Tropical Agricultural Research & Extension 27 (1): 2024

RESEARCH ARTICLE

PHYSICOCHEMICAL AND MICROBIAL CHARACTERISTICS OF SELECTED DRIED FISH PRODUCTS IN SRI LANKAN MARKETS

Thennakoon TMNP[1], Subodinee AAM[2], Koralagama DN[3], Hirimuthugoda NY[1]*

[1]Department of Animal Science, Faculty of Agriculture, University of Ruhuna, Kamburupitiya, 81100, Sri Lanka.

[2]Department of Food Science and Technology, Faculty of Agriculture, University of Ruhuna, Kamburupitiya, 81100, Sri Lanka.

[3]Department of Agricultural Economics and Agribusiness, Faculty of Agriculture, University of Ruhuna, Kamburupitiya, 81100, Sri Lanka.

Received: 27 June 2023, Accepted: 18 January 2024, Published: 31 March 2024

ABSTRACT

The study was carried out to evaluate the physicochemical and microbiological properties of selected dried fish (Boat dried fish, local- land dried fish, and imported dried fish) and Maldive fish samples from markets in Colombo (CD) and Matara (MD) districts. Dried fish samples of the Shark (*Carcharodon carcharias*), Skipjack Tuna (*Katsuwonus pelamis*), Mackerel Tuna (*Decapterus russelli)*, Queenfish (*Seriphus politus*), Moonfish (*Mene makulata*), Bombay duck (*Harpadon nehereus*) and Maldive fish samples of Skipjack Tuna and Mackerel Tuna were analyzed. The results revealed that all chemical parameters are affected by the interaction of the source and types of dried fish. *Aspergillus spp* and *Saccharomyces spp* were identified in the majority of the samples. The highest mean value of moisture (WB%), crude protein%, crude fat%, total ash%, NaCl%, pH, and histamine (mg/kg) content of dried fish were shown by, CD Local Shark (53.2 ± 0.2), MD Bombay duck (61.83 ± 0.80), MD Bombay duck (14.70 ± 1.39), MD Moonfish (28.20 ± 1.16), MD Moonfish (20.50 ± 0.49), CD Local Mackerel (7.87 ± 0.06), CD Local Mackerel (127) respectively. However, no any significant difference reported in sensory evaluation particularly on smell, taste, texture, saltiness, and overall acceptability of samples. The findings of the research can be used as baseline information for the future development of product quality in the dried fish industry in Sri Lanka.

Keywords: Dried fish, Food safety, Histamine content, Dried fish quality, Physiochemical analysis, Sensory evaluation

INTRODUCTION

Fish is a highly nutritious food and an excellent source of protein, vitamins, minerals, essential fatty acids, omega-3 fatty acids (HUFA), and Eicosapentaenoic (EPA) acids. In developing countries, including Sri Lanka, fish and fish products are the primary and preferred source of animal protein (Wijayaratne and Maldeniya 2003). Fish is also the world's most popular protein source and has long been called the "poor man's protein" (Hirimuthugoda *et al*. 2014).

Dried fish is defined as "a fish product that is produced using drying procedures where the moisture content in the fish is decreased to suitable qualities, whether using oldest or modern techniques under clean conditions" (Wijayaratne and Maldeniya 2003). Dried fish is a traditionally accepted diet for many developing countries especially in South and Southeast Asia and a main source of micro-nutrient, enjoying their

Corresponding author: nyhirimuthugoda@yahoo.com

characteristic flavor and are widely used as an ingredient in seasoned foods such as soups and sauces.

"Maldivian fish" or "Hikimas" in Maldivian is a "Hot-smoked, salted product made form dried tuna fish traditionally produced in the Maldives". It is a common ingredient used for flavoring and thickening fish in the Maldives and is a protein component in many countries including Sri Lanka. Skipjack Tuna (*Katsuwonus pelamis*) is the main fish species used to produce maldive fish (Mohamed, 2013). According to Luck and Pager (2000), technically, common salt does not show antimicrobial action, but it can slow down or inhibit the vital activity of water and microorganisms or reduce its effects. However, excessive use of salt in the production of dry fruits creates unnecessary economic and marketing costs and may also lead to serious health problems.

Histamine is one of the biogenic amines that occur naturally in food, and other biogenic amines, such as tyramine and putrescine can be formed as a result of metabolic processes in microorganisms (Therapy I, 2002). Histamine poisoning or scombroid poisoning is a sanitary problem related to the high content of biogenic amines (Taylor and Eitenmiller, 1986). Consumption of tuna fish with high or low concentrations of histamine causes food poisoning due to the association of other substances with strong histamine toxicity (Murray *et al*. 1982).

Microbiological properties of dried fish play a vital role due to high perishability and lead to rapid deterioration due to poor handling and lack of storage facilities. Traditionally, salting and sun-drying of fish have been developed to minimize post-harvest deterioration and provide a product with microbiological properties favorable for consumption at a reasonable price. Regarding the distribution of various microbes in dried fish, *Aspergillus* spp along with *Aspergillus niger* are mainly resistant to sunlight which makes them more prone to survive under tropical climates (Atapattu and Samarajeeva 1990). The peroxide value refers to the degree of lipid oxidation in dried fruits and ultimately leads to the formation of flavors and odors (Majumdar *et al*. 2017).

However, the consumers' reasons for choosing certain foods are complex and varied. Food consumption, like any other complex human behavior, is influenced by several interrelated factors, including food quality aspects (such as taste, texture, and odor), as well as personal characteristics such as personality, preferences, attitudes, perceptions, and knowledge (Furst *et al*. 1996; Siscovick *et al*. 2000; Lavie *et al*. 2009).

The main objective of this study is to analyze whether dried fish in Sri Lanka safety for consumption or not by analyzing the histamine content, PV value, acid value and salt content. Further, the study evaluates the nutritional profile specially in terms of proteins and fat content. Therefore, this research simply discusses and compares the physiochemical, microbiological and sensory parameters regarding selected local, imported, boat dried fish and selected types of Maldive fish, in selected markets in Sri Lanka. Especially, because there is a knowledge gap due to lack of previous studies related to analysis of Boat dried fish and local dried fish like Bombay duck, Penna and Moonfish dried fish. Besides, the study reveals the importance of the shelf life of dried fish and health concerns, which are mostly ignored by the consumers who are only conscious on the market price.

MATERIALS AND METHODS

This project was carried out by the Department of Food Science and Technology and the Department of Animal Science, Faculty of Agriculture, Ruhuna University. The research was facilitated by the Dried fish matters project, Sri Lanka through the funding of Manitoba University, Canada.

Dried fish samples including boat-dried fish, local land-dried fish, and imported dried fish samples were purchased in triplicates from retail shops in two randomly selected districts such as Colombo (CD) and Matara (MD). All dried fish samples were brought using airtight polythene bags separately and were stored at room temperature (25 C^0), until analysis. The samples included different dried fish varieties including *Katsuwonus pelamis* (Skipjack Tuna), *Decapterus russelli* (Mackerel scad), *Carcharodon carcharias* (Shark) *Seriphus politus* (Queenfish), *Harpadon nehereus* (Bombay duck), *Mene makulata* (Moonfish) and Maldive fish samples of Mackerel and Skipjack Tuna.

