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# COMPARATIVE STUDY OF SALTING PROCEDURES FOR SALTED DRIED HERRING (*Clupea harengus*).

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## ABSTRACT

The aim of the study was to compare the effects of two different salting procedures on salt uptake, protein and moisture content, water activity ($a_w$) weight yield, colour and quality of herring fillets. One group of herring fillets was brined with 20% brine solution for one day before dry salting while another group was dry salted only. After 27 days of salting, the fillets were desalted. Samples were taken after brining, during dry salting and after desalting. Quality of final desalted products was determined by sensory evaluation. A significant increase in yield and salt content ($p<0.05$), and a significant ($p<0.05$) decrease in $a_{w,}$ moisture and protein content was obtained by brining. The L*(whiteness), a*(redness) and b*(yellowness) values of the fish fillets decreased during brining. During the dry salting step, further increase in salt content and decreases in water content were observed. After 27 days of dry salting, no significant differences in moisture content, $a_w$ and salt content between treatments was observed however, there were significant increases in protein yield, L* and b* in pre-brined fish fillets. Content of moisture, $a_w$, L* and a* values were not significantly different after desalting in fish fillets belonging to both groups. However significant increases of weight in pre-brined herring fillets and b* value and content of salt were recorded in single dry salted herring fillets after desalting. According to the sensory evaluation, there was no significant difference of flavour, texture and taste between the two groups of herring fillets.

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# 1 INTRODUCTION

Salting is a traditional fish preservation method in Sri Lanka. Salted dried and salted fermented fish products are very popular. Salted fish plays a major role as protein source for the people who live away from the coast in Sri Lanka. It also plays a considerable role in the economy of Iceland. The demand of salted and dried fish products in Sri Lanka is met by the local production and imports. In 2009 local salted dried fish production was about 38,650 MT and amount of imports were about 45,650 MT (NARA 2009).

There are differences in salting procedures between Iceland and Sri Lanka. In Sri Lanka, large pelagic fish such as skipjack tuna *(Katsuwonus pelamis),* silky shark *(Carcharhinus falciformis)* and honeycomb stingray *(Himantura uarnak*) are salted using dry salt for two to three days, followed by sun drying after removal of excess salt. Small pelagic fish species like rainbow sardine (*Dussumieria acuta)* and Commerson's anchovy *(Stolephorus commersonii)* are salted by using a salt solution (brining).

In Iceland, large species like cod (*Gadus morhua*), saithe (*Pollachius virens)*, ling (*Molva molva)* and tusk (*Brosme brosme)* are salted by multi-step salting procedures after filleting or butterfly filleting (split fish). Presalting methods such as brine injection and/or brining are used prior to dry salting, which involves stacking the fish with alternating layers of salt for 10-14 days under chilled conditions (<7°C) to avoid growth of halophilic bacteria. Presalting improves yield and quality of final product in comparison with a single dry salting step, which was the original salting procedure. Usually, after salting the fish is packaged and exported without drying. In Iceland, salting of pelagic fish species like herring *(Clupea harengus*) is mainly conducted by dry salting methods like brining to limit the access of oxygen and thereby retard oxidation.

Women play an important role in the salted dried fish industry in Sri Lanka by processing and selling in the market the fish caught by their husbands or purchased from the local vendors. There is considerable contribution by women in salted dried fish industry in Iceland, even though the industry is well developed and facilitated by highly automated processing factories.

There are many differences in processing methods used in salting and drying in Iceland and Sri Lanka, and practices and processing methods used in Iceland can be applied with modifications to the fisheries industry in Sri Lanka. These include drying under controlled conditions to obtain a final product of high quality and yield, minimizing wastage during processing, preparation of different products such as desalted and frozen salted products for different market segments, and the use of combined salting methods.

