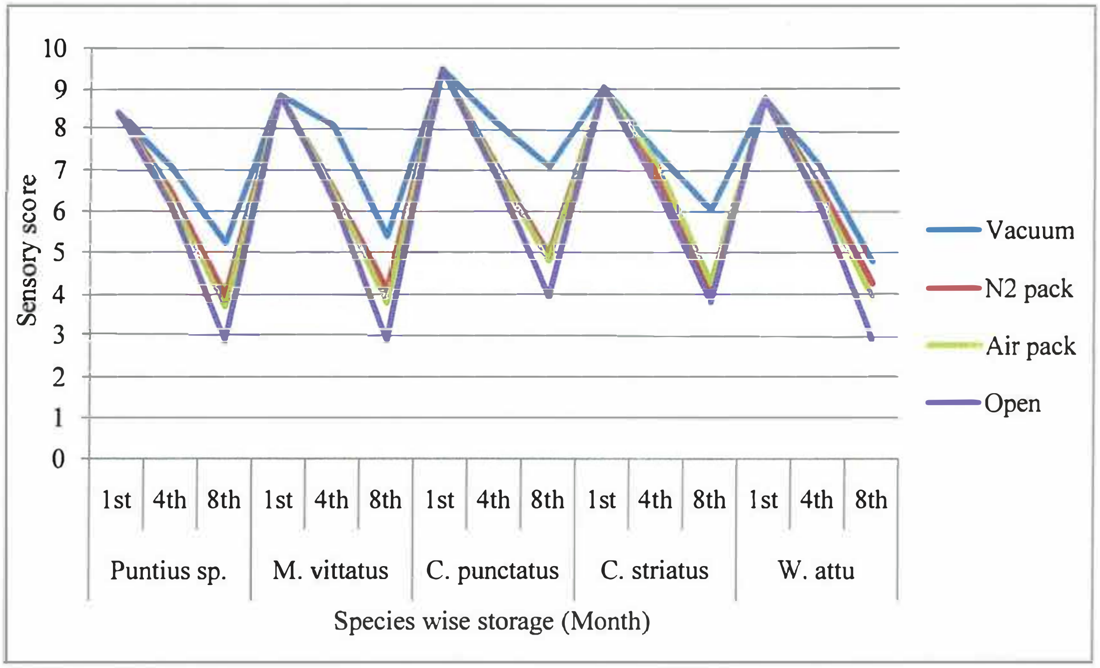


Fig.7.1 Changes in sensory scores of dried fish stored in different packaging methods and storage duration.

Plate 7.3 Fungus and beetles affected dried fish from open packaging

7.4. Discussion

The sensory evaluations showed that at the beginning of storage in different packaging methods the initial scores were same depending on the individual species. During storage, dried samples preserved in various packaging approaches produced different degree of smell, color and texture. In the present study, considerable declines in sensory scores were observed with the increase of storage period in respect of various packaging techniques. This decline indicates the decrease in quality giving rise to the subsequent development of faded yellowish or brownish color having off and rancid odor accompanied with relatively soft and less firm or flexible texture. Present finding resembles the observations of Islam *et al.* (2005).This finding was also identical to the results of Farid *et al*. (2014b). In the beginning of storage most of the samples appeared with desired quality attributes having firm and flexible texture with natural colour of dried fish . However, as storage period progressed, the natural color gradually turned to yellowish or brownish, and the case of changes in color may be partially influenced due to lipid oxidation during storage which was, in most cases, relatively prominent in air and open packing than that of products stored in vacuum or nitrogen packing. Regenstein JM and Regenstein CE (1997) opined that anaerobic atmosphere of nitrogen and vacuum packing are presumed to decrease or cease the rate of lipid oxidation that results in rancidity. Likewise, Clucas and Ward (1996) suggested that dried fatty fish are more prone to rancidity and rancid fish have characteristic flavors and odors which may be unpleasant and lead to consumer rejection, so adequate protective packaging is needed minimize this problem. Moreover, with regards to textural changes, Balachandran (2001) reported that during drying, excessive temperature coupled with lower relative humidity results in partial cooking of fish muscle causing case hardening which bring about denaturation of protein making the products more likely to lose juiciness of the meat and to be brittle or elastic in nature. He also mentioned that discoloration is likely to take place due to non-enzymatic browning developed through Maillard reaction.

Present results revealed that fungal growth was also observed in all packaging techniques except vacuum pack. With respect to moulds or fungal growth in dried fish, Clucas and Ward (1996) reported that it can grow on salted or unsalted dried fish whenever there is enough moisture. Moulds are also temperature sensitive with an optimum temperature for growth of 30-35°C.The moulds flourish if the storage conditions are damp and the salt concentration on the surface of the fish is more than 5%. Throughout storage period, most of the samples stored in vacuum pack exhibited comparatively better sensory attributes such as glazing oily surface with moderately firm and flexible texture, while most of the dried fish from other packing showed somewhat objectionable color, odor and texture, which may be attributed to some extent to the favorable atmosphere in vacuum packing. Present observations agreed with the results of Ochieng *et al.* (2015) who reported that vacuum packing demonstrated best performance in case of solar rack dried Sardines during storage.

After 4 month of storage, the sensory evaluations based on hedonic scale score revealed that with respect to different packing techniques, all the samples exhibited satisfactory sensory characteristics having moderate score which remained above the borderline of acceptability; however, after 8 month of storage, in all the cases dried fish stored in vacuum pack was awarded with highest scores ranging from 4.80±0.42 (*W. attu*) to 7.10±0.57 (*C. punctatus*). In a similar study, Farid *et al.* (2014b) observed that during storage period the sensory score rapidly decreased and at the end of the storage where the score was 5 in case of Shoal (5th month) and Taki (8th month). It was of interest to observe that after 8 month, except *W. attu* all the samples of vacuum packing obtained the sensory scores which were above the benchmark of acceptability. As shown in figure, the values were likely to decrease with storage period. However, this trend showed relatively less variations with respect to the samples of vacuum packing indicating that modified atmosphere of vacuum packing or absence of air might have effectively influenced the quality and kept the fish in good quality over a relatively longer period. This observation was in agreement with findings of Payap (2011) who reported that vacuum packaging could extend shelf-life, prevent oxidative rancidity and improve organoleptic quality by maintaining odor and flavor in seafood. However, after 8 month of storage, samples of other packaging methods acquired relatively less scores and all of which were below the threshold value (sensory score 5) set for acceptable products based on hedonic scale score. This result also revealed that with respect to performance, nitrogen and air sealed pack samples demonstrated more or less identical results in most cases; however, dried samples stored in open pack had the least mean values of general acceptance, which were attributable to the hygroscopic nature of salt treated dried fish, and in open packing this moisture absorption process got encouraged further which resulted in more rancidity and fungal growth that made the test panelists reject the dried fish samples for human consumption. Present observation was more or less similar with the findings of Hasan *et al.* (2016). At the end of 8 month of storage, few cases of beetle infestation were noticed in open pack. This might be due to the fact that the adults might have laid the eggs on raw fish before or during the drying process or storage. With respect to this problem, Clucas and Ward (1996) stated that insect pests can inflict heavy losses of dried fish during storage and the most common pests are dermestid beetles which begin infestation at moisture contents of less than 40%; optimum levels are about 15%. However, the presence of salt in fish can reduce the damage caused by Dermestes beetle (locally called "*Kaissha poka*"). With regards to preventing this infestation, Nowsad (2007) suggested that fish should be dried within box, tunnels or racks covered with mosquito nets to restrict the entry of flies and beetles, and dried fish should be packaged with appropriate packaging materials (polythene coated with polystyrene or polypropylene) on the drying spot as soon as the drying is complete; in addition, dried fish must not be kept open or exposed in the room or store house. One of the major problems encountered during storage of dried fish in different packaging, particularly in vacuum and nitrogen packaging, was puncture or damage of packaging films caused by sharp spines or protrusions of any sharp bones, which let the air get into the vacuum pack and the nitrogen get expelled through the leakage. Puncture of packaging materials of dried fish is a very common and challenging issue. To address the issue, Balachandran (2001) opined that ideal packaging materials for dried fish should be inert in nature and resistant to mechanical abrasion and puncture and also should prevent gain or loss of moisture, oxygen or other gases. However, complete removal of superficial hard spines or bones before packaging can significantly minimize this setback in respect of dried fish storage through MAP, particularly in case of vacuum package.

Chapter 8

Status of Awareness of Dried Fish Processors

Chapter 8

Status of Awareness of Dried Fish Processors

8.1. Introduction

A major goal for food processing industries is to provide safe, wholesome and acceptable food to the consumers. However, this can be very difficult as contamination of products in a food processing environment may take place at all stages, during production and processing (Beuchat, 1995). Each year, millions of people worldwide suffer from food-borne diseases and illnesses resulting from the consumption of contaminated food, which have become one of the most widespread public health problems in the contemporary world (WHO, 2000). In less developed countries, many people are poisoned because of the consumption of foods produced under unhygienic conditions, lack of hygiene education, drought, contaminated waters, inappropriate food storage conditions, lack of cleaning and pesticide residue (Eves & Kipps, 1995). Contaminated and unhygienic food production is a major problem which now Bangladesh is badly suffering from due to poor health literacy and low level of awareness (Ali, 2013).

In Bangladesh, many informal and traditional activity for food processing like fish drying is yet to receive due attention and has not been subjected to proper inspection, though it badly requires adequate interventions and should be given some thought in order to facilitate the effort of enhancing food safety. However, in Bangladesh the incidents of contamination of processed food products like dried fish treated with hazardous insecticides have gained consideration amongst consumer due to widespread media attention (BCHRD, 2015).