Composite samples (including the top, middle, and bottom parts of the dried fish) of all dried fish and Maldive fish samples were cleaned, ground, and used for the proximate analysis, NaCl, peroxide value, and pH determination. The ground composite samples that dried at 80 C^0 for 9 hours were used for crude fat determination.

Determination of Moisture percentage and Total Ash Percentage

Determination of wet basis moisture content (WB%) was done using the oven-dry method (105 C^0 for 8 hours) and total ash percentage using the dry ash method according to Pearson (1970).

Moisture wet basis percentage =

$$\frac{\text{Dry weight of the sample g}}{\text{Wet weight of the sample g}} \times 100$$

Total ash percentage =

$$\frac{\text{W g}}{\text{The initial weight of the sample g}} \times 100$$

Determination of crude protein and fat percentages

Crude protein and fat percentages were determined by the Kjeldahl method and the Soxhlet method (Pearson 1970).

Crude protein percentage =

$$\frac{14.01 \times \text{Burette reading (ml)} \times 0.1\text{N}}{\text{The initial weight of the sample g} \times 10} \times 6.25$$

Crude fat percentage =

$$\frac{(\text{W2} - \text{W1})\ \text{g}}{\text{The initial weight of the sample g}} \times 100$$

Determination of NaCl

The percentage of salt content was determined using the "modified Mohr" method. 1 g of powdered samples was weighed and dissolved in 30 mL of boiling distilled water, of which the EC was zero (equivalent to Milli-Q water). 1 ml of 5% potassium chromate solution was added as an indicator. The sample was titrated against 0.1N silver nitrate solution until the initially yellow solution turned to a white precipitate forming silver chloride and the endpoint occurred when all the chloride ions precipitated and reacted with the chromate ions of the excess silver ion indicator to form a precipitate of red-brown silver chromate. To express the NaCl content as a percentage, the titer value is recorded and substituted in the following formula.

NaCl percentage =

$$\frac{\text{Titer value} \times \text{Normality of AgNO3} \times 58.4 \times 100}{\text{Weight of sample} \times 1000}$$

Determination of histamine and peroxide value (PV)

Peroxide value was determined using the iodometric titration method (Wu and Mao 2008; Majumdar *et al*. 2017) and histamine content was determined using the fluorometric method according to Staruszkiewicz (1977). This was conducted by the National Aquatic resources Research and Development Agency (NARA), Crow island, Colombo.

PV =

$$\frac{(\text{Burette reading} - \text{Blank burette reading})\ \text{ml} \times \text{Normality of Sodium thiosulphate dm3 mol} \times 1000}{\text{Sample weight g}}$$

Microbial analysis

Identification of fungus

For fungal colony observation, the culturing process was carried out using a PDA medium with a Chloramphenicol antibiotic to obtain a bacteria-free culture. This process was carried out for 3 weeks on all dried and Maldivian fish samples and the resulting fungi were morphologically examined and identified every week. Fungal identification was done according to Alsohaili and Bani-Hasan 2018; Atapattu and Samarajeewa 1990.

Sensory Evaluation

For sensory evaluation, all dried fish samples were deep-fried in coconut oil for 10 minutes at a temperature of 160-180 C^0 in order to evaluate their organoleptic properties by the sensory panelist and apply the same conditions for all samples. The sensory characteristics of fried dried fish were assessed by a semi-trained panel of 30 people based on a 5-point hedonic scale of each sample. The panel was asked to evaluate seven parameters (color, aroma, texture, appearance, taste, saltiness, and overall acceptability) of nine samples (Boat Shark, Imported Shark, Local Shark, Boat Skipjack Tuna, Imported Skipjack Tuna, Local Skipjack Tuna, Boat Mackerel, Imported Mackerel, Local Mackerel) of the fried dried fish treatments on a scale of 5 to 0.

Data analysis

Chemical quality data were analyzed using SAS 9.1.3 statistical package and results are presented with the mean and standard deviation of triplicates. Statistical analysis was conducted using MS Excel 2010. Sensory results were evaluated using one one-way ANOVA test with Kruskal Wallis non-parametric test in Statistical 10 software.

RESULTS AND DISCUSSION

Nutritional value of dried fish

Fresh fish consists of 75-80% moisture, 15-25% protein, 1-2% total mineral, and 4-5% crude fat (Praveen Kumar *et al*. 2017). Generally, during the drying process, the moisture content of dried fish decreases. The percentage moisture content of boat, local, and imported dried fish samples ranged from 53.2 ± 0.21 to 32.10 ± 0.29%, while it was around 21% in both Maldivian fish samples (Table 1). The highest wet base moisture content was observed in the CD Local Shark dried fish sample. However, Dharmadasa *et al*. (2019); Edirisinghe *et al*. (2013) reported two ranges of humidity from 9.85 ± 1.91 to 11.70 ± 2.81% and 16.20 to 37.10% respectively. Improper storage facilities, improper drying, lack of moisture determination methods, the quality of fresh fish samples, environmental conditions, and genetic makeup of selected fish (Majumdar *et al*. 2017; Praveen Kumar *et al*. 2017) may account for these differences. Both Maldivian fish samples contained the lowest wet basis moisture content of all dry fish species tested. According to SLS 811:1988, the maximum moisture content of Maldivian fish should be less than 16% and the values obtained in Maldivian fish samples exceeded the standard. However, the values obtained in Maldivian fish samples in our study did not show a large significant difference between the moisture content of Skipjack Tuna and Mackerel Maldivian fish samples.

The highest total ash content (28.20 ± 0.67%) was observed in local MD Moonfish dried fish samples. Siddhnath *et al*. . (2020); Edirisinghe *et al*. (2013); Reksten *et al*. (2020) have observed different ash contents such as 12.73% in Dried Shark, 22.57% in Queenfish, 17.60% Skipjack Tuna, and 24.30 ± 0.20% in Mackerel dried fish respectively. The incineration process removes all the organic matter leaving all the organic matter as ash and the open space sun drying process can result in wind-borne dust deposition, insect and bird infestation, and significant loss of moisture. This has been attributed to increased total mineral content (Clucas and Ward 1996; Immaculate *et al*. 2012; Mustapha *et al*. 2014).