Unlike Sri Lanka, the dry fish industry is a profitable industry in Iceland. Profit in the dry fish industry in Sri Lanka is low due to loss of weight and quality during salting and drying. In most instances people try to maintain weight by reducing drying time and using improper and inadequate salting, which causes a lot of quality problems like spoilage, denaturation of protein, dark colouring and bad odours. In addition, current drying methods in Sri Lanka increase the risk of cross contamination by dust and animals such as flies, cats, dogs and birds during sun drying. Physical quality of the final product can be affected by temperature fluctuations when drying outdoors, and finally affect the prices of products. People avoid using other drying methods (ex. oven drying) due to higher investment costs. Therefore, dry salting methods that are used in Iceland could be a good solution to avoid such difficulties while increasing quality and profit, and providing benefits for both consumers and producers. If it is possible to replace the sun drying method by in house dry salting, it may become very popular in salted dried fish production in Sri Lankan household industry, and salting and drying procedures can be within affordable investment.

Herring (*C. harengus)* was used in this study to compare different salting methods. Fish species belonging to the herring family (Clupeidae) in Sri Lanka include spotted sardinella (*Amblygaster sirm*) and smooth belly sardinella (*Amblygaster leiogaster*) caught by small coastal vessels using gill nets. These vessels are made from fibreglass and equipped with an out-board engine. The catch is normally landed within 6-8 hours of capture and the fish is quite fresh when landed, unlike catches from vessels that operate offshore and may stay out for several weeks at a time.

**Objectives:**

To compare the effect of presalting (brining) before dry salting, and single dry salting on the:

- Changes of chemical composition in fish muscle during salting.
- Protein yield in fish muscle.
- Final yield and quality.

## 2 LITERATURE REVIEW

Salting is a one of the main traditional methods used for preserving fish due to its ability to create unfavourable environment for the growth of microorganisms by lowering the water activity of the fish muscle. Salting is not only an important preservation method, but it also results in particular sensory properties of the product such as aroma and flavour (Harris and Tall 1994). Quality of the final product depends on several factors, for example, condition of the raw material and the method used for salting and drying. The exact salting procedure varies between producers and countries, and may depend on fish species and climatic conditions. In Iceland, the most common salting process of cod fillets consist of injection and/or brining, dry salting and desalting steps (Andre *et al.* 2005, Thorarinsdottir *et al*. 2011). Traditionally salting of herrings has been carried out in a vat or barrels using different salting methods like dry salting, brine salting and mixed salting (Voskresensky 1965).
Absorption of salt into fish muscle occurs due to concentration gradients between the fish muscle and the surrounding media and within the muscle. Osmosis effects play a certain role in driving transfer of water from the muscle (Voskresensky 1965), as well as pressure gradients, when muscle protein aggregate at concentrations above 10-12% (Thorarinsdottir *et al*. 2011). During salting, water-holding capacity of fish muscles decrease with aggregation of protein (Martínez-Alvarez and Gómez-Guillén 2006).
Salt soluble proteins and non-protein nitrogen components may diffuse out of the muscle as part of the liquid lost from the muscle during salting (Andres et.al 2002), especially at low salt concentration in the muscle (<6%) where the solubility of muscle proteins is relatively high. The pH of the brine is also important to control leaching of salt soluble proteins. More actin and myosin heavy chains are released in brine of pH 6.5 than pH 8.5 (Martínez-Alvarez and Gómez-Guillén 2005).
Decrease in water-soluble and myofibrillar proteins has been observed during the ripening by SDS-PAGE in the production of Teruel dry-cured ham, which was attributed to salting out effect and changes in myofibrillar protein during ripening process (Larrea *et al*. 2006) and similar results have been reported by Garcia *et al*. (1997) during the ripening of Spanish Dried Beef 'Cecina'.

Biochemical and chemical changes in the muscle during salting and storage, termed as ripening, result in changes in flavour and texture of the products, which are favoured by consumers. Among these changes is oxidation of highly unsaturated lipids, which is accelerated by salting and aggregation of proteins leads (Harris and Tall 1994). The myosin heavy chain is most susceptible to denaturation by heavy salting (Thorarinsdottir *et al.* 2002). Structural changes of proteins in the fish muscle are influenced by salting rates and salting time, i.e. on the salting procedure applied (Barat *et al.* 2002). Therefore, subsequent weight changes during salting and rehydration differ depending on the method used. Injection of salt into fish fillets before brining and dry salting has been shown to increase the water retention in the final product. Injecting salt into fillets will allow for more even distribution of salt already in the beginning of salting, in comparison with brining (Thorarinsdottir *et al.* 2011).