Among the fish products dried fish (Locally named as '*Shutki*') is the most popular food items in Bangladesh. It is a concentrated source of protein and mineral and can combat against protein malnutrition (Bhuiyan et al. 2009). In Bangladesh 18-20% fish from mostly low-cost marine, with a few minor carps and small freshwater fish are sun-dried (Nowsad, 2014).Traditional drying methods in tropical countries include direct sun drying with the fish placed either directly on the ground or on mats or racks, which are likely to be contaminated by sand or dust and infested with fly larvae (Bremner, 2002).

Quality is a consistent conformance to a standard (Sallis, 1992). As safety and quality are essential and integral part in preparation of fisheries products through processing, dried fish production needs to comply with safety standards (Nowsad, 2014). It is reported that post-harvest losses of products, both qualitative and quantitative, arise mainly due to lack of awareness and knowledge among the people engaged in handling, processing, distributing (FAO, 2003). Coulter and Disney (1987) found a 22% loss in dried fish in Bangladesh due to insect infestation. In most of the areas insecticides are considered to be an easy means of preventing infestation. However, optimum use of salt may be effective to minimize this loss. Similarly, it has been reported that damage can be heavy where salt is not used and drying condition is poor, as much as 25-30% under very humid conditions in Bangladesh (Doe, 1977; Ahmed, 1978). Almost all the hazardous chemicals are likely to result in health impairing effects; however, many commercial dry fish processors often apply several harmful insecticides in order to avoid insect infestation (Bala and Hossain 1998a). Application of these dangerous chemicals has been implicated with several short term and long term health complications including nausea, poor breathing, pain in lung, liver damage and cancer (Nowsad, 2007). Though chemical control methods are usually effective, but there are serious health and environmental problems associated with it (Reza *et al.* 2005a).

Microorganisms are another potential menace for safe dried fish production. Different sources of water are found to harbor microbial pathogens which cause subsequent illness and it is estimated that 80% of all illnesses are linked to use of water of poor microbiological quality (Okonko *et al*., 2008, 2009). Apart from the microorganisms that fishes have at the time of capture, more is added via unhygienic practices, contaminated equipment and rough handling which result in a faster spoilage rate (Adedeji and Adetunji, 2004). According to 'Fish and Fishery Products Official Controls Protocol' provided by DoF (2015), staffs handling fish products are to be in good health and observe adequate hygienic behavior and undergo training on health risks. In addition, fish processing equipments, containers and vessels along with potable water should be used to prevent contamination, and adequate number of toilets with effective drainage system, clean premises of processing area and hygienic and environment friendly waste disposal need to be ensured. Besides, as per provision of 'Fish and Fish Products (Inspection and Quality Control) Rules 1997' which deals with safety and quality issues of fisheries products, no person will carry out any fish processing or curing activities without having license from concerned authority; and DDT or other harmful insecticides are completely prohibited except few specific bio-degradable insecticides with permitted dose approved by competent authority (DoF, 2010).

Quality dried fish products have the demand both in domestic and international markets though the people involved in value chain are likely to add relatively little value and make little profit. The reasons for this are small-scale production with poor quality products caused by unhygienic environment and unhealthy practices, lack of adequate market access due to institutional and non-institutional barriers e.g. high marketing cost, price exploitative market players and their unethical dominance (Chakraborty, 2016).

Some research works (Flowra, 2013; Azam, 2002; Samad *et al.* 2009; Nowsad, 2002, 2003, 2005 and Reza *et al.*, 2005a; Ahmed *et al.*1993 and DFID, 2001) have been conducted on fish drying techniques and bio-chemical quality but study on safety and quality issues from food safety perspective with particular emphasis on awareness and behavior of dried fish processors in *Chalan Beel* area has not been ever attempted. Therefore, the present study is intended to examine the status of awareness among the dried fish processors in indifferent fish drying sites of *Chalan Beel.*

8.2. Materials and methods

The present study was conducted in *Chalan beel* area at Singra Upazila, Natore; Atrai, Naogoan; Chatmohor and Vangura, Pabna and Tarash Upazila under Sirajganj district to evaluate the status of awareness among dried fish processors from different drying sites adjacent to *Chalan Beel.* Data were collected on awareness of dried fish processors regarding safety and hygiene issues by using structured questionnaire. A total of 60 dried fish processors were selected randomly from the study areas and were subjected to interview. Structured questionnaire was pre-tested in field level and modified with necessary corrections which were finally administered to the respondents.

8.2.1. Statistical analysis

Questionnaire based data were coded and analyzed using IBM SPSS version 20 Statistical package and presented as descriptive statistics percentage, means; and Chi square test was also carried out to evaluate the impact of training with respect to different Awareness variables. Finally, tabulated data were analyzed in Microsoft Excel to generate graphs and tables.

8.3. Results and Observations

8.3.1. Socio-economic characteristics

Data concerning socio-economic characteristics have been summarized in Table 8.1 which reveals that around 60% of the dried fish processors belonged in the age group of 46-60, and among the respondents primary level was dominated with 48.3%, while 13.3, 20 and 3.3% were illiterate, secondary and above secondary level respectively. Most of the processors (65%) had eleven-twenty years of experience in fish drying business and majority of them relied on fish drying as primary or main occupation. All most all the drying sites had very poor infrastructure lacking minimum logistic equipments and facilities to meet the standard of hygienic and sanitary atmosphere for safe dried fish production. Surprisingly, 55% of the processors reported that they had no toilet facility. Moreover, 73% of the drying places did not have access to electricity.

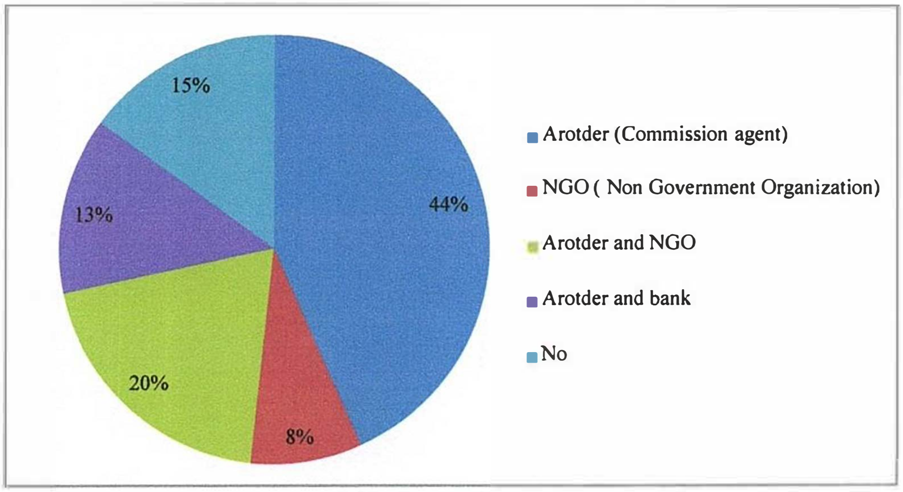


Fig.8.1 Sources of loan/capital for dried fish processor

With respect to sources of loan, commission agent (*Arotder*) appeared to be the highest (44%) loan provider followed by 20, 15, 13 and 8% from *Arotder* and NGO, not received, *Arotder* and bank and lastly from NGO respectively. However, the result gives a clear indication that 77% of the respondents were somehow engaged in taking loan from *Arotder*, which ultimately made the processor likely to be illegally deprived of obtaining fair price of their products (Fig.8.1).

Table 8.1 Socio-economic characteristics of dried fish processors

Parameters	Group	Number Observed (%)
Age	20-30	1.7
	31-45	38.3
	46-60	60.0
Educational level	Illiterate	13.3
	Can sign	15.0
	Primary	48.3
	Secondary	20.0
	above SSC	3.3
Year of Experience	six-ten	18.3
	eleven - twenty	65.0
	above twenty	16.7
Pattern of Occupation	Primary occupation	65.0
	Secondary occupation	35.0
Electricity connection	Preset	27.0
	Absent	73.0
Toilet facility	Pit/kacha	33.3
	Sanitary	11.7
	Absent	55.0

According to the response, monthly income of majority (55%) of the dried fish processors ranged from 5001-10000, while 30 and 5% of them earned in the range of 10001-15000 and above 15000 respectively (Fig.8.2).

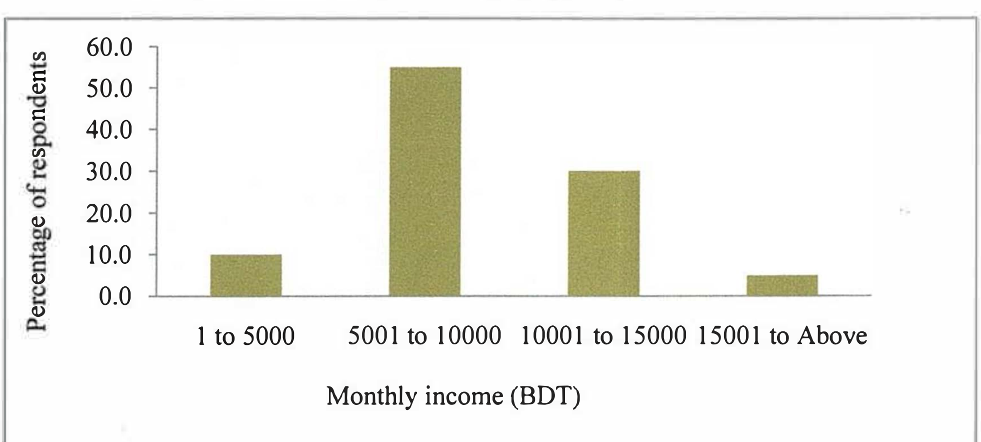
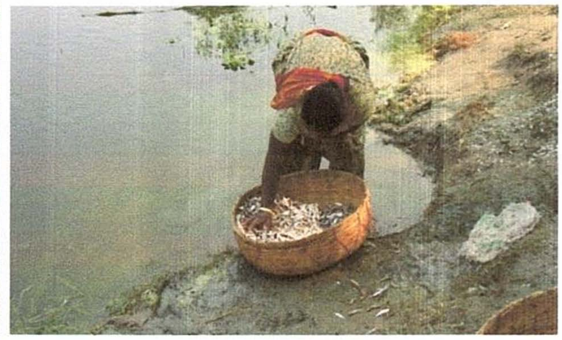