The crude protein content of dried fish has been increased during the processing of raw fish because the range of protein content of raw fish varied from 15% to 25% (Praveen Kumar *et al*. 2017; Siddhnath *et al*. 2020). The collected types of local, imported, and boat-dried fish samples in this study are, in the range of 61.83 ± 0.46 - 44.30 ± 0.66 %, and Bombay duck dried fish sample showed the highest crude protein, 61.83 ± 0.46% (Table 1). According to Edirisinghe *et al*. (2013), the CP % of 17 dried fish samples varied from 41.4 to 52.8%. Maldivian fishes contained the highest crude protein percentages of all the dried species tested, which varied from 71.00 ± 2.7% to 76.50 ± 1.13%. Maldivian fish samples did not show much significant difference (Table 2). Siddhant *et al*. (2020) revealed that the crude protein content of dry fish changed from

37.41% to 77.62% due to different drying methods. Drying by various methods such as rack drying, sun drying and conventional drying methods can increase the crude protein content of dried fish (Immaculate *et al*. 2012). The crude fat content of selected dry fish varied from 14.70 ± 1.01% to 3.1 ± 0.34 % (Table 1). Local Mackerel, Local Shark, and Imported Shark dry fish samples contained relatively low crude fat content ranging from 3.10 ± 0.34% - 3.60 ± 0.42% while the highest crude fat content was observed in Bombay duck (14.70 ± 1.01%). There was a significant difference between Bombay duck dried fish (14.70 ± 1.01%) with all other selected dried fish samples. Reksten *et al*. (2020) revealed that 0.5% to 3.0% of crude fat was observed in 19 fresh fish species in Sri Lanka. An increase in fat content from 12.85% to 28.03% and 20.25% was also observed in oven-dried and oven-dried tilapia (Chukwu, 2009). Also, the crude fat percentage of 17 types of dried fish has been observed to vary from 1.0% to 6.5% (Edirisinghe *et al*. 2013). It has also been observed that dried silver carp (*H. moitrix*)

Table 1: Proximate analysis of nine different dried fish samples collected from the boat, imported, and local dried fish in Colombo District (CD) in Sri Lanka

Fish species	Type of dried fish	Moisture (WB%)	Total mineral %	Crude protein %	Crude fat %
Linna/Mackerel (Decapterus russelli)	Boat Mackerel	39.1 ± 2.58	17.9 ± 0.16	56.7 ± 0.72	8.9 ± 2.55
	Local Mackerel	44.6 ± 0.47	19.2 ± 2.17	50.1 ± 1.32	3.1 ± 1.14
	Imported Mackerel	42.5 ± 0.06	17.3 ± 0.8	53.3 ± 2.03	6.8 ± 0.1
Mora/Shark (Carcharodon carcharias)	Boat Mora/Shark	42.0 ± 0.87	18.7 ± 0.01	52.1 ± 0.96	8.4 ± 0.1
	Local Mora/Shark	53.2 ± 0.21	18.4 ± 0.12	51.2 ± 1.10	3.1 ± 0.34
	Imported Mora/ Shark	47.6 ± 0.51	17.5 ± 0.02	55.3 ± 0.5	3.6 ± 0.42
Balaya/Skipjack Tuna (Katsuwonus pelamis)	Boat Balaya/ Boat Skipjack Tuna	44.2 ± 0.48	14.8 ± 0.33	60.5 ± 0.72	7.7 ± 0.92
	Local Balaya/Tuna	46.9 ± 0.85	18.9 ± 1.20	55.4 ± 0.56	7.5 ± 0.37
	Imported Balaya/ Tuna	42.7 ± 0.28	16.9 ± 0.25	51.7 ± 0.18	6.1 ± 2.12

Each value in the table represents the mean ± SD of the individual replicates

Table 2: Proximate composition of locally available dried fish and Maldive fish in Matara District (MD) in Sri Lanka

Type of dried fish	Moisture % (WB%)	Total mineral %	Crude protein %	Crude fat %
Local dried fish				
"Katta"/Queenfish (*Seriphus politus*)	48.00 ± 0.90	25.30 ± 1.53	56.90 ± 0.83	12.10 ± 0.74
"Penna"/Moonfish (*Mene makulata*)	37.20 ± 1.96	28.20 ± 0.67	44.30 ± 0.66	11.90 ± 0.64
"Bombili"/Bombay duck (*Harpadon nehereus*)	32.10 ± 0.29	10.00 ± 0.80	61.83 ± 0.46	14.70 ± 1.01
Maldive dried fish				
"Balaya"/Skipjack Tuna (*Katsuwonus pelamis)*	21.40 ± 0.6	13.90 ± 2.41	76.50 ± 1.13	10.10 ± 0.61
"Linna"/Mackerel (*Decapterus russelli*)	21.10 ± 1.06	12.80 ± 0.9	71.00 ± 2.7	7.60 ± 1.35

Each value in the table represents the mean ± SD of the individual replicates produced by conventional, improved, and solar drying methods contained crude fat ranging from 6.21 to 7.04% (Rasul *et al*. 2018). There, the crude fat content was increased with decreasing water (Burt, 1988). However, prolonged heat treatment leads to the removal of lipids with moisture evaporation (Praveen Kumar *et al*. 2017).

Physicochemical parameters

Salt is important in food production because it promotes shelf life by lowering water activity and therefore reducing the amount of water required for the growth and development of many microorganisms (Betts, 2007). According to the World Health Organization, the recommended level of maximum requirement for adults (above 16 years) is 2-5 g per day (WHO, 2003) and NaCl is very essential for life. The percentage of NaCl in all tested samples collected from boat, local, and imported dried fish varied from 6.10 ± 0.31 to 19.10 ± 0.45 %, and Moonfish dried showed the highest content of NaCl (20.50 ± 0.28%) (Table 3). Maldivian fishes contain the lowest content of NaCl compared to all other dried fish species tested, and Maldivian fish have significant differences between both species. According to SLS 811:1988, the minimum salt content of Maldivian fish is 4%, 16% (w/w) of its moisture content. Based on the data obtained, the NaCl content of Skipjack Tuna exceeded the SLS specification. According to the Sri Lankan Institute of Industrial Technology (ITI), the maximum salt content found in dried fish is 12% and the salt content of dried fish samples from most markets in Sri Lanka varies from 14.05 to 17.41% (Nuwanthi *et al*. 2016). Also, varied between 2.43- 26.82% in 12 samples collected from Chennai (Nuwanthi *et al*. 2016). It has been observed that salt content varies from 16% to 20% in salt-fermented dry fish and 21% to 26% in salt-fermented and dried products in India (Das *et al*. 2020). In Indonesia, the salt content of salted catfish varied from 11.34% to 19.50%, and salted anchovies varied from 2.31% to 7.39% (Lubis *et al*. 2021). As the standard value of NaCl in dried fish is 12%, all tested species of dried fish vary beyond that level and 5% is the standard value of salt content in Maldivian fish, so the tested Skipjack Tuna Maldivian fish samples are beyond this level. It has become a matter of regret that the relevant authorities are not monitoring the amount of salt in the dried fish in the Sri Lankan market. Excessive salt consumption increases the risk of non-communicable diseases (NCDs) such as hypertension, cardiovascular disease, kidney disease, and stroke (WHO, 2003). Also, there is a correlation between sodium

Table 3: Selected Physicochemical parameters of the nine different dried fish samples collected from the boat, imported and local dried fish in Sri Lanka

