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...
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 from 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 air-
tight polythene bags separately and were stored at room temperature (25°C), 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 Maldivian 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 Maldivian 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 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 for 8 hours) and total ash percentage using the dry ash method according to Pearson (1970).

\[
\text{Moisture wet basis percentage} = \frac{\text{Dry weight of the sample} \times 100}{\text{Wet weight of the sample}}
\]

\[
\text{Total ash percentage} = \frac{Wg}{\text{The initial weight of the sample}} \times 100
\]

**Determination of crude protein and fat percentages**

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

\[
\text{Crude protein percentage} = \frac{14.01 \times \text{Burette reading (ml)} \times 0.1N \times 6.25}{\text{The initial weight of the sample} \times 100}
\]

\[
\text{Crude fat percentage} = \frac{(W2 - W1) g}{\text{The initial weight of the sample} \times 100}
\]

**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.

\[
\text{NaCl percentage} = \frac{\text{Titer value} \times \text{Normality of AgNO}_3 \times 58.4 \times 100}{\text{Weight of sample} \times 1000}
\]

**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.

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

**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 Alshohaili 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 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); 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 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

<table>
<thead>
<tr>
<th>Fish species</th>
<th>Type of dried fish</th>
<th>Moisture (WB%)</th>
<th>Total mineral %</th>
<th>Crude protein %</th>
<th>Crude fat %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linna/Mackerel (Decapterus russelli)</td>
<td>Boat Mackerel</td>
<td>39.1 ± 2.58</td>
<td>17.9 ± 0.16</td>
<td>56.7 ± 0.72</td>
<td>8.9 ± 2.55</td>
</tr>
<tr>
<td></td>
<td>Local Mackerel</td>
<td>44.6 ± 0.47</td>
<td>19.2 ± 2.17</td>
<td>50.1 ± 1.32</td>
<td>3.1 ± 1.14</td>
</tr>
<tr>
<td></td>
<td>Imported Mackerel</td>
<td>42.5 ± 0.06</td>
<td>17.3 ± 0.84</td>
<td>53.3 ± 2.03</td>
<td>6.8 ± 0.1</td>
</tr>
<tr>
<td>Mora/Shark (Carcharodon carcharias)</td>
<td>Boat Mora/Shark</td>
<td>42.0 ± 0.87</td>
<td>18.7 ± 0.01</td>
<td>52.1 ± 0.96</td>
<td>8.4 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>Local Mora/Shark</td>
<td>53.2 ± 0.21</td>
<td>18.4 ± 0.12</td>
<td>51.2 ± 1.10</td>
<td>3.1 ± 0.34</td>
</tr>
<tr>
<td></td>
<td>Imported Mora/Shark</td>
<td>47.6 ± 0.51</td>
<td>17.5 ± 0.02</td>
<td>55.3 ± 0.5</td>
<td>3.6 ± 0.42</td>
</tr>
<tr>
<td>Balaya/Skipjack Tuna (Katsuwonus pelamis)</td>
<td>Boat Balaya/Boat Skipjack Tuna</td>
<td>44.2 ± 0.48</td>
<td>14.8 ± 0.33</td>
<td>60.5 ± 0.72</td>
<td>7.7 ± 0.92</td>
</tr>
<tr>
<td></td>
<td>Local Balaya/Tuna</td>
<td>46.9 ± 0.85</td>
<td>18.9 ± 1.20</td>
<td>55.4 ± 0.56</td>
<td>7.5 ± 0.37</td>
</tr>
<tr>
<td></td>
<td>Imported Balaya/Tuna</td>
<td>42.7 ± 0.28</td>
<td>16.9 ± 0.25</td>
<td>51.7 ± 0.18</td>
<td>6.1 ± 2.12</td>
</tr>
</tbody>
</table>

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

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

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

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

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 (Harpadan 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).