Brining increases the uptake of salt while providing a barrier to contacts of the fish with oxygen, which can initiate the rancidity. Strength of the brine also affects the changes in water holding capacity and yield of the final product due to influences on conformational changes and aggregation of proteins in fish muscle (Nguyen *et al.*

2010). Low brine concentration results in better water holding capacity and yield compared to the higher concentrations (Barat *et al.* 2002, Brás and Costa 2010). Brine concentration, soaking time and rate of stirring has greater effect on the rate of salt uptake than the fat content and size of fish (Aitken and Baines 1969). Birkeland *et al.* 2005 observed that higher brine concentrations, low temperatures and presence of skin significantly reduced the weight gain of herring fillets during brining. Herring fillets absorb salt faster than the knobbed or gutted herrings (Gudmundsdottir and Stefansson 1997) and the sensory properties of fresh fillets after marinating in higher salt concentrations are better than frozen herring fillets (Szymczak *et al.* 2011). In brining, the salt concentration can be better controlled than dry salting, especially at low concentrations of salt. Increased weight yield, in spite of reduced protein yield and salt after desalting, is an indicator of increased water holding capacity in pre-brined fish fillets. According to Thorarinsdottir *et al. (*2004) higher concentration of salt causes a higher degree of protein aggregation.

Quality of the final dried fish products depends on many factors. Quality of the raw materials is a very important factor. Processing of fish during pre-rigor can lead to lower quality than processing in rigor and post rigor. Processing of cod fillets in post rigor and in rigor has given greater yield during salting than the fillets processed in pre-rigor stage. Salting of fish fillets during rigor causes undesirable texture properties such as firmer and less juicy flesh, and rough and dry fish surface (Sorensen *et al.* 1997).

Colour of the fish fillets is a very important sensory attribute in the marketing. Colour of the fish fillets mainly depends on its pH and factors like water, protein, lipids, muscle pigments and their interactions. Lightness (L* value) changes with the content of moisture in the fish muscle. Reduction of moisture during drying can increase the whiteness (Barat *et al.* 2002, Brás and Costa 2010). Lipid oxidation increases the yellowness (b* value) of fish fillets while non-enzymatic browning reactions and oxidation of haemoglobin at low pH increase the redness (a* value) of herring fillets (Szymczak, 2011).

Desalting of heavily salted fish fillets is an important step in the salt fish processing industry as it is used in the preparation of many traditional dishes. The end user at home mainly carries out desalting by soaking the product in water for 24 hours in a refrigerator or at ambient temperature, and this process can be improved by frequent exchange of water. However, the study done by Barat *et al.* (2004) showed that when cod fillets were desalted without exchange of water and the desalting time extended, the waste was reduced and the yield increased.

There are two main changes expected during the desalting process, reduction of NaCl concentration to an acceptable level for consumption, and rehydration to obtain high sensory quality and high process yield. A great loss of water-soluble protein during rehydration of stock fish has been recorded due to protein solubilisation (Luccia *et al.* 2004).

# 3 METHODOLOGY

## 3.1 Processing of herring fillets

In this study conventional dry salting of herrings were compared to salting where a brining stage was added at the beginning of the process (Figure 1).