Fish species	Type of dried fish	Salt %	pH	PV (meq/1 kg of fat)	Histamine (mg/kg)
Linna/Mackerel (*Decapterus russelli*)	Boat Mackerel	15.8 ± 0.40	6.20 ± 0.00	0.13 ± 0.00	24.43 ± 2.83
	Local Mackerel	17.40 ± 0.04	7.87 ± 0.06	0.22 ± 0.03	127.17 ± 2.05
	Imported Mackerel	15.40 ± 0.21	5.50 ± 0.00	0.46 ± 0.06	38.81 ± 2.37
Mora/Shark (*Carcharodon carcharias)*	Boat Shark	19.10 ± 0.45	6.90 ± 0.00	0.11 ± 0.03	5.24 ± 0.87
	Local Shark	18.80 ± 0.49	6.27 ± 0.06	0.18 ± 0.00	1.97 ± 1.72
	Imported Shark	19.00 ± 0.27	5.83 ± 0.06	0.21 ± 0.06	1.27 ± 0.04
Balaya/Skipjack Tuna (*Katsuwonus pelamis)*	Boat Skipjack Tuna	14.20 ± 0.47	5.80 ± 0.00	0.12 ± 0.02	60.33 ± 1.66
	Local Skipjack Tuna	18.80 ± 0.22	6.00 ± 0.00	0.19 ± 0.01	69.35 ± 2.87
	Imported Skipjack Tuna	18.40 ± 0.38	5.60 ± 0.00	0.14 ± 0.01	17.49 ± 3.37

Each value in the table represents the mean ± SD of the replicate analysis intake and high blood pressure in older people and those with diabetes, with a tendency to reduce sodium by replacing part of the sodium with other substances (Osheba, 2013).

According to the results, it was observed that the pH value of all types of dried fish samples tested in the study varied from 7.87 ± 0.06 to 5.50 ± 0.00 and imported mackerel dried fish showed the lowest pH value (5.50 ± 0.00). Meanwhile, local mackerel dried fish showed the highest pH value (7.87 ± 0.06) (Table 3). During the drying process, the production of nitrogenous compounds may lead to an increase in the pH value of sun-dried fish (Praveen Kumar *et al*. 2017). According to Dharmadasa *et al*. (2019), the pH of common salted dried fish (CSDF) and herb-salted dried fish (HSDF) was observed to vary from 4.96 to 5.93. During drying, pH may decrease because true lactic acid fermentation does not occur and the addition of salt to the fish decreases the pH of fish due to increased acidic compounds (Praveen Kumar *et al*. 2017). It has been reported that the pH value of salt-fermented dried fish samples varies from 5.32 to 6.6 in the acidic range (Das *et al*. 2020), and that of a shark (*Carcharodon carcharias*) and Bombay duck (*Harpadon nehereus*) varies from 8.07 - 8.27 (Azam *et al*. 2003). It has also been observed that the highest and lowest pH values ranging from 6.33 to 6.65 were obtained from conventionally produced dried fish and solar tunnel drying methods, respectively (Rasul *et al*. 2018). The pH values of both Maldivian fishes in this study were almost similar (6.2 ± 0.00 - 6.4 ± 0.00) and there was no significant difference (Table 4).

Oxidative degradation of polyunsaturated fatty acids in fish muscle, known as lipid peroxidation, can result in off-flavor, off-flavor development, and shortened shelf life of foods (Ramanathan and Das 1992; Majumdar *et al*. 2017). The peroxide value (PV), which indicates the extent of primary oxidation (the initial stage of oxidative changes), and the anisidine value, which indicates the occurrence of secondary oxidation, have previously been used in one study to evaluate fats from raw and dried grass carp fillets (Wu and Mao 2008). In comparison, the variation in PV value during boat dried production has not yet been observed in Sri Lanka. Therefore, PV values were done here only for fish species used in the production of boat dried fish. The peroxide value of the dried fish samples in this study varied from 0.11 ± 0.03 to 0.46 ± 0.06 meq/1kg fat (Table 3) and there is a significant difference among all tested dried fish compared to previous research results. Joseph (1992) observed that 25.3 - 33.2 millimoles of O_2/kg fat were the peroxide value of the dried fish products in Kerala. Seer fish and split open fish showed high PV values may be due to high-fat content that

Table 4: Selected Physicochemical parameters of locally available dried fish and Maldive fish in Matara District (MD) in Sri Lanka

Type of dried fish	Salt %	pH
Local dried fish		
"Katta"/Queenfish (*Seriphus politus*)	19.60 ± 0.38	7.5 ± 0.00
"Penna"/Moonfish (*Mene makulata*)	20.50 ± 0.28	7.5 ± 0.00
"Bombili"/Bombay duck (*Harpadon nehereus*)	6.10 ± 0.31	6.5 ± 0.00
Maldive dried fish		
"Balaya"/Skipjack Tuna (*Katsuwonus pelamis)*	3.50 ± 0.04	6.2 ± 0.00
"Linna"/Mackerel (*Decapterus russelli*)	5.00 ± 0.17	6.4 ± 0.00

Each value in the table represents the mean ± SD of the replicate analysis leads to rapid lipid oxidation because the pre-oxidant reaction of the fish and high flesh area was exposed to drying temperature respectively.

Praveen Kumar *et al*. (2017) observed that the high temperature caused the reduction of the PV value of *Pangasius hypophthalmus* from 2.99 to 2.50 with the temperature difference from 50 C^0 to 70 C^0 under different dying methods and un-salted sun drying and salted sun-drying dried fish types were varied from 3.89 to 4.53 meq of O_2/kg of fat. Rasul *et al*. (2018) studied about physiochemical, microbiological, and sensory properties of dried silver carp (*Hypophthalmichthys molitrix*) influenced by various drying methods. According to the results, the PV value varied from 9.13 to 15.56 meq/kg of lipid with different drying methods.

Wu and Mao (2008) observed the nutritional and sensory properties of Grass carp (*Ctenopharyngodon idellus*) using different drying methods (hot air drying and microwave drying). According to the results, the quality of extracted fat from dried and raw fish was determined using PV value, while there was a significant difference ($p \leq 0.05$). After drying, PV value was decreased significantly, but no significant difference between dried fish from hot air drying and microwave drying. Contrary to peroxide values, drying significantly increased anisidine values, the highest being with hot air drying. Wu and Mao (2008) found that, high temperatures, able to speed up the breakdown of peroxides into their carbonyl compounds that cause to reduce the PV value while increasing the anisidine value which was the best example of the secondary oxidation products (hyperoxide decomposition secondary oxidation products) high drying temperatures. During drying at high temperatures, both hydrolytic and oxidative degradation has occurred because unstable hypo peroxides are breakdown through fission, dehydration, and eventually produce the free radicles, into alcohols, aldehydes, ketones, acids, dimers, trimers, polymers, and cyclic compounds (Fritsch, 1981; Tan *et al*. 2002; Aboubakar *et al*. 2006).