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

<table>
<thead>
<tr>
<th>Type of dried fish</th>
<th>Salt %</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local dried fish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Katta”/Queenfish (Seriphus politus)</td>
<td>19.60 ± 0.38</td>
<td>7.5 ± 0.00</td>
</tr>
<tr>
<td>“Penna”/Moonfish (Mene makulata)</td>
<td>20.50 ± 0.28</td>
<td>7.5 ± 0.00</td>
</tr>
<tr>
<td>“Bombili”/Bombay duck (Harpadon nehereus)</td>
<td>6.10 ± 0.31</td>
<td>6.5 ± 0.00</td>
</tr>
<tr>
<td>Maldiv dried fish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Balaya”/Skipjack Tuna (Katsuwonus pelamis)</td>
<td>3.50 ± 0.04</td>
<td>6.2 ± 0.00</td>
</tr>
<tr>
<td>“Linna”/Mackerel (Decapterus russelli)</td>
<td>5.00 ± 0.17</td>
<td>6.4 ± 0.00</td>
</tr>
</tbody>
</table>

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 to 70°C under different drying methods and un-salted sun drying and salted sun-drying dried fish types were varied from 3.89 to 4.53 meq of O₂/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 ≤ 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-Salguero 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 “Scombrotxin 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 liquefaciens, 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 shigelloides, 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

![Image of fungi in dried fish samples]

**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 LDF), 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 niloticus 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 x 102 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-Wallis 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

<table>
<thead>
<tr>
<th>Type of dried fish</th>
<th>Appearance</th>
<th>Color</th>
<th>Smell</th>
<th>Taste</th>
<th>Texture</th>
<th>Saltiness</th>
<th>Overall Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boat Shark</td>
<td>40.62&lt;sup&gt;a&lt;/sup&gt;</td>
<td>36.67&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>49.10&lt;sup&gt;a&lt;/sup&gt;</td>
<td>47.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>43.53&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46.67&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Imported Shark</td>
<td>46.55&lt;sup&gt;a&lt;/sup&gt;</td>
<td>51.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>41.95&lt;sup&gt;a&lt;/sup&gt;</td>
<td>48.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>50.57&lt;sup&gt;a&lt;/sup&gt;</td>
<td>51.37&lt;sup&gt;a&lt;/sup&gt;</td>
<td>51.75&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Local Shark</td>
<td>49.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>48.60&lt;sup&gt;a&lt;/sup&gt;</td>
<td>48.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>39.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>38.87&lt;sup&gt;a&lt;/sup&gt;</td>
<td>41.60&lt;sup&gt;a&lt;/sup&gt;</td>
<td>38.08&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Boat Skipjack Tuna</td>
<td>50.55&lt;sup&gt;a&lt;/sup&gt;</td>
<td>55.67&lt;sup&gt;a&lt;/sup&gt;</td>
<td>37.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>43.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>44.53&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>43.16&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Imported Skipjack Tuna</td>
<td>44.52&lt;sup&gt;a&lt;/sup&gt;</td>
<td>41.33&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>48.57&lt;sup&gt;a&lt;/sup&gt;</td>
<td>52.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>50.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>49.68&lt;sup&gt;a&lt;/sup&gt;</td>
<td>52.74&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Local Skipjack Tuna</td>
<td>41.43&lt;sup&gt;a&lt;/sup&gt;</td>
<td>39.50&lt;sup&gt;b&lt;/sup&gt;</td>
<td>50.80&lt;sup&gt;a&lt;/sup&gt;</td>
<td>41.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>41.77&lt;sup&gt;a&lt;/sup&gt;</td>
<td>39.97&lt;sup&gt;a&lt;/sup&gt;</td>
<td>37.83&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Boat Mackerel</td>
<td>38.68&lt;sup&gt;b&lt;/sup&gt;</td>
<td>37.67&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>44.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>47.48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>43.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45.20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Imported Mackerel</td>
<td>44.27&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>49.52&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46.89&lt;sup&gt;a&lt;/sup&gt;</td>
<td>47.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>42.40&lt;sup&gt;a&lt;/sup&gt;</td>
<td>49.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>44.90&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Local Mackerel</td>
<td>53.86&lt;sup&gt;a&lt;/sup&gt;</td>
<td>49.31&lt;sup&gt;a&lt;/sup&gt;</td>
<td>42.98&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45.17&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46.76&lt;sup&gt;a&lt;/sup&gt;</td>
<td>43.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46.45&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
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.

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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.

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