Fig.8.2 Monthly average income of dried fish processors

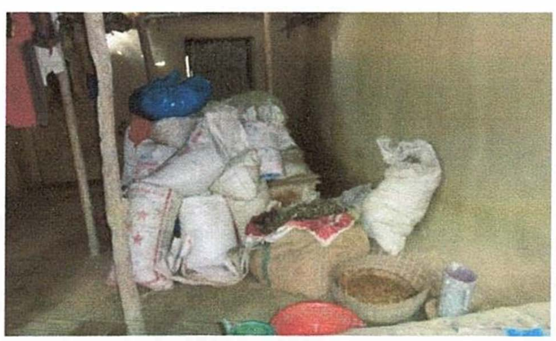
a. Dressing before drying



b. Washing before drying

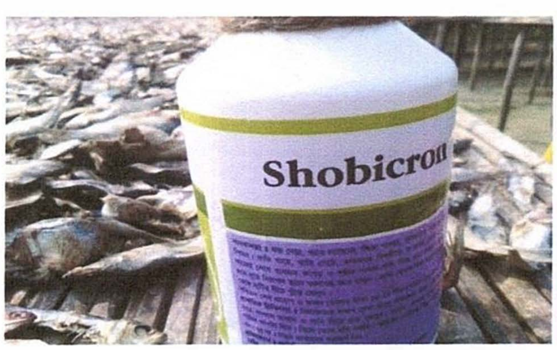
c. Drying in traditional method

d. Temporary storage in tent

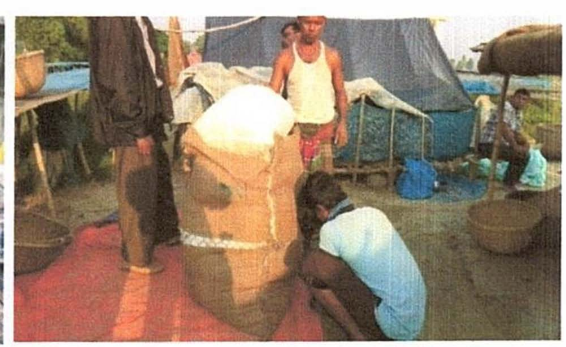


e. Temporary storage in different bags

f. Temporary storage on floor



g. Commonly used pesticides



h. Packing in gunny bag of jute

Plate 8.1 (a-h) Prevailing practices usually seen in traditionally fish drying

8.3.2. Safety and quality issues in dried fish processing and impact of training

In respect of awareness building and fish drying related training, 60% of the respondents were found to receive only single training for the first time (Fig. 8.3). Prevailing status of awareness observed in traditional fish drying have been presented in Plate 8.1(a-h); however, most of pictures show that the present scenario does not comply with hygienic and sanitary practices needed for ensuring safety and quality in dried fish processing. Present study reveals that out of 60 dried fish processors, 62% of them were found to practice dressing on partial basis for some fishes, particularly big and fleshy fishes however 30% did not practice dressing and only 3% among them practiced dressing in case of all species.

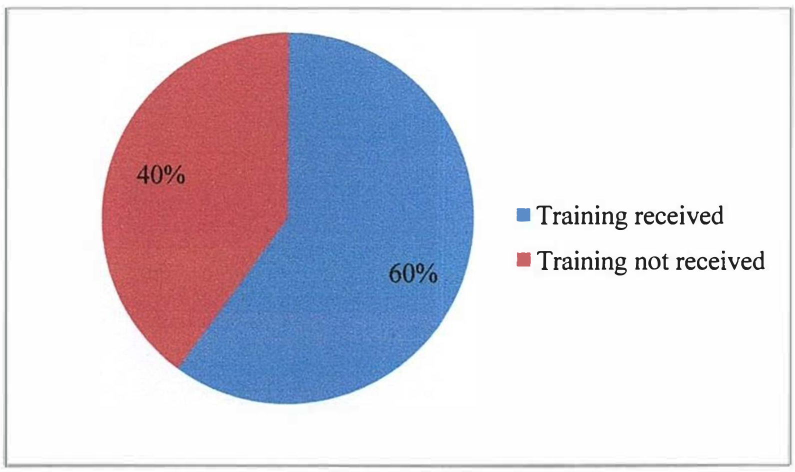
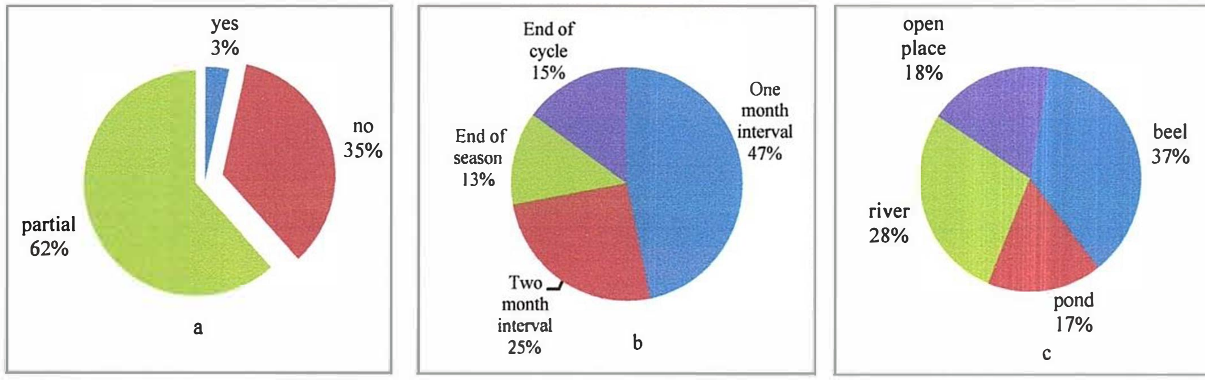


Fig.8.3 Status of receiving training

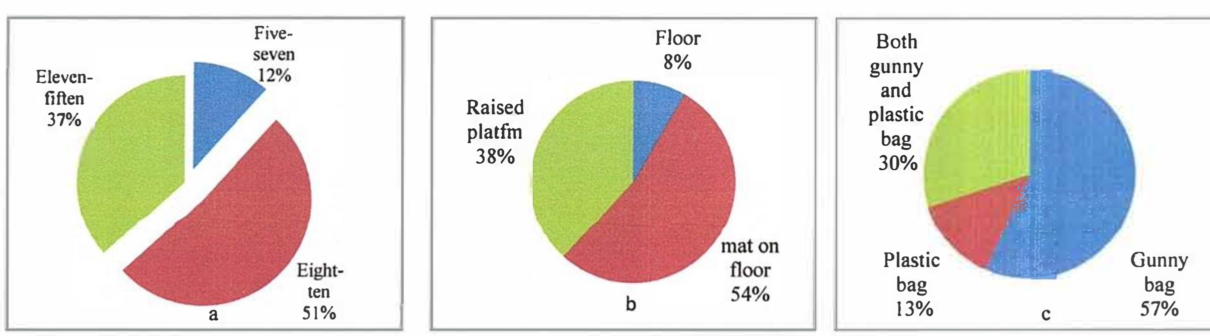
In terms of frequency of washing, most of them (47%) were found to wash drying racks at one month interval and 13 % would clean at the end of drying season. In case of dumping waste, maximum amount (37%) were disposed directly into the *beel* water followed by 28, 18, and 17 % into the river, open place and pond water respectively (Fig. 8.4a-c).



(a) Dressing practices (b) Washing of drying racks (*Bana*) (c) Waste disposal place

Fig.8.4 (a-c) Hygiene and safety status in fish drying

Majority (51%) of processors were found to treat fish with salt at the rate of 8-10% before drying and allow it until the salts get dissolved. Before selling, 54, 38 and 8% of the respondents were observed to keep dried fish with different packing bag and store on mat on the floor, raised platform and direct on concrete floor respectively. However, many (57%) of them used gunny bag for packing during temporary storage (Fig.8.5a-c).



(a) Salt application in drying (b) Temporary storage place (c) Dried fish packaging bag

Fig.8.5 (a-c) Status of salt treatment, temporary storage and packaging

Most of the respondents (68.3%) were not used to washing hand with soap or ash before and after drying operation and majority of them (65%) appeared to be knowledgeable in case of damaging impacts of pesticides. However, training on raising awareness regarding the habit of washing hands and creating knowledge, it showed significant effects ($P<0.05$). In contrast, findings also revealed that training had no significant impacts ($P>0.05$) with respect to pesticide application. Very few respondents (21.7%) were found interested to maintain concerned government office linkage and many of them (61.7%) expressed positive views on cooperative formation. Nevertheless, these responses were not significantly impacted by training (Table 8.2).

As far hygiene and sanitation is concerned, safe source of water is indispensible in terms of processing activity like dried fish production. However, in the present study 31.7% of the processors were found to use *beel* water, while river and pond water was used by 28.3% respondents for each, and only 6.7% of them would use safe tube well water for processing activities, which could serve as a potential source of microbial contamination. In addition, with respect to selection of water source, training seemed to have no significant effect ($P>0.05$) (Table 8.2 and Fig.8.6).