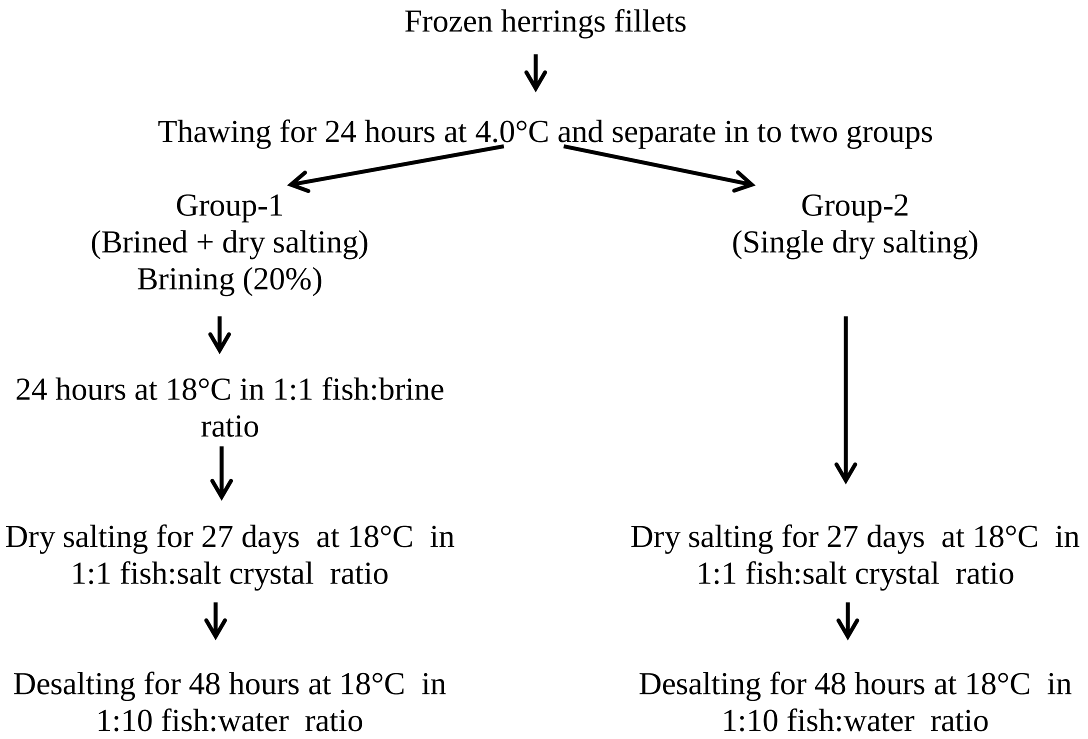


Figure 1: A flow chart illustrating the design of the study methodology for processing of the herring fillets.

Herring fillets were received as a 13.5 kg frozen block. The fillets were thawed for 24 hours at 4.0°C before starting the experiment. The fillets were divided into two groups of about 6.0 kg each.

The main objective of the study was to evaluate the effect of brining prior to dry salting on the physiochemical changes of herring fillets. Half of the fillets were dry salted while the other half was put in brine followed by dry salting. Both trials were carried out at a temperature of 18.0 ± 2.0 °C.

Industrial crystal salt was used for preparation of 20% brine by adding 2.0 kg of salt to 8.0 L of water in a plastic container. The brine solution was mixed well and kept overnight for the salt to fully dissolve.

Five kg of fish fillets were immersed in the brine solution using 1:1 ratio of fish to brine for 24 hours at 18.0 ± 2.0 °C, and a high was applied to avoid the top layer of fillets rising to the surface. The fillets were drained well after 24 hours before dry salting.

Dry salting was carried out using industrial salt in 1:1 ratio of fish to salt. The fish fillets were stacked in a plastic tray, which has a perforated bottom and the tray kept in a large plastic box. The first layer of fish fillets was put on salt sprinkled on the bottom of the plastic tray and layer of salt crystals separated layers of fish fillets. Two groups of fish fillets were dry salted in this experiment, one that had been subjected to brining and the other that was just thawed. Both were kept at 18.0 ± 2.0 °C for 27 days.

Desalting was done after 27 days of dry salting. Excess salt crystals were removed and the fillets weighed before desalting. The fillets were placed in a plastic container with water in a 1:10 ratio for 48 hours, without agitating the medium, under 18.0 ± 2.0 °C.