Histamine is formed during the microbial decomposition of scombroid and non-scombroid fish such as mackerel and sardines (Chaudhury *et al*. 2008). This is because the muscle tissue of scombroid fish contains large amounts of free histidine, which is converted to histamine under conditions favorable to bacterial growth and histidine decarboxylase synthesis (Taylor and Eitenmiller 1986). However, in fish muscle, histidine can be catalyzed in two ways. Histidine deamination produces urocanic acid and histidine decarboxylation produces histamine (Mackie and Fernandez-Salguéro 1977). However, various known bacterial species are capable of histidine decarboxylase and produce histamine (Kung *et al*. 2010). But only 3 bacterial species are capable of causing scombroid poisoning, *Morganella morganii*, *Klebsiella pneumoniae,* and *Hafnia alve*. Poisoning of histamine called "Scombrotoxin poisoning" because, the frequent association of the illness has occurred with the consumption of spoiled scombroid fishes such as tuna, mackerel, bonito, and saury which contained a high amount of histamine in their muscles (Taylor & Eitenmiller, 1986; Köse, 2010; Murray *et al*., 1982). But non-scombroid fishes such as herrings, anchovy, mahi-mahi, bluefish, sardine are also implicated; Köse, 2010; Kung *et al*., 2010). Primarily, histamine formation relates to marine fish species and there is no risk of potential when using freshwater fish as raw materials (Huss *et al*., 2004). Poisoning of histamine shows symptoms (pseudo allergic reactions) such as urticaria, eczema, diarrhea, spasm of the bronchi, rash, nausea, vomiting, flushing, tingling, and itching of the skin (Taylor & Eitenmiller, 1986). The severity of these symptoms depends on the amount of histamine ingested or sensitivity to histamine (Kung *et al*., 2010). Not only histamine putrescine and cadaverine may also cause to implicate this type of poisoning (Ryder *et al*., 2014). 50 ppm-500ppm range has been reported as that protentional to occur histamine poisoning and finally the effect for human health (Ryder *et al*., 2014). There are some other isolated bacterial species they are capable of producing histamine (Steve and Marci 1983). Some of them are *Proteus* *vulgaris, Proteus mirabilis, Enterobacter aerogenes, Enterobacter cloacae, Serratia fonticola, Serratia lickfaciens, Raoultella* (formerly Klebsiella) *planticola, Raoultella ornithinolitica* (Lin and Hwang 2007). Meantime, some of them are non-enteric bacterial species such as Clostridium spp., *Vibrio alginolyticus, Acinetobacter lofii, Plesiomonas shigeloides, Pseudomonas pudida, Pseudomonas fluorescens*, Aeromonas spp., and Photobacterium spp . Histamine poisoning is one of the known sanitary problems associated with fish with higher biogenic amines (Taylor and Eitenmiller 1986). Not only histamine but also tyramine, putrescine is some naturally occurring biogenic amines, but increased levels of these amines may be due to bacterial contamination of the respective foods (Veciana-Nogués *et al*. 1997). Therefore, the

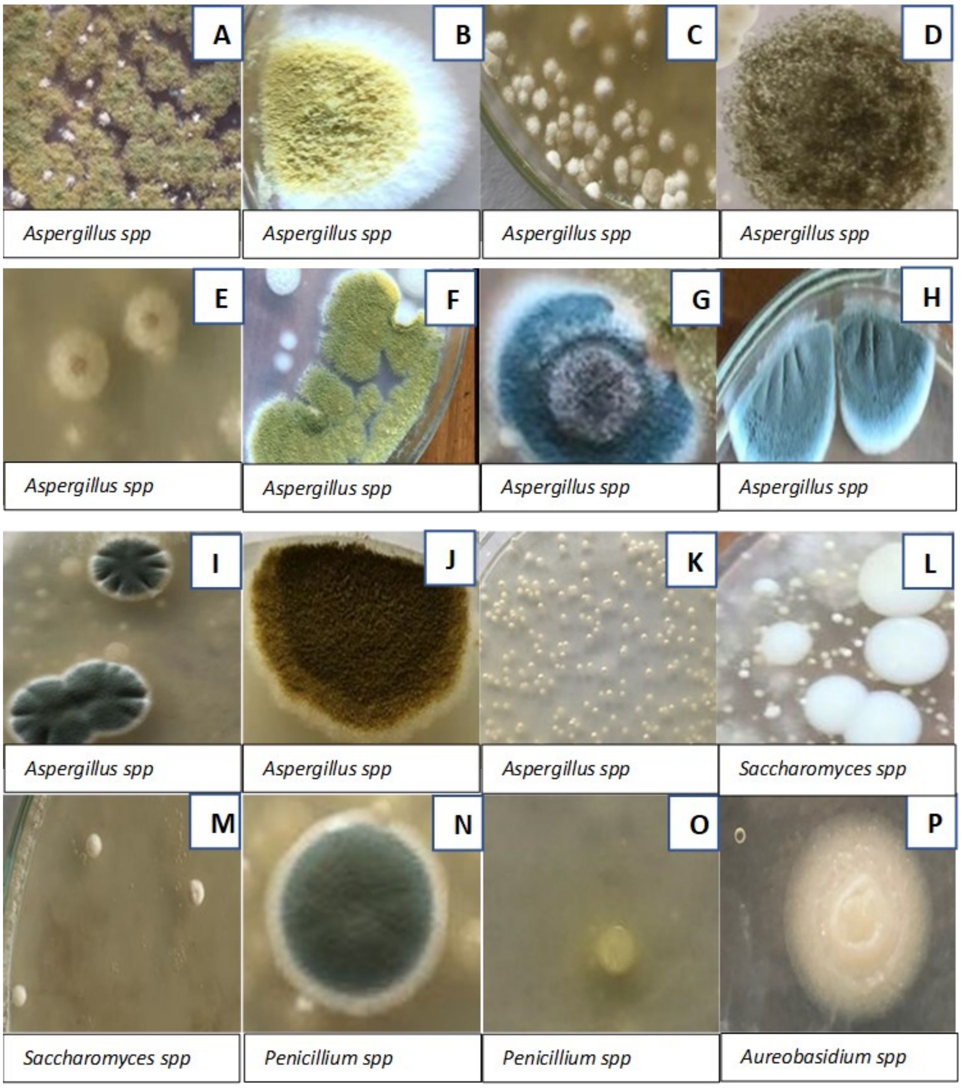

Figure 1: Types of fungus in nine different dried fish samples collected from the boat, imported and local dried fish in Sri Lanka
A (*Carcharodon carcharias* BDF), **B** (*Katsuwonus pelamis* IDF), **C** (*Katsuwonus pelamis* IDF), **D** (Katsuwonus *pelamis* MF), **E** (*Decapterus russelli* IDF), **F** (*Carcharodon carcharias* IDF), **G** (Katsuwonus *pelamis* MF), **H** (*Carcharodon carcharias* IDF), **I** (*Decapterus russelli* MF), **J** (*Decapterus russelli L*DF), **K** (Katsuwonus *pelamis* MF), **L** (Katsuwonus *pelamis* MF), **M** (*Decapterus russelli* MF), **N** (*Decapterus russelli* IDF), **O** (*Decapterus russelli* MF), **P** (*Carcharodon carcharias* IDF). IDF- Imported dried fish; MF – Maldive fish; LDF- Local dried fish

activity of bacteria or bacterial enzymes contributes to the production of biogenic amines and even after the responsible bacteria have been killed, the bacterial enzymes may persist with the production of biogenic amines (Therapy 1, 2002).