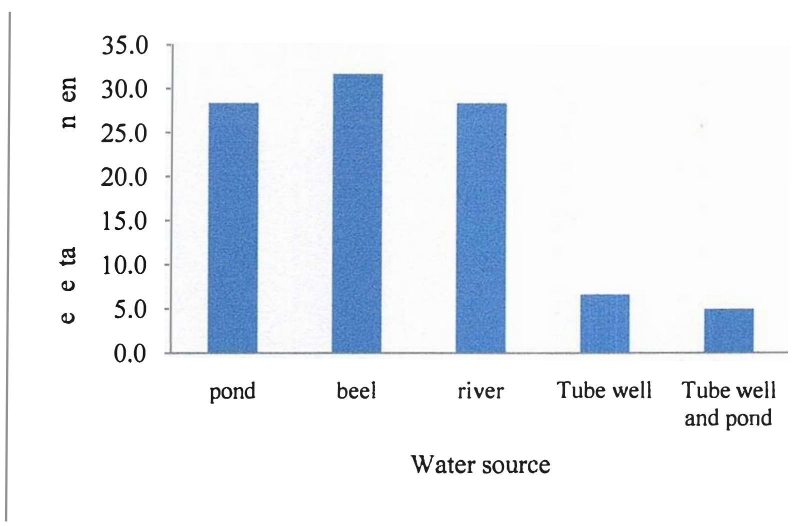


Fig.8.6 Sources of water for dried fish processor

Table 8.2 Bivariate distribution of the respondents in terms of training with different awareness variables

Variable	Participation in Training		Total	χ^2_{cal} and P value
	Yes	No		
Water source				
Pond	10(58.8%)	7(41.2%)	17(28.3%)	χ^2_{cal} =1.36 P =0.85
Beel	12(63.2%)	7(36.8%)	19(31.7%)	
River	10(58.8%)	7(41.2%)	17(28.3%)	
Tube well	3(58.8%)	1(58.8%)	4(6.7%)	
Tube well and pond	1(33.3%)	2(66.6%)	3(5.0%)	
Total	36(60.0%)	24(40.0%)	60(100%)	
Wash Hand with Ash or Soap				
Yes	15(78.9%)	4(21.1%)	19(31.7%)	χ^2_{cal} =4.15 P =0.041
No	21(51.2%)	20(48.88%)	41(68.3%)	
Total	36(60.0%)	24(40.0%)	60(100%)	
Know side effect of Pesticide				
Yes	28(71.8%)	11(28.2%)	39(65%)	χ^2_{cal} =6.45 P =0.011
No	8(38.1%)	13(61.9%)	21(35%)	
Total	36(60.0%)	24(40.0%)	60(100%)	
Apply Insecticides				χ^2_{cal} =0.44 P =0.83
Yes	19(61.3%)	12(38.7%)	31(51.7%)	
No	17(58.6%)	12(41.4%)	29(48.3%)	
Total	36(60.0%)	24(40.0%)	60(100%)	
Govt. Office Linkage				χ^2_{cal} =0.59 P =0.44
Yes	9(69.2%)	4(30.8%)	13(21.7%)	
No	27(57.4%)	20(42.6%)	47(78.3%)	
Total	36(60.0%)	24(40.0%)	60(100%)	
Interested to form Cooperative				
Yes	25(67.6%)	12(32.4%)	37(61.7%)	χ^2_{cal} =2.3 P =0.13
No	11(47.8%)	12(52.2%)	23((38.3%)	
Total	36(60.0%)	24(40.0%)	60(100%)	

8.3.3. Use of pesticides and implications for legal and regulatory measures

In adverse weather like incessant rain in monsoon and prolonged foggy days in winter, several types of harmful agricultural pesticides were found to be applied during the study period at the dose of one liter solution mixed with 1.5-2.5ml pesticide for 80-140kg fish. It was observed that the extent and severity of use was likely to rise when the weather condition gets deteriorated and in most cases big fleshy fish were subjected to pesticide treatment. Alarmingly, in many cases pesticides were used regardless of its prescribed dose instructed on the bottle (Table 8.3).

Table 8.3 Commonly used pesticides in dried fish of *Chalan Beel* area

Name	**Group Name of pesticides**	**Amount of insecticide mixed with water (ml/ liter water)**	**Amount of fish treated with pesticides solution (Kg raw fish/liter)**
Sobicron 425 EC	Profenofos and Cypermethrin	2.5	80-100
Sumithion 50 EC	Fenitrothion	2	100-120
Syperin 10 EC	Sypremethrin	1.5 - 2	100-140
Ricon 60 EC	Diazinon	2	100-120
Karate 2.5 EC	Lamda-cyhalothrin	1.5 - 2	80-120

8.4. Discussion

With respect to socio-economic status, majority of the processors (60%) belonged in the age group of 46-60 years and most of them (65%) had eleven to twenty years of fish drying experience. In addition, educational status of majority of respondents was low, among them 48.3% were in primary level, 13.3% were illiterate and 15% could sign only. This result was comparable with the finding of Flowra *et al.* (2012) who reported that educational level of dried fish processors of Tarash, Sirajgsnj was very poor. Majority of the processors (65%) were found to consider fish drying as primary occupation. Average monthly income varied in most cases from 5000 to 15000 BDT. Monthly incomes of majority (55%) of the processors ranged between 5001 to 10000 BDT. Azam (2002) and Flowra *et al.* (2012) observed almost similar results in Kuakata and Tarash respectively as far monthly income is concerned. Results revealed that among the respondents 60% received training on safe dried fish production in 2015. However, according to processors, this training was the very first training since they had started fish drying business. Terming it inadequate, most of the processors expressed desire for more follow up training.

Surprisingly, most of the processing sites (73%) lacked electricity connection having been located in a place where no electricity pole was available within vicinity. Moreover, majority (55%) of the fish drying sites were found to be devoid of toilet facility and 33.3% had pit or *kacha* toilet; however, according to fishery product control protocol of DoF (2015) this is an obvious indication of noncompliance with sanitary and healthy practices, and which ultimately could serve as source of fecal contamination putting dried products at risk of microbial hazards.

Proper dressing is a precondition for producing healthy dried fish. Nevertheless, majority of processors (64.7%) occasionally practiced dressing activities including de-scaling, gutting, splitting lateral muscle and washing of fish before drying which are accomplished usually in large and thick fishes like Soal, Boal, Silver carp, Taki etc. whereas 35% processors were not in practice of dressing as most of them were involved in drying of small sized fish; however, only 3.3% were engaged in complete dressing both for small and large fish. This result supported the findings of Nowsad (2007) who observed that fish is not adequately washed and dressed before drying and this problem is very much associated with the small fish in which adhered blood, slime and juice from the rotten abdomen contaminate the entire lot and thus deteriorate the quality. Regardless of the environmental issue, most of the processors were likely to dump dressing and other waste materials directly in *beel* (36.7%), pond (16.7%), river (28.3%) and even in open places (18.35%), which can result in pollution in surrounding environment increasing risk of more blow fly infestation and microbial contamination. Consequently, unhealthy and polluted environment could invite more blowflies making the dried fish more vulnerable.

In many cases, drying racks (*Bana*) were not adequately washed and cleaned on regular basis after each production cycle. Among them 46.7 and 25.3% of processors would wash drying racks after one and two month's interval respectively, while only 13 and 15% of them were found to wash it at the end of every drying cycle and after entire season respectively. Though the practice goes against hygienic and sanitary habits, in most of the sites drying racks are usually kept spread outside and remained exposed to dogs, cats, birds and flies which may graze leaving unhealthy and risky impacts. As a result, in some cases cross contamination of fish is resulted from dirty racks which harbor pathogenic organisms and this could be attributed to inadequate and irregular washing. Similar problems were pointed out by (Nowsad, 2014). In a similar study, Adeyeye (2015) also reported that in Nigeria drying materials and facilities used for processing were not always properly cleaned and washed immediately after use, and this would result in accidental contamination which is a threat to food safety.

In all the cases, fish were subjected to preliminary treatment with salt before drying which ranged from 5 to 15%. Majority of the processors (51.7%) used 8-10% salt varying in respect of quality of raw fish and weather condition. In cloudy and rainy or foggy days fish were more likely to be subject to salt treatment with higher dose in order to harden the fish, reduce contamination and remove water, which ensures protection against spoilage. However, fish were prone to get contaminated due to use of low-cost non-brand open salt having impurities which could serve as a source of bacterial contamination. Present results are identical to the observations made by some researchers (Nowsad, 2007, Samad *et al.*, 2009 and Flowra *et al.*, 2012).

For temporary storage, majority of the processors (56.7%) used jut made gunny sack (locally called '*Jhail*') and many of them (53.3%) were found to store dried fish on mat spread on the earthen floor, while 38.3% processors stored on slightly elevated bamboo made rack under the tent made of thin plastic sheet and bamboo splits until marketing. Generally, when dried fish are kept exposed in unsanitary way on mat spread on the ground or on bamboo made rack it makes dried fish susceptible to moisture absorption and contamination ultimately resulting in quality deterioration. As the fish remain uncovered and without adequate packaging, beetles and mites infestation of the finished products become more likely to take place. Almost same findings were reported by Reza (2005b) for dried fish processors of Cox's Bazar District. This result was also consistent with the observations made by Nowsad (2007) who found that dried fish is stored in gunny sacs made of jut or plastic or in bamboo made baskets which are vulnerable to environmental and biological conditions.

Due to belonging in insolvent segments of society, most of the processors were involved in taking loan from commission agents (*Arotder*) and other locally available lending institutes. Majority (77%) of the respondents (including those involved in taking loan from bank and NGO) were engaged in borrowing capital from commission agents as they are often persuaded by the agents with an ill intention to force them to sell dried fish to the specific lending agents (*Arotders*). Chantarasti (1994) stated that majority of the fish drying professionals were engaged in borrowing money for their business. It was observed that due to lack of any alternative marketing option, almost all of the dried fish processors of *Chalan Beel* areas get compelled to sell their products in Saidpur dried fish wholesale market of Nilphamary district which is located far away from the drying sites.