### 3.2 Sampling plan and analysis of samples

From both groups of fish fillets, samples were collected after thawing and brining on days 1, 2, 4, 6, 8, 15, 20 and 27, after dry salting, and after desalting. Three fillets were collected from each group at each sampling point for chemical analysis. Four fillets, which were separated and tagged in each experimental group, were used for weight and colour measurements. Separate groups of fish fillets were used for colour and weight measurements in each trial. Weight of fillets was recorded after thawing, brining, and then after days 1, 15 and 27, after dry salting, and finally after desalting.
Three colour measurements were recorded from each fillet, from the front part, the middle and the tail part. Salt adhered on fish fillets was removed carefully before measurements were taken. L* values were recorded for "whiteness" (L* 0 = Black and L* 100 = white), a* values for red-green colours (+a = intensity in red and –a* = intensity in green) and b* values for "yellowness" were recorded using KONICA MINOLTA colour meter. Average value of the L*, a* and b* values of four fish fillets were used to calculate the mean values and standard deviation.

Determination of moisture in fish fillets was carried out according to the ISO 6496:1999(E) standard methods. The fillets were skinned and then blended using a lab blender to get the homogenized sample. Approximately 5.0 g of homogenized sample was weighted in a crucible using an analytical balance. Samples were dried in a drying oven at 103 ± 2.0 °C for four hours and allowed to cool for 30 minutes in a desiccator before recording the final weight. Three samples were prepared from three fish fillets for determination of moisture. Results were expressed to the nearest 0.1% using the following equation.

$$W_1 = \frac{M_3 - (M_5 - M_4)}{M_3} \times 100$$

where,
$W_1$ = Percentage of moisture present in fish muscle in grams.
$M_3$ = Weight of the sample in grams.
$M_4$ = Weight of the crucible in grams.
$M_5$ = Total weight of the sample and crucible after drying in grams.

Determination of water activity of fish fillets were done using NOVASINA water activity meter. Blended fish muscle from three fish fillets were used for analysis.

Approximately 2.0 g of sample obtained from blended fish fillets was weighted and mixed with 200 ml of distilled water in a 250 ml plastic bottle. The bottle was tightly closed and shaken well in a shaker for 45 minutes and allowed to settle. 20 ml of supernatant was measured accurately using a burette and mixed with 20 ml of 0.1 N $HNO_3$ in a 250 ml beaker and titrated with 0.1 N $AgNO_3$ using 716-DMS Titrino machine made in Swiss. Results were directly read from the equipment as a percentage, in grams. The equipment was calibrated using a standard salt solution before starting the titration.

The pH values were measured using skinned and blended samples of fish fillets with a M80 portable pH meter. The pH meter was calibrated for pH-4, pH-7 and pH-10 before starting measurements.

Total protein in fish muscle was measured by using the semi macro Kjeltec method. Approximately 1.0 g of crushed and homogenized sample from the fish fillets was accurately weighed and mixed with a catalyst tablet and 12 ml of 98% sulphuric acid in a digestion flask then heated for four hours at 420°C. Digested samples were left to cool for about 30 minutes and the amount of protein measured using a Kjeltec analyser. Results were read directly from the equipment as a percentage.
Protein yield was calculated as follows.

$$\text{Protein yield} = (MP_t / MP_0)*100$$

where,
$MP_t$ = Weight yield after time ‘t’ * % protein after time ‘t’
$MP_0$ = Initial weight of fish fillet * Initial % of protein in raw fillets
‘t’ indicates the different processing stages, i.e. brined, dry salted etc.

Sensory evaluation was carried out on desalted and cooked fish fillets with the participation of five trained panellists according to ISO 8586. Texture, taste, colour and odour of the cooked fish fillets were evaluated (Table 1).

Skinned fillets were soaked in an abundant amount of water for two hours for further desalting before cooking for sensory evaluation. Evaluation was performed for steam cooked (five minutes) herring fillets in a small aluminium box covered with a lid. Samples coded with a three-digit number were presented in a random manner. The assessors used water to clean the palate between samples.

Mean values of the three results obtained from three fish fillets in each sampling points and parameters were statistically analysed with Student t-test under 95% confidence level in Microsoft Excel to evaluate the influence of salting methods on salt penetration, changes in amount of protein, effect on moisture level and final yield of fish fillets. Sensory results were statistically analysed by using ANOVA (GLM, Duncan’s test).