Since lactic acid fermentation leads to increased histamine production, protein-rich foods such as fish, meat, and cheese-free histidine as well as sparkling wine and beer are considered histamine-containing foods (Fletcher *et al*. 1998). There are different methods for histamine analysis. Fluorimetry and liquid chromatography (LC) are physicochemical methods (Stratton *et al*. 1991). The reverse-phase HPLC method is the most important chromatographic method for determining the histamine content as a fluorescent derivative (Aygün *et al*. 1999). Enzyme immunoassay is a method for the quantitative analysis of histamine (Therapy 1, 2002). How the Histamine value changes during the production of dry beans in the boat have not been comparatively observed in Sri Lanka so far. Also, a comparison of histamine values of imported, local, and boat-dried fish of the same fish species has not been done in Sri Lanka so far. Additionally, as it has not been reported to be present in *Seriphus politus, Mene makulata,* and *Harpadon nehereus*, their histamine values were not examined in this study. The measured histamine content of dried fish samples varied from 1.27 ± 3.37 to 127 ± 2.05 mg/kg (Table 3). Local and imported shark-dried samples contained the lowest amount of histamine, while local mackerel-dried samples contained the highest amount of histamine. Ryder *et al*. (2014), found that a range of 50-500 mg/kg of histamine leads to toxicity and eventually affects human health. Most dried fish samples were safe for human consumption except local mackerel, boat skipjack Tuna and local skipjack Tuna dried varieties (<50 mg/kg). SLS 811:1988 stated that the histamine content of Maldivian fish should not exceed 200 mg/kg, which is the maximum histamine content to be safe for consumption. However, the collected Skipjack Tuna Maldive fish sample contained 23 mg/kg and was found to be safe.

There are several ways to control histamine production in fish products. The formation of histamine must be controlled before the preparation of the product example: the raw material phase, because once the histidine carboxylase enzyme is formed, even if the responsible bacteria do not exist, a process of histidine production continues and the histamine produced cannot be removed by heat or freezing (Köse, 2010).

Control of bacterial histamine production in fisheries is highly dependent on low-temperature storage after capture. Naturally, histamine-producing bacterial species grow in the gills and guts of live fish in ocean water. Therefore, the production of histamine can be eliminated by sanitation and elimination, but if it is done under unsanitary conditions, it can cause the production of histamine to accelerate in the fish meat (Taylor and Speckhard 1983). Fish that tend to be exposed to warm water or air must go through the freezing process to prevent histamine formation (Köse, 2010). This is because fish shape and size, handling methods, and cooling methods are all factors that affect the growth of histamine-producing bacteria (Taylor and Speckhard 1983). However, the majority of fish are salted and dried without gutting, which contains a large number of bacteria that produce decarboxylase, which has a strong effect on histamine formation (Kung *et al*. 2010).

Fungal colony observations

According to the results, there were no observations of fungal colonies among most dried fish species in the first culture second culture, and the third culture. *Saccharomyces* spp were observed in both Skipjack Tuna dried varieties (boat and imported), local mackerel-dried varieties, and Maldivian fish varieties (Figure 1). *Aspergillus* spp and *Penicillin spp* were observed in many dried fish and Maldivian fish samples(Figure 1). Atapattu and Samarajeeva (1990) have studied the fungi associated with dried fish in Sri Lanka and according to them 51% were contaminated with *Aspergillus* spp and *Aspergillus niger* was predominant. In addition, *Aspergillus flavus, Aspergillus* *fumigatus, Aspergillus glaucus, Aspergillus restrictus, Aureodasidium* spp, *Basipetospora halophila, Cladosporium herbarum, Gleomastix spp, Penicillium chalybeum, and Penicillium expansum* were observed. Nuwanthi *et al*. (2016), found that Goldstripe sardinella (*Sardinella gibbosa*) dried spices contained yeasts, molds, and coliforms at different salt levels. Dharmadasa *et al*. (2019) observed that samples of dried *Oreochromis niloticu*s processed with common salt and herb salt contained different types of yeasts, molds, and aerobic microorganisms. The microbial quality of raw sun-dried fish and commercially available sun-dried fish contained 1 x102 CFU/ml, respectively while the total fungal count (TFC) of experimentally sun-dried fish was zero (Patterson and Ranjitha 2009).

Sensory attributes of dried fish

Three samples of different types of sharks dried on the boat, the preference for imported and local dried was not significant ($p > 0.05$). However, the data related to the mean score obtained for each parameter is ranked. In terms of appearance and aroma quality parameters, the local dried shark was found to be the best (Table 5). In terms of color, texture, saltiness, and overall acceptability parameters. Imported Shark dried fish was the best out of all the samples. Further, Boat Shark fish was found to be the best for taste. The Kruskal-Walli's test confirmed that the preference for Skipjack Tuna fish based on a 5 -point hedonic scale was not significantly different for all quality parameters of appearance, aroma, taste, texture, saltiness, and overall acceptance ($p < 0.05$) between the color of local imported, imported boats and local boats dried Skipjack Tuna. The mean score obtained for each parameter were ranked. Skipjack Tuna (Boat dried) scored highest for appearance and color where as the local dried skipjack Tuna was best in terms of aroma quality. On the other hand, imported dried skipjack Tuna scored highest for its taste, texture, saltiness, and overall acceptable quality parameters.

There was a significant difference ($p < 0.05$) in color, aroma, taste, texture, saltiness, and overall acceptance among boat-imported, imported-local, and boat-local mackerel-dried varieties. Imported Shark, Imported Skipjack Tuna, and Local Mackerel dried varieties scored higher indicating higher acceptance than other dried products. Local Shark and local skipjack Tuna dried varieties have low odor, spoilage by worms, and some maggots in the finished product, resulting in unacceptable or less acceptable dried fish

Table 5: Comparison of sensory properties of the nine different dried fish samples collected from the boat, imported and local dried fish in Sri Lanka