It was also found that during glut period, processors had no choice but to sell products at low profit margin or even sometimes suffering loss as in most cases commission agents and buyer often make syndicate with unfair motive to dictate the sale price regardless of the quality of products, and in this way, processors are deprived of getting fair price. As a result, processors get unenthusiastic or discouraged to produce quality products which require more cost involvement. However, all the processors expressed dissatisfaction regarding poor and unethically dominated marketing system and were eager to find new marketing options. To get rid of the illegal influence and clutch of commission agents, they expressed willingness to get soft term loan from concerned banks and government offices. Ahmed *et al.* (1993) and Mazid, (1994) reported that involvement of large number of middlemen and commission agents reduce benefit of the fish producers.

Water supply is one of the most critical factors when making products which are safe to eat and which meet the required microbiological standards (Clucas and Ward, 1996). Among the respondents around 32% were found to use *beel* water and for each source 28% processors would use river and pond water, while very few (6.7%) used tube well water. However, with respect to selection of water source, training seemed to have no significant effect (P>0.05). Most of the drying sites had no access to tube well water or potable water for adequate washing of dressed fish and utensils and also for maintaining personal hygiene. Consequently, despite having training, processors were likely to use *beel* or river water which can serve as a potential source of pathogenic bacteria. Emikpe (2011) reported that pond, river and Beel water may be the source of contaminants due to indiscriminate deposition of human, animal excreta and other environmental wastes into natural water, particularly during the rainy season fecal matter from various sources are washed from contaminated land and get mixed into different water bodies.

Many hygiene problems arise from the staff themselves. It is therefore important to ensure that they are healthy, and that they have a basic understanding of the need for personal hygiene. Staff must be instructed to wash their hands after every operation and after visit to lavatory (Clucas and Ward, 1996). Proper hand washing and disinfection has been recognized as one of the most effective measures to control the spread of pathogen (Montville *et al.*, 2001). In the present study, most of the respondents (68.3%) were not habituated to washing hand with soap or detergent before and after drying operation and also to maintaining appropriate degree of hygiene and sanitation. However, in case of awareness with regards to habit of washing hands, training appeared to have significant influence ($P<0.05$). Adeyeye (2015) reported that smoked dried fish were subject to repeated contamination from unwashed hands of processors and vendors. Reza (2005a) observed that lack awareness of the processors about food safety and quality aspects contribute to production of poor quality and unsafe dried fish. Nowsad (2007) also mentioned that people engaged in sun drying do not have minimum knowledge on public health and sanitation.

Indiscriminate use of unsafe and health-hazardous insecticides is a serious threat to public health and residual effects of such compounds are well-known Nowsad (2007). Results revealed that majority of the processors (65%) were found to be knowledgeable on harmful effects of insecticide application, which could be attributed to the impact of awareness-raising training. Statistical analysis indicated that with respect to developing awareness regarding harmful impact of pesticides, training exhibited significant effect ($P<0.05$); however, training did not have significant impact ($P>0.05$) in terms of careless behavior regarding insecticide application (51.7%), which was an interesting contrast to their reported level of awareness indicating that they were less willing to put their knowledge into practice. In addition, despite giving knowledgeable response, many of the processors used insecticides on regardless violating the law from sheer ignorance, which could be attributed to the lack of regular monitoring, inadequate enforcement of legal actions by concerned responsible authority. Surprisingly, when asked about the preventive or monitoring measures taken by concerned government department to curb the abuse of dangerous chemicals, most of the respondents reported that they had never faced such type of inspection activities, which also encouraged them to commit such malpractice with the sense of audacity. Nowsad (2016) reported that only awareness development can substantially reduce the risk of consuming unsafe fishery products caused by contamination from nature; however, control of deliberative abuse of hazardous pesticides may require adequate national policy and strong enforcement. Ali (2013) reported that in case of law concerning food safety, unnecessary bureaucracy resulting in poor coordination, inadequate monitoring and insufficiency of penalties have ultimately made most of the laws ineffective.

In the study, many processors were unaware about the proper dose limit and residual effect of insecticides; most of those chemicals belonged in different groups of agricultural insecticide, which might prove fatal for human health. This findings similar with that reported by Flowra *et al.* (2013) with regard to use of insecticides at Singra Upazila of *Chalan Beel*. Those respondents who were not involved in applying insecticides stated that they usually practice high dose of salt instead of insecticide during adverse weather in order to prevent fly infestation and bacterial spoilage. Nowsad (2007) reported that in cloudy and rainy days fish require to be treated with 15-30% of salt and extra salt adhered to the body surface need to be removed before drying through adequate washing so that dried fish remain less salty and salt concentration does not exceed 3-7% science consumer usually prefer dried fish that contains little or no salt.

There was not a single cooperative society of dried fish processors in the study area. With respect to awareness regarding communication with organization, very few respondents (21.7%) were found interested to maintain concerned government office linkage, while many of them (61.7%) expressed positive views on cooperative formation. However, the statistical analysis revealed that training had no significant effects on attitude in case of these responses. In a similar observation, Nowsad (2007) reported that small entrepreneurs formed a cooperative society named "Nazirartek Fish Traders Multipurpose Cooperative Society" which appeared to be effective in establishing the rights of fish-drying activities and dried fish business. In fact, cooperative society can significantly help to reduce illegal dominance of commission agents (*Arotder*) and to get fair price of the products.

Conclusion and Recommendations

Conclusion and Recommendations

The study was intended to evaluate safety and quality aspects of traditional and experimental dried fish (*C. punctatus*, *M. vittatus*, *C. striatus*, *W. attu* and *Puntius* sp.) focusing on the assessment of shelf-life, nutritional quality, pesticide residue, awareness status of processors, performance of different improved drying techniques namely Black Polythene Sheet (BPS), White Tin Sheet (WTS), Black Tin Sheet (BTS), White Plastic Tunnel (WPT), Hanging Box (HB) and Traditional Method (TRD) and effectiveness of various packaging methods (nitrogen Package, air package, open/unsealed package and vacuum package) for dried fish.

Among all the techniques WPT exhibited satisfactory performance showing average temperature, drying time and drying rate as 38.14°C, 25.20hour and 98.61g/hour respectively. However, in all the cases efficiency was considerably influenced in respect of weather, particularly the key factors are temperature, humidity and air flow. Therefore, this technique of low cost solar tunnel dryer can be constructed in different sizes using locally available materials and introduced in *Chalan Beel* area for the production of good quality and safe dried fish.

The nutritional qualities were satisfactory both in traditional and experimental dried fish; however, the levels were slightly higher in experimentally prepared samples when it comes to protein and fat content, though it was not the case for all species. Moreover, these samples contained relatively less moisture indicating better quality. Minerals contents for both types of samples were similar to raw fish or even more which varied significantly in respect of species.

In the present study, the sequence of heavy metals accumulation in dried fish muscle is Cu >Pb> Cr > Cd. From food safety point of view, Pb, Cd, and Cr contents remain below the respective recommended limit while Cu is slightly higher than the prescribed limit of FAO. However, all the THQ values were far below 1 suggesting that consumer would not experience significant health risks regarding non-carcinogenic toxic effect if they only ingest individual heavy metal through the dried fish of *Chalan Beel* area. Experimental dried fish samples showed considerably less coliform count keeping better quality due to maintaining hygienic environment and sanitary practices. Besides, no fecal coliforms were detected in experimental samples. On the other hand, fecal coliforms were observed in *C striatus* (1.5×10^2), *W. attu* (2×10^2) and *Puntius* sp. (2.5×10^2 cfu/g) in case of case of traditional sample. However, both the traditional and experimental dried fish samples were free from pathogenic bacteria like *V. cholerae* and *Salmonella.* Some traditional samples (*W. attu*, C. *punctatus* and *C. striatus*) were found to contain Chlorpyrifos residues which gives evidence that the abuse of harmful pesticides, a notable anthropogenic contaminant, is still in practice in this area.

At the end of storage period, it seemed quite clear that both drying method and storage period had significant impact on spoilage indicators when preserved in normal plastic container at ambient temperature. During storage experimental samples appeared to be of better quality having more acceptability in respect of different quality attributes. After 8th month of storage of experimental samples, TVB-N, POV, p^H, SPC varied from 65.45 (*Puntius sp.*) to 89.5 mg/100g (*C. striatus*), 18.5 (*M. vittatus*) to 38.2mEq/kg (*C. striatus*), 6.53 (*M. vittatus*) to 7.9 (*C. striatus*), 4.71(*M. vittatus*) to 5.98 LogCFU/g (*C. striatus*) respectively and the sensory score was rated from 'like moderately' with 7.25 (*C. punctatus*) to 'dislike slightly' with 4.5 (*Puntius* sp.). However, if drying is done properly with desired moisture content and storage techniques are improved further, dried fish is likely to have longer shelf-life which could enhance consumer preference and fetch high market price.

With respect to socio-economic and awareness status, educational level and monthly income of majority of the processors were found comparatively lower. Surprisingly, 73% and 55% of the drying yards did not have access to electricity and sanitary toilet facilities respectively. Majority (77%) of the processors were somehow engaged in taking loan as advance money from commission agents (*Arotder*), which make them fall victim to unwritten supply contract and this way unscrupulous syndicates of commission agents and buyers dictate the sale price regardless the quality of the products; consequently processors sometimes feel unmotivated to produce good quality products. Considerable numbers of processors (65%) were observed to show knowledgeable response regarding harmful effects of insecticide application; however, 51.7% of them were found to be involved in pesticide application and most of them were unaware about the proper dose limit. In fact, in this case training did not have significant impact in terms of changing the malpractice of deliberative abuse of hazardous pesticides. Some processors mentioned that they had never faced any type of regulatory or monitoring as well as inspection activities taken by concerned government department, which also encouraged them to commit such pesticidal malpractice on regardless.