Table 1: Sensory attributes, scale definition and attribute description. O-odour, F-flavour, T-texture.

| **Sensory attribute** | **Scale anchors** | **Attribute description** |
|---|---|---|
| O_rancid | none \|\| much | Rancid odour |
| F_rancid | none \|\| much | Rancid flavour |
| F_bitter | none \|\| much | Bitter flavour |
| F_earthy | none \|\| much | Earthy, musty flavour |
| Flavour intensity | none \|\| much | Flavour intensity |
| T_crumbly | none \|\| much | Crumbles or falls apart when pressed with a fork |
| T_tough | tender \|\|tough | Tough when chewing several times. |

# 4 RESULTS

## 4.1 Yield (%)

The herring fillets increased in weight during brining (14.10 ± 1.2%). Fillets that were brined prior to dry salting maintained a significantly higher weight yield ($p<0.05$) throughout salting and desalting than fillets that were only dry salted (Figure 2). The yield of both single salted and pre-brined fish fillets gradually decreased during dry salting, down to 63.1 ± 4.3 % and 77.90 ± 3.5 % respectively. After desalting, weight of single dry salted and pre-brined fish fillets increased up to 77.60 ± 7.0% and 93.6 ± 5.0 %. Pre-brined herring fillets were significantly heavier ($p<0.05$) than the single salted herring fillets at the end of the dry salting period and after desalting.

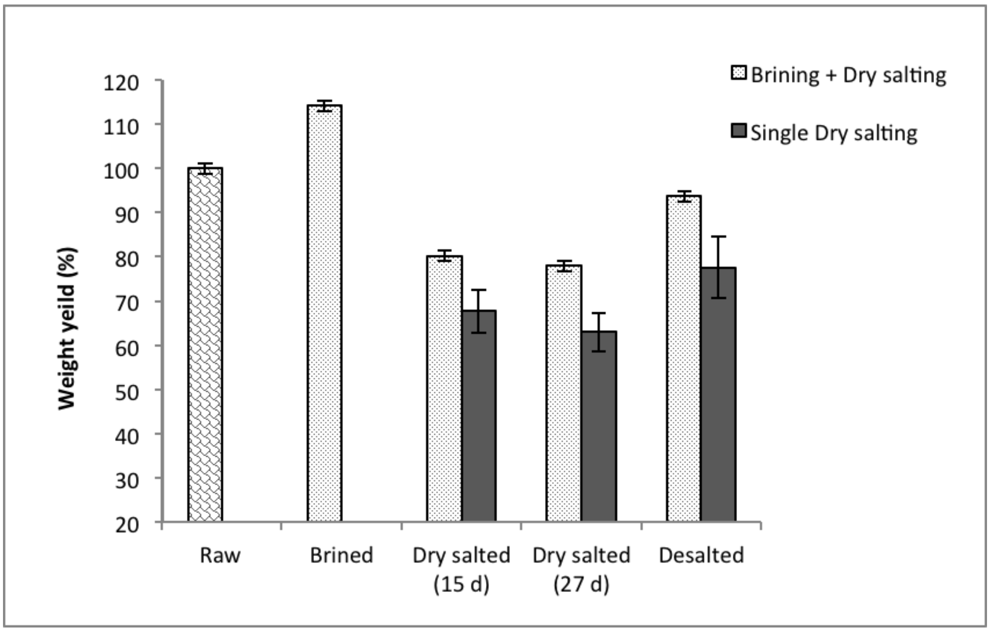


Figure 2: Changes in weight yield of herring fillets (n= 4) during single dry salting, brined (one day), followed by dry salting, and desalting for two days (average ± standard deviation).

## 4.2 Moisture content (%)

Initial moisture content of the herring fillets was 68.0% (Figure 3) that decreased down to 63.6% after brining for 24 hours in 20% brine solution. Moisture content of the single dry salted herring fillets and pre-brined dry salted herring fillets decreased to 50.2% and 49.2% respectively, after 24 hours of dry salting. Moisture levels of both groups slowly decreased during the 27 days of dry salting to 44.5 % and 47.3 % in single dry salted and pre-brined dry salted fillets respectively.