Type of dried fish	Parameters						
	Appearance	Color	Smell	Taste	Texture	Saltiness	Overall Acceptability
Boat Shark	40.62^{a}	36.67^{a}	46.35^{a}	49.10^{a}	47.07^{a}	43.53^{a}	46.67^{a}
Imported Shark	46.55^{a}	51.23^{a}	41.95^{a}	48.05^{a}	50.57^{a}	51.37^{a}	51.75^{a}
Local Shark	49.33^{a}	48.60^{a}	48.20^{a}	39.35^{a}	38.87^{a}	41.60^{a}	38.08^{a}
Boat Skipjack Tuna	50.55^{a}	55.67^{a}	37.13^{a}	43.07^{a}	44.53^{a}	46.85^{a}	43.16^{a}
Imported Skipjack Tuna	44.52^{a}	41.33^{ab}	48.57^{a}	52.18^{a}	50.20^{a}	49.68^{a}	52.74^{a}
Local Skipjack Tuna	41.43^{a}	39.50^{b}	50.80^{a}	41.25^{a}	41.77^{a}	39.97^{a}	37.83^{a}
Boat Mackerel	38.68^{b}	37.67^{a}	46.50^{a}	44.22^{a}	47.48^{a}	43.08^{a}	45.20^{a}
Imported Macke-rel	44.27^{ab}	49.52^{a}	46.89^{a}	47.05^{a}	42.40^{a}	49.94^{a}	44.90^{a}
Local Mackerel	53.86^{a}	49.31^{a}	42.98^{a}	45.17^{a}	46.76^{a}	43.26^{a}	46.45^{a}

production and high sensitivity scores. Good texture, color, aroma, and taste result in high acceptance (Praveen Kumar *et al*. 2017).

CONCLUSION

All tested dried fish samples and Maldive fish samples exceeded the standard moisture content (w/w). Therefore, necessary steps need to be taken to aware the producers and trades on this. Tested Maldive fish samples showed higher crude protein content, while crude fat and total mineral contents were higher in tested dried fish samples: Bombay duck dried fish and Moonfish dried fish, respectively. Moreover, Samples tested for histamine were in the acceptable range. From a microbiology point of view, the most prominent fungi were *Saccharomyces, Aspergillus,* and *Penicillium*. Furthermore, the sensory evaluation test proved no significant difference among dried fish samples particularly locally produced and imported. These data can be used as a baseline data to conduct awareness programmes and to develop better techniques and technologies for dried fish producers and traders in Sri Lanka.

ACKNOWLEDGEMENT

Authors are thankful to the Faculty of Agriculture, University of Ruhuna for providing the necessary facilities for conducting this study and also remain grateful to the Dried Fish Matters Sri Lanka project for financial assistance. The project director is Prof Derek Johnson, Manitoba University, Canada.

AUTHOR CONTRIBUTION

TTMNP contributed to the sampling, laboratory work, analysis of the results and drafting the manuscript. DK contributed to drafting the manuscript and providing the financial support . SAAM and HNY contributed to designing the project, computational work and to the writing and editing of the manuscript.

REFERENCES

Aboubakar D, Almeck K, Tchiegang C, Kapseu C, Fanni J and Parmentier M 2006 Changes in *Canarium schweinfurthii* Engl. oil quality during microwave heating. European Journal of Lipid Science and Technology, 108 (5): 429–433.

Alsohaili SA and Bani-Hasan BM 2018 Morphological and molecular identification of fungi isolated from different environmental sources in the northern eastern Desert of Jordan. Jordan Journal of Biological Sciences, 11(3): 329–337.

Atapattu R and Samarajeewa U 1990 Fungi associated with dried fish in Sri Lanka. Mycopathologia, 111(1): 55–59.

Azam K, Basher MZ, Ali MY, Asaduzzama M and Hossain MM 2003 Comparative study of organoleptic, microbiological and biochemical qualities of four selected dried fish in summer and winter. Pakistan Journal of Biological Sciences, 6(24): 2030–2033.

Aygün O, Schneider E, Scheuer R, Usleber E, Gareis M and Märtlbauer E 1999 Comparison of ELISA and HPLC for the determination of histamine in cheese. Journal of Agricultural and Food Chemistry, 47(5), 1961–1964, https://doi.org/10.1021/jf980901f

Betts G, Everis L and Betts R 2007 From Microbial issues in reducing salt in food products. Woodhead Publishing, 174-200.

Burt JR 1988 Fish smoking and drying: the effect of smoking and drying on the nutritional properties of fish. ElseviernApplied Science, London, new York.

Choudhury M, Kumar SM, Sivakumar K, Thangaradjou T and Kannan L 2008 Inhibition of Actinomycetes to histamine producing bacteria associated with Indian Mackerel fish (*Rastrellinger kanagurata Cuvier*). Journal of Fisheries and Aquatic Sciences, 3(2): 126–136.

Chukwu O 2009 Influences of drying methods on nutritional properties of Tilapia fish (*Oreochromis nilotieus*). World Journal of Agricultural Sciences 5, 5 (2): 256-258.

Clucas IJ and Ward AR 1996 Post-harvest fisheries development: a guide to handlin preservation, processing and quality. Chartan Maritime, Kent, Me4 TB, United Kingdom.

Das O, Kumar SH and Nayak BB 2020 Relative abundance of halophilic archaea and bacteria in diverse salt-fermented fish products. Food Secience and Technology, 117(1): 108688.

Dharmadasa RM, Lintha A, Wijesekara RGS, Abeysinhe DC and Ranasinghe P 2019 Use of *Halosarcia indica* (Willd.) Paul G. Wilson extracts for low salted dried fish production. World Journal of Agricultural Research, 7(4): 132–136.

Edirisinghe DM, Cumaranatunga PRT, Radampola KK and Kirindearachchige PY 2013 Analysis of proximate composition and consumer preference of three reef fish species. Sri Lanka Journal. Aquatic Science, 18(1): 27–36.

Fletcher GC, Summers G and Van VPWC 1998 Levels of histamine and histamine-producing bacteria in smoked fish from New Zealand markets. Journal of Food Protection, 61(8): 1064–1070.

Fritsch CW 1981 Measurements of frying fat deterioration: A brief review. Journal of the American Oil Chemists' Society, 58(3): 272–274.

Furst T, Connors M, Bisogni CA, Sobal J and Falk LW 1996 Food choice:conceptual model of the process. Appetite, 26(3): 247–266.

Hirimuthugoda NY, Pethiyagoda NA and Madusanka ST 2014 Factors affecting the consumer preference and consumer buying behavior of dried fish: a case of Southern province in Sri Lanka [Conference poster]. Proceedings of the International Symposium on Agriculture and Environment 2014, Ruhuna, Sri Lanka, 27 November 2014: 419–421.

Huss HH, Ababouch L and Gram L 2004 Assessment and management of seafood safety and quality. Fisheries Technical Paper 444, 1(1), 378.

Immaculate J, Sinduja P and Jamila P 2012 Biochemical and microbial qualities of Sardinella fimbriata sun dried in different methods. International Food Research Journal, 19(4):1699–16703.

Joseph KG, Nair PR, Nair TSU and Mathen C 1992 Retail marketing and quality of salted fish in remote villages of Kozhikode district, Kerala. Fishery Technology, 3(2), 103–112.

Köse S 2010 Evaluation of seafood safety health hazards for traditional fish products: Preventive measures and monitoring issues. Turkish Journal of Fisheries and Aquatic Sciences, 10(1): 139–160.