The results of the study based on sensory evaluation revealed that vacuum packaging was found to exhibit impressive performance in delaying spoilage and protecting quality deterioration and thereby considerably extending shelf-life of dried fish products. During the storage, most of the samples stored in air sealed and open package produced faded fishy and rancid odor with faded whitish and yellowish color having relatively soft, semi-elastic and less-firm texture; and Nitrogen package also demonstrated relatively lower performance showing somewhat objectionable color, odor and texture at the end of storage; however, throughout the storage period, most of the samples stored in vacuum package exhibited better sensory attributes with glazing oily surface having moderately firm and flexible texture. After, 8^{th} month of storage vacuum package showed comparatively satisfactory performance obtaining higher sensory score varying from 4.80 (*W. attu*) to 7.10 (*C. punctatus*). Nevertheless, it should however be emphasized that success of this packaging could be enhanced if the initial quality of the dried fish is ensured before packaging.

Recommendations

1. Persuasive measures like motivational campaign and awareness-raising training on good and hygienic manufacturing practices need to be arranged.
2. Suitable and effective training modules on safe dried fish production have to be developed.
3. Continuous quality control inspections and regulatory monitoring by concerned authority also must be ensured in order to curb the deliberative abuse of pesticide.
4. Less harmful or botanical pesticides with prescribed dose should be given priority in case of emergency.

5. Concerned quality control agencies should initiate regulatory intervention for fish drying and marketing activities through introducing licensing system for dried fish producers and wholesalers.
6. Gradual implementation of Hazard Analysis and Critical Control Point (HACCP) system is required to promote safety and hygiene.
7. Some supporting initiatives like providing soft-term loan facility for dried fish processors should be ensured to reduce unethical influence of commission agents.
8. Alternative wholesale marketing outlets need to develop within vicinity on priority basis to liberate dried fish processors from the exploitation of monopoly syndicate of Saidpur wholesale market.
9. Cooperative society by the dried processors of *Chalan Beel* area should be formed to establish their rights and business interests.
10. Suitable place adjacent to *Chalan Beel* should be allocated for fish drying.
11. Cold storage for dried fish preservation needs to be constructed.
12. Along with electricity facility tube well and sanitary toilet facilities need to be ensured
13. Concerned authority should come forward and devise adequate policy to address the prevailing problems of this neglected sector and also should take new projects.
14. More research endeavors need to be made to further improve the performance of drying techniques. Moreover, techniques of MAP packaging for dried fish needs further research focusing on biochemical changes and effects of temperature during storage.

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Appendices

Appendices

Appendix Table-I Raw weight (g) of fish samples before drying in different drying techniques

Drying Technique	*Puntius* sp.	*C. striatus*	*C. punctatus*	*W. attu*	*M. vittatus*	Total Weight (g)
BPS	600	730	1045	855	805	4035
WTS	640	795	630	930	830	3825
BTS	515	1080	595	785	910	3885
WPT	460	785	620	1005	855	3725
BOX	500	575	595	795	450	2915
TRD	650	550	700	1000	570	3470

Appendix Table-II Weight (g) of samples after drying in different drying techniques

Drying Technique	*Puntius* sp.	*C. striatus*	*C. punctatus*	*W. attu*	*M. vittatus*	Total Weight (g)
BPS	210	260	375	310	335	1490
WTS	255	285	225	340	287	1392
BTS	180	390	210	285	315	1380
WPT	160	265	190	340	285	1240
BOX	190	200	190	290	150	1020
TRD	230	190	235	330	210	1195

Appendix Table-III Average temperature, relative humidity, time and drying rate for different drying techniques

Drying Techni ue	Temperature °C	Relative Humidity %	Time hour	Drying rate /hour
BPS	29.20	46.58	35.00	72.71
WTS	28.46	48.70	32.00	76.03
BTS	30.76	42.90	30.00	83.5
WPT	38.14	33.20	25.20	98.61
BOX	23.98	64.00	32.60	58.13
TRD	24.88	62.40	32.00	71.1

Appendix Table-IV Temperature (°C) for various drying techniques at different time

Time	BPS	WTS	BTS	WPT	BOX	TRD
9am	23.5	24.3	24.8	32	22	22.7
11am	29.5	28	31.5	35.5	23.4	24.2
1pm	34.5	34	37	48.7	28	29
3pm	31.5	30	32	40.5	25	26.5
5pm	27	26	28.5	34	21.5	22
Average	29.2	28.46	30.76	38.14	23.98	24.88

Appendix Table-V Relative Humidity (%) for various drying techniques at different time

Time	BPS	WTS	BTS	WPT	BOX	TRD
9am	56.9	56	54.5	53	77	75
11am	46	49	42	34	68	64
1pm	35	39	31	18	48	45
3pm	43	45.5	40	25	52.5	54
5pm	52	54	47	36	78	74
Average	46.58	48.7	42.9	33.2	64.7	62.4

Appendix Table-VI Day wise weight (g) in different drying techniques for *Puntius* sp.

Drying Technique	Initial weight	1th day	2nd day	3rd day	4th day	5th day
BPS	600	460	350	260	210	-
WTS	640	480	355	255	-	-
BTS	515	370	260	180	-	-
WPT	460	295	200	160	-	-
BOX	500	370	265	190	-	-
TRD	650	470	335	230	-	-

Appendix Table-VII Day wise weight (g) in different drying techniques for *M. vittatus*

Drying Technique	Initial weight	1th day	2nd day	3rd day	4th day	5th day
BPS	805	618	470	360	335	-
WTS	830	638	485	355	287	-
BTS	910	675	490	315	-	-
WPT	855	590	415	285	-	-
BOX	450	335	255	190	150	-
TRD	570	405	300	210	-	-

Appendix Table-VIII Day wise weight (g) in different drying techniques for *C. striatus*

Drying Technique	Initial weight	1th day	2nd day	3rd day	4th day	5th day
BPS	730	605	510	435	345	260
WTS	795	630	525	405	335	285
BTS	1080	835	660	545	460	390
WPT	785	550	440	340	265	-
BOX	575	450	360	280	215	200
TRD	550	425	330	265	220	190

Appendix Table-IX Day wise weight (g) in different drying techniques for *W. attu*

Drying Technique	Initial weight	1th day	2nd day	3rd day	4th day	5th day
BPS	855	715	595	485	390	310
WTS	930	755	605	490	410	340
BTS	785	600	475	380	320	285
WPT	1005	770	605	455	340	-
BOX	795	635	510	415	345	290
TRD	1000	810	645	515	410	330

Appendix Table-X Day wise weight (g) in different drying techniques for *C. punctatus*

Drying Technique	Initial weight	1th day	2nd day	3rd day	4th day	5th day
BPS	1045	815	595	465	410	375
WTS	630	475	350	275	245	225
BTS	595	405	300	245	210	-
WPT	620	380	285	235	190	-
BOX	595	425	280	240	210	190
TRD	700	545	420	340	280	235

Appendix Table-XI Proximate composition of traditional and experimental dried fish samples

Species	Protein (%)		Ash (%)		Fat (%)		Moisture (%)	
	Trad.	Exp.	Trad.	Exp.	Trad.	Exp.	Trad.	Exp.
C. punctatus	79.28	76.40	15.32	19.79	3.49	5.00	12.83	11.80
	78.38	73.44	14.97	19.95	3.95	4.65	11.97	11.62
	78.83	74.92	14.62	19.87	3.72	5.35	12.40	11.98
M. vitttus	64.57	59.88	14.88	25.29	13.28	15.20	12.36	9.80
	63.71	58.76	15.47	23.33	15.54	16.15	12.84	10.14
	65.43	61.00	16.10	24.31	14.41	14.25	12.60	9.97
C. striatus	63.32	79.71	24.46	16.29	2.95	4.43	20.33	14.53
	60.86	79.96	26.96	18.00	3.29	3.97	20.90	14.87
	62.09	79.46	25.71	17.14	3.12	4.20	21.47	14.70
W. attu	66.48	71.22	19.89	16.44	11.10	4.88	15.50	10.43
	63.10	73.10	21.85	15.88	11.43	5.10	16.13	11.30
	64.79	69.37	20.87	17.00	10.77	5.32	14.87	12.17
Puntius sp.	51.57	59.30	29.91	26.65	15.10	20.50	16.70	9.32
	50.32	57.95	28.86	25.50	14.57	20.16	17.18	9.20
	49.10	60.65	30.96	27.80	15.30	20.84	16.22	9.10

Appendix Table-XII Mineral contents of traditional and experimental dried fish samples

Species	Iron (mg/100g)		Calcium (mg/100g)		Potassium (mg/100g)		Phosphorus (mg/100g)	
	Trad.	Exp.	Trad.	Exp.	Trad.	Exp.	Trad.	Exp.
C. punctatus	4.62	4.42	134.40	28.49	9.20	9.18	485.77	261.62
	4.61	4.36	134.25	28.74	9.19	9.18	488.92	258.46
	4.61	4.28	134.18	28.99	9.18	9.18	482.62	264.77
M. vitttus	14.47	15.20	190.83	132.91	9.12	9.03	535.45	442.10
	14.35	15.15	190.61	132.67	9.14	9.03	539.57	445.23
	14.41	15.25	190.36	132.39	9.16	9.02	531.33	438.97
C. striatus	3.40	2.73	95.74	20.87	8.46	7.80	229.78	336.35
	3.40	2.79	94.53	20.82	8.46	7.80	231.91	335.14
	3.40	2.85	93.42	20.79	8.47	7.80	227.66	337.56
W. attu	14.86	10.66	184.86	93.95	9.47	8.65	413.97	374.08
	14.65	10.80	184.26	93.61	9.47	8.61	417.23	371.95
	14.47	10.92	183.74	93.26	9.47	8.56	410.71	376.22
Puntius sp.	6.93	5.24	160.70	40.86	8.90	8.31	441.82	450.08
	6.92	5.10	159.42	40.55	9.00	8.31	444.93	447.57
	6.83	4.88	158.30	40.21	9.12	8.31	438.70	452.59

Appendix Table-XIII Heavy Metal contents traditional and experimental dried fish samples

Species	Lead (μ/g)		Cadmium (μ/g)		Chromium (μ/g)		Copper (μ/g)	
	Trad.	Exp.	Trad.	Exp.	Trad.	Exp.	Trad.	Exp.
C. punctatus	1.2859	.1782	.0207	.0145	.9294	1.0039	3.2200	6.6300
	1.2936	.1791	.0188	.0147	.8984	1.0459	3.0300	6.4400
	1.2883	.1791	.0198	.0146	.9138	1.0249	3.0300	6.4400
M. vittus	.6326	.2399	.0160	.0091	.7364	.6416	22.9300	28.0800
	.5859	.2408	.0166	.0090	.7217	.6679	24.4400	26.9700
	.6088	.2399	.0163	.0090	.7291	.6546	23.6800	27.5200
C. striatus	.8963	.2421	.0179	.0115	1.0116	1.0406	6.9900	6.3000
	.9425	.2421	.0178	.0116	.9781	1.1374	6.4600	6.3040
	.9194	.2421	.0179	.0116	.9949	1.0888	6.6000	6.3000
W. attu	.6152	.1640	.0141	.0173	.6275	.4290	28.7800	24.0900
	.6182	.1640	.0139	.0184	.6454	.4659	27.4200	22.8700
	.6172	.1640	.0140	.0178	.6363	.4476	28.0000	23.5700
Puntius sp.	1.5586	1.0209	.0149	.0117	1.4474	1.2396	5.8900	8.3932
	1.6254	.9691	.0156	.0117	1.4975	1.3150	6.1000	6.3398
	1.6000	.9954	.0143	.0117	1.4725	1.2773	6.1000	6.5100

Appendix Table-XIV Modified sensory score table Peryan and Pilgrim (1957)

Species	Senso characteristics of dried fish			Average score
	Odor/smell	Texture	color	
C. unctatus (Taki				
C. striatus Shol)				
W. attu (Boal)				
M.vittatus(Tengra)				
Puntius sp. (Puti)				

Please put your score based on following acceptability level

Acceptability level	Score
Like Extremely (LE)	9-10
Like Very Much (LVM)	8-8.9
Like Moderately (LM)	7-7.9
Like Slightly (LS)	6-6.9
Neither Like Nor Dislike (NLND)	5-5.9
Dislike Sli htl (DS)	4-4.9
Dislike Moderately (DM	3-3.9
Dislike Ver Much DVM)	2-2.9
Dislike Extremely (DE)	1-1.9

Appendix Table-XV Changes in sensory evaluation score in different storage

Storage period	Traditional Sample					Experimental Sample				
	C. striatus	***C. punctatus***	***W. attu***	***Puntius sp.***	***M. vittatus***	***C. striatus***	***C. punctatus***	***W. attu***	***Puntius sp.***	***M. vittatus***
1st Month	8.00	8.50	7.67	6.50	8.25	9.00	9.50	8.50	8.33	8.83
4th Month	6.92	7.17	6.67	3.67	6.17	8.08	8.17	7.58	6.25	7.50
8th Month	4.00	5.42	3.00	1.83	4.83	6.00	7.25	5.50	4.50	5.83

Appendix Table-XVI Changes in TVB-N contents (mg/100g) in different storage period

Storage period	Traditional Sample					Experimental Sample				
	C. striatus	***C. punctatus***	***W. attu***	***Puntius* sp.**	***M. vittatus***	***C. striatus***	***C. punctatus***	***W. attu***	***Puntius* sp.**	***M. vittatus***
1st Month	25.2	24.3	22.1	19.7	16.5	23.7	18.8	20.5	13.2	16.3
4th Month	76.4	61.9	69.6	56.7	40.7	53.5	38	49.9	44.8	29.5
8th Month	115.4	95.8	98.3	82.5	78.2	89.5	74.5	82.3	65.45	70.8

Appendix Table-XVII Changes in peroxide value (mEq/kg) in different storage period

Storage period	Traditional Sample					Experimental Sample				
	C. striatus	***C. punctatus***	***W. attu***	***Puntius sp.***	***M. vittatus***	***C. striatus***	***C. punctatus***	***W. attu***	***Puntius sp.***	***M. vittatus***
1st Month	17.5	15.9	13.8	9.6	8.1	12.8	12.3	9.2	8.7	7.4
4th Month	24	21.6	19.5	18.1	12.2	18.2	20	16.3	15.25	10.7
8th Month	45.5	31.6	29.5	35.4	34.2	38.2	28.3	25.5	32.25	18.5

Appendix Table-XVIII Changes in pH values in different storage period

Storage period	Traditional Sample					Experimental Sample				
	C. striatus	*C. punctatus*	*W. attu*	*Puntius* sp.	*M. vittatus*	*C. striatus*	*C. punctatus*	*W. attu*	*Puntius* sp.	*M. vittatus*
1st Month	6.42	6.45	6.32	5.86	5.49	6.3	6.2	6.02	5.45	6.13
4th Month	7.59	7.05	6.69	6.8	7.22	6.55	6.45	6.34	5.93	5.97
8th Month	8.05	7.72	7.39	5.75	7.88	7.9	7.39	7.22	6.85	6.53

Appendix Table-XIX Changes in standard plate count in different storage period

Sample type	Storage period	*C. striatus* (cfu/g)	*C. striatus* (Log CFU/g)	*C. punctatus* (cfu/g)	*C. punctatus* (Log CFU/g)	*W. attu* (cfu/g)	*W. attu* (Log CFU/g)	*Puntius* sp. (cfu/g)	*Puntius* sp. (Log CFU/g)	*M. vittatus* (cfu/g)	*M. vittatus* (Log CFU/g)
Traditional sample	1st month	3750	3.57	2300	3.36	54100	4.73	28700	4.46	39000	4.59
		2650	3.42	1500	3.18	79900	4.90	37300	4.57	53000	4.72
		3200	3.51	1900	3.28	67000	4.83	33000	4.52	46000	4.66
	4st month	8320	3.92	4700	3.67	111920	5.05	100400	5.00	104000	5.02
		14000	4.15	11100	4.05	123420	5.09	89600	4.95	94000	4.97
		11160	4.05	7900	3.90	100420	5.00	95000	4.98	99000	5.00
	8st month	1568500	6.20	59800	4.78	2305000	6.36	112900	5.05	170000	5.23
		1531500	6.19	76800	4.89	2285500	6.36	1140000	6.06	196000	5.29
		1550000	6.19	68300	4.83	2324500	6.37	1151000	6.06	183000	5.26
Experimen al sample	1st month	3650	3.56	920	2.96	18500	4.27	1300	3.11	620	2.79
		4550	3.66	1480	3.17	31500	4.50	540	2.73	900	2.95
		4100	3.61	1200	3.08	25000	4.40	920	2.96	760	2.88
	4st month	18100	4.26	8350	3.92	56960	4.76	4800	3.68	6560	3.82
		13500	4.13	10850	4.04	79600	4.90	5500	3.74	8000	3.90
		15800	4.20	9600	3.98	68280	4.83	4100	3.61	7280	3.86
	8st month	963500	5.98	94800	4.98	885600	5.95	66000	4.82	52500	4.72
		937900	5.97	76200	4.88	901300	5.95	84000	4.92	56800	4.75
		989100	6.00	85500	4.93	917000	5.96	75000	4.88	48200	4.68

Appendix Table-XX Sensory or organoleptic evaluation in different packaging systems on 1st, 4th and 8th month.

Packaging method	Panel member	*Puntius* sp.			*M. vittatus*			*C. punctatus*			*C. striatus*			*W. attu*		
		1st	4th	8th	1st	4th	8th	1st	4th	8th	1st	4th	8th	1st	4th	8th
Vacuum	1	8.5	7	5.5	9	8.5	5.5	9.5	8	7	9	7	6.5	8.5	7	5
	2	8	7	5	9	8	5	9.75	8.5	6.5	9.5	8	6	9	7.5	5
	3	8.5	7	5	8.5	7.5	5.5	9.5	7.5	6	8.5	7	6	9.5	7	4
	4	9	7	5	9	8.5	6	9	8	7.5	8	8	7	8.75	6.5	4.5
	5	9	7.5	5.75	9	8	5	9.25	8.5	7	9	7.5	5	8.5	7.5	5.5
	6	8.5	7.5	4.5	8.5	7.5	4.5	9.5	8.5	8	9.75	7	7.5	8	7	5
	7	8	7	5	9	8	6	10	8	7.5	9.5	7.5	5	9	7.5	4.5
	8	8	6.5	6	9	9	5.5	9	8.5	7	9	8	5.5	8	7	5
	9	8.5	7	5.5	8.5	8	6	9.75	8	7.5	9.25	7	6	9.5	7.5	4.5
	10	8	7	5	9	7.75	5	9.5	8.5	7	9	7.5	6	9	7	5
N_2 pack	1	8.5	7	4	9	6	4	9.5	7	5	9	7	4.5	8.5	7	4.5
	2	8	6.5	4	9	6.5	4	9.75	7	5.5	9.5	7.25	4	9	6.5	4
	3	8.5	7	4.5	8.5	7	3.5	9.5	7.5	5	8.5	7	4	9.5	7	4.75
	4	9	6.5	4	9	7	4	9	7	5.5	8	7	4	8.75	6.5	3.5
	5	9	6	3	9	6	4	9.25	7.5	4.5	9	6	4.5	8.5	6	4
	6	8.5	6	4.5	8.5	6.5	4.5	9.5	7	5	9.75	7	4	8	7	5
	7	8	7	4.5	9	7	4	10	7	4	9.5	7.5	4	9	7	4.5
	8	8	6	4	9	6	4	9	7	5	9	6	3.5	8	6	4
	9	8.5	6.5	4.5	8.5	6.5	3.5	9.75	7.5	5.5	9.25	7	4	9.5	6.5	4.5
	10	8	6	4	9	7	4	9.5	7	4.5	9	7.5	3	9	7	4

Air pack	1	8.5	7	4	9	6	4	9.5	7	4	9	7	4.5	8.5	6	4.5
	2	8	6	3.5	9	6.5	3	9.75	6.5	5.5	9.5	7.25	4	9	6.5	4
	3	8.5	6.5	4	8.5	7	5	9.5	7.5	5	8.5	7	5	9.5	7	4
	4	9	6.5	3.5	9	7	4	9	7	5.5	8	7	4	8.75	6.5	3.5
	5	9	6	3	9	6	4	9.25	7.5	4.5	9	7.5	4.5	8.5	6	4
	6	8.5	6	3	8.5	6.5	3.5	9.5	7	5	9.75	7	4.75	8	7	3.5
	7	8	6.5	3	9	7	3	10	7	4	9.5	7.5	4	9	6.5	4.5
	8	8	6.5	4	9	6	4	9	7	5	9	7	5	8	6	4
	9	8.5	6	4	8.5	6.5	4	9.75	7.5	4.5	9.25	7	4	9.5	6.5	3.25
	10	8	6	5	9	6.5	3.5	9.5	7	5	9	7.5	3	9	7	4
Open	1	8.5	6	3	9	6	3	9.5	7	5	9	6.5	4.5	8.5	6	2.5
	2	8	6.5	3	9	6.5	3	9.75	6.5	3.5	9.5	6.75	4	9	6.5	3
	3	8.5	6	3.5	8.5	6	2.5	9.5	7.5	3.5	8.5	6	3	9.5	6.25	2.5
	4	9	6.5	3	9	7	3	9	7	4	8	7	4	8.75	6.5	3.5
	5	9	6	2.5	9	6	2.5	9.25	7.5	4	9	6.5	4.5	8.5	6	3
	6	8.5	6.5	3	8.5	6.5	3.5	9.5	7	4	9.75	6.75	3	8	7	3.5
	7	8	5	2	9	6.5	2	10	6	4	9.5	6	4	9	6.5	3
	8	8	6	3.25	9	6	3	9	7	3	9	6.5	4.25	8	6	3
	9	8.5	6.5	3	8.5	6.5	3	9.75	7.5	4	9.25	7	4	9.5	5.5	2.5
	10	8	6	2.5	9	6	3.5	9.5	6	4.5	9	7	3	9	6	3

Appendix Table-XXI List of interviewed dried fish processors of *Chalan Beel* area

SL No.	Name	Upazila	Drying place	District
1	Siddiqur Rahaman	Tarash	Moishluti	Sirajganj
2	Mofajjol Hosen	Tarash	Moishluti	Sirajganj
3	Almas	Tarash	Moishluti	Sirajganj
4	Sahalom	Tarash	Moishluti	Sirajganj
5	Abdul Gofur	Tarash	Moishluti	Sirajganj
6	Delwar Hossain	Tarash	Moishluti	Sirajganj
7	Sohidul Islam	Tarash	Moishluti	Sirajganj
8	Najir	Tarash	Moishluti	Sirajganj
9	Nannu Hossen	Tarash	Moishluti	Sirajganj
10	Kosir Uddin	Tarash	Moishluti	Sirajganj
11	Mofj Uddin	Atrai	Vortetulia	Naogaon
12	Afzal Hosen	Atrai	Vortetulia	Naogaon
13	Abdul Khaleque	Atrai	Vortetulia	Naogaon
14	Navikul Islam	Atrai	Vortetulia	Naogaon
15	Sadek Molla	Atrai	Vortetulia	Naogaon
16	Moynul	Atrai	Vortetulia	Naogaon
17	Ripon Pramanik	Atrai	Vortetulia	Naogaon
18	Mazed Islam	Atrai	Vortetulia	Naogaon
19	Jillur rahman	Atrai	Vortetulia	Naogaon
20	Abdus Satter	Atrai	Vortetulia	Naogaon
21	Kader Box	Atrai	Vortetulia	Naogaon
22	Abdul sorder	Atrai	Vortetulia	Naogaon
23	Abdul Pramanic	Atrai	Vortetulia	Naogaon
24	Zobber sorder	Atrai	Vortetulia	Naogaon
25	Najmul	Atrai	Vortetulia	Naogaon
26	Mozahar molla	Atrai	Vortetulia	Naogaon
27	Monju Molla	Atrai	Vortetulia	Naogaon
28	Rampodo Sil	Atrai	Vortetulia	Naogaon
29	Ersad Ali	Atrai	Vortetulia	Naogaon

30	Abdul Wahed	Atrai	Vortetulia	Naogaon
31	Roghunath	Atrai	Vortetulia	Naogaon
32	Abdul Mannan	Atrai	Vortetulia	Naogaon
33	Asraf	Atrai	Vortetulia	Naogaon
34	Elahi Paramanik	Atrai	Vortetulia	Naogaon
35	Pochu mollla	Atrai	Vortetulia	Naogaon
36	Samim	Atrai	Vortetulia	Naogaon
37	Doulat	Singra	Ningoin	Natore
38	Jahidul	Singra	Ningoin	Natore
39	Joynal	Singra	Ningoin	Natore
40	Mukul	Singra	Ningoin	Natore
41	Azhar Ali	Singra	Ningoin	Natore
42	Abdus Salam	Singra	Ningoin	Natore
43	Nasir Hosen	Singra	Ningoin	Natore
44	Sanwer Hosen	Singra	Ningoin	Natore
45	Dulal Hossen	Vangura	Ostomonisa	Pabna
46	Jamal	Vangura	Vangura	Pabna
47	Sohid	Vangura	Kalikadoho	Pabna
48	Firoze	Vangura	Kalikadoho	Pabna
49	Asraf	Vangura	Vangura	Pabna
50	Uzzal	Vangura	Vangura	Pabna
51	Lutfor Rahman	Chatmohor	Beelchalan	Pabna
52	Golam	Chatmohor	Beelchalan	Pabna
53	Joyder	Chatmohor	Beelchalan	Pabna
54	Jahidul Islam	Chatmohor	Beelchalan	Pabna
55	Hazu Pramanik	Chatmohor	Beelchalan	Pabna
56	Zia Kholifa	Chatmohor	Beelchalan	Pabna
57	Raihan Hossen	Chatmohor	Beelchalan	Pabna
58	Abdul aziz	Chatmohor	Beelchalan	Pabna
59	Mukul	Chatmohor	Beelchalan	Pabna
60	Sofiqul Islam	Chatmohor	Beelchalan	Pabna

Questionnaire for dried fish producers to study on the awareness status

Department of Fisheries

University of Rajshahi

Address of dry fish processor **Date:**

- Operator name: Mobile no.
- Location: Dist. UZ: Union: Vill:
- Processing area (decimal) Lease/own Lease cost / year:
- Drying experience in year :
- Rest of the time of year what occupation: which one is Primary/Secondary?
- Previous Training received on fish drying, sanitation and hygiene Y/N
- Level of education: Primary/ SSC/ HSC/B.S/MS
- Fish drying time from to month
- Where are the main drying places other than this spot?

A. Pre-drying activities

1. What are the main sources of raw fish?
2. Are the fishes preliminary washed after buying from wholesale market? Y/N
3. What type of fish crates or fish holds are used?
4. During transport of raw fish to drying spot, are the fish iced adequately? Y/N
5. Distance from wholesale market to drying spot
6. sRequired time to reach
7. Means of transportation from fish market to drying site.
8. Types of containers used for raw fish carrying?
9. Electricity facility available. Y/N

B. Drying activities

1. Is the drying site located close to housing or infrastructure and likely to get contaminated with chemicals or microbes? Y/N/Partial
2. Protective enclosure of drying spot to prevent animals or birds. Y/N
3. Is the drying spot clean and contamination free?
4. Available dry fish storage shed to be safe from rain. Y/N
5. Do the toilet and washing facilities exist in drying spot? Y/N Type of Toilet:
6. Is there any waste/garbage disposal bins in drying site? Y/N
7. Are quality fresh fish with good handling practices used for drying?
8. Does any pre-processing like scaling, gutting, splitting, filleting take place? Y/N
9. For what purpose dressing wastes are used?
10. What are the dumping places of wastages?
11. If yes, are hygienic practices (washing water/ dressing place/ equipments etc) followed? Y/N
12. Which water is used to wash fish before drying?
13. Do you wash hand before drying?
14. Are the utensils and containers washed after every operation?
15. What ingredients are used (like salt, red pepper, turmeric etc.) with raw fish before drying?
16. Are the salt clean and safe and its amount of application?
17. Are the clean mats, racks, nets, polythene sheet used?
18. Are the sick people allowed to work in drying site?
19. Is mosquito net used to prevent blow fly?
20. What types of elevated racks are used and its preparation cost along with lasting time?

21. What species of fish are usually used for drying?
22. How much time does it take to complete drying? Species wise..
23. During foggy and rainy day how much time is needed to complete drying?
24. What are the problems faced during drying activities?
25. Do you know the effects of pesticides?
26. Is there any use of insecticide? If used its name and dose:
27. Are the equipments like rack, nets, plastic sheet, and containers washed after drying?
28. How much dried fish is obtained from 1 kg raw fish?
29. Where are the dried fish kept in temporary storage before marketing?
30. What kind of packaging is used for dried fish marketing?
31. What is the pick season for drying?
32. What are the average prices of fishes based on species in wholesale market?
33. What species of fishes are in high demand?
34. Is the demand of dry fish is increasing day by day?
35. Do you get loan from Arotder?
36. To whom you sell your dried fish? Lending Arotder /any Arotder
37. What is the amount of Arotder commission?
38. Have you got any loan from other sources?
39. Are you interested in co-operative formation?
40. Do you maintain concerned government office linkage?