Kung HF, Lee YC, Huang YR, Lin WF, Lin CM, Chen WC and Tsai YH 2010 Biogenic amines content, histamine-forming bacteria, and adulteration of pork and poultry in Tuna dumpling products. Food Control, 21(7): 977–982.

Lavie CJ, Milani RV, Mehra MR and Ventura HO 2009 Omega-3 Polyunsaturated Fatty Acids and Cardiovascular Diseases. Journal of the American College of Cardiology, 54(7): 585–594.

Lin WF and Hwang DF 2007 Application of PCR-RFLP analysis on species identification of canned tuna. *Food Control*, *18*(9), 1050–1057. https://doi.org/10.1016/j.foodcont.2006.07.001

Lubis YM, Zaidiyah Y and Dinti SS 2021 Chemical and microbiology assessment of salted fish (anchovy and catfish) product in Banda Aceh district as a parameter of food safety. IOP Conference Series: Earth and Environmental Science, 644(1): 012062.

Luck E and Pager M 2000 Chemical conservation of food: Characteristics, uses, effects. Acribia, 1(1):46–98.

Mackie IM and Fernandez-Salguéro J 1977 Histidine metabolism in fish. Urocanic acid in mackerel (*Scomber scombrus*). Journal of the Science of Food and Agriculture, 28(10): 935–940.

Majumdar BC, Afrin F, Rasul G, Khan M and

Shah AKMA 2017 Comparative study of physical, chemical, microbiological and sensory aspects of some sun-dried fishes in Bangladesh. Brazilian Journal of Biological Sciences, 4(8): 323–331.

Mohamed S 2013 Toxigenic Fungi and Mycotoxin Production in Maldive Fish (Smoked Dried Tuna Fish), PhD thesis, University of Massey, Palmerston North, New Zealand.

Murray CK, Hobbs G and Gilbert RJ 1982 Scombrotoxin and scombrotoxin-like poisoning from canned fish. Journal of Hygiene, 88(2): 215–220.

Mustapha MK, Ajibola TB, Salako AF and Ademola SK 2014 Solar drying and organoleptic characteristics of two tropical African fish species using improved low-cost solar driers. Food Science and Nutrition, 2(3): 244–250.

Nuwanthi SGLI, Madage SSK, Hewajulige IGN and Wijesekera RGS 2016 Comparative study on organoleptic, microbiological and chemical qualities of dried fish, Goldstripe Sardinella (*Sardinella gibbosa*) with low salt levels and spices. Procedia Food Science, 6(1): 356–361.

Osheba AS 2013 Technological attempts for production of low sodium smoked herring fish (Renga). Advance Journal of Food Science and Technology, 5 (6): 695–706.

Patterson J and Ranjitha G 2009 Qualities of commercially and experimentally sun-dried fin fish, Scomberoides tol. African Journal of Food Science, 3 (10): 299–302.

Pearson D 1970 The Chemical analysis of foods (No. Ed. 7). Churchill, London, 6,422-540.

Praveen KG, Martin XKA, Nayak BB, Kumar HS, Venkateshwarlu G and Balange KA 2017 Effect of different drying methods on the quality characteristics of *Pangasius hypophthalmus*. International Journal of Current Microbiology and Applied Sciences, 6 (10): 184–195.

Ramanathan L and Das NP 1992 Studies on the control of lipid oxidation in ground fish by some polyphenolic natural products. Journal of Agricultural and Food Chemistry, 40 (1): 17–21.

Rasul MG, Majumdar BC, Afrin F, Bapary MAJ and Shah AKM Azad 2018 Biochemical, microbiological, and sensory properties of dried silver carp (*Hypophthalmichthys molitrix*) influenced by various drying methods. Fishes, 3(3): 25.

Reksten AM, Somasundaram, Thiruchenduran, Kjellevold M, Nordhagen A, Bokevoll A, Pincus LM, Rizwan AAM, Mamun A, Thilsted S, Harakshingh, Htut T and Askre I 2020 Nutrient composition of 19 fish species from Sri Lanka and potential contribution to food and nutrition security. Journal of Food Composition and Analysis, 91 (October 2019):103508.

Ryder J, Iddya K and Ababouch L 2014 Assessment and management of seafood safety and Quality: current practices and emerging issues. FAO Fisheries and Aquaculture Technical Paper, 1(1), 574.

Siddhnath, Ranjan A, Mohanty BP, Saklani P, Dora KC and Chowdhury S 2020 Dry Fish and Its Contribution Towards Food and Nutritional Security. Food Reviews International, 1(1)1–29.

Siscovick DS, Raghunathan TE, King, Weinmann S, Bovbjerg VE, Kushi L, Cobb LA, Copass MK, Psaty BM, Lemaitre R, Retzlaff B and Knopp RH 2000 Dietary intake of long-chain n-3 polyunsaturated fatty acids and the risk of primary cardiac arrest. American Journal of Clinical Nutrition, 71(1): 208–212.

Staruszkiewicz WF 1977 Fluorometric determination of histamine in Tuna:collaborativstudy. Journal - Association of Official Analytical Chemists, 60(5): 1131–1136.

Steve LT and Marci WS 1983 Isolation of histamine-producing bacteria from frozen Tuna. Marine and Fishery Review, 45(4-6): 35–39.

Stratton JE, Hutkins RW and Taylor SL 1991 Biogenic amines in cheese and other fermented foods: A review. Journal of Food Protection, 54(6): 460–470.

Tan CP, Che Man YB, Jinap S and Yusoff MSA 2002 Effects of microwave heating on the quality characteristics and thermal properties of RBD palm olein. Innovative Food Science and Emerging Technologies, 3(2): 157–163.

Taylor SL and Eitenmiller RR 1986 Histamine food poisoning: Toxicology and clinical aspects. Critical Reviews in Toxicology, 17 (2): 91-128.

Taylor SL and Speckhard MW 1983 Isolation of histamine-producing bacteria from frozen Tuna. Marine Fisheries Review, 45(4-6): 35–39.

Therapy I 2002 The histamine content in some samples of food product. Food Science, 22(3): 81–86.

Veciana-Nogués M, Mariné-Font A and Vidal -Carou M 1997 Biogenic amines as hygienic quality indicators of Tuna. relationships with microbial counts, ATP-related compounds, volatile amines, and organoleptic changes. Journal of Agricultural and Food Chemistry, 45(6): 2036–2041.

Wijayaratne B and Maldeniya R 2003 The role of fisheries sector in the coastal fishing communities of Sri Lanka. National Aquatic Resources Research and Development Agency Crow Island, Mattakuliya, Colombo 15, Sri Lanka

World Health Organization and International Society of Hypertension Writing Group 2003 (ISH) statement on management of hypertension. Journal of hypertension, 21(11): 1983–1992.

Wu T and Mao L 2008 Influences of hot air drying and microwave drying on nutritional and odorous properties of grass carp (*Ctenopharyngodon idellus*) fillets. Food Chemistry, 110 (3): 647–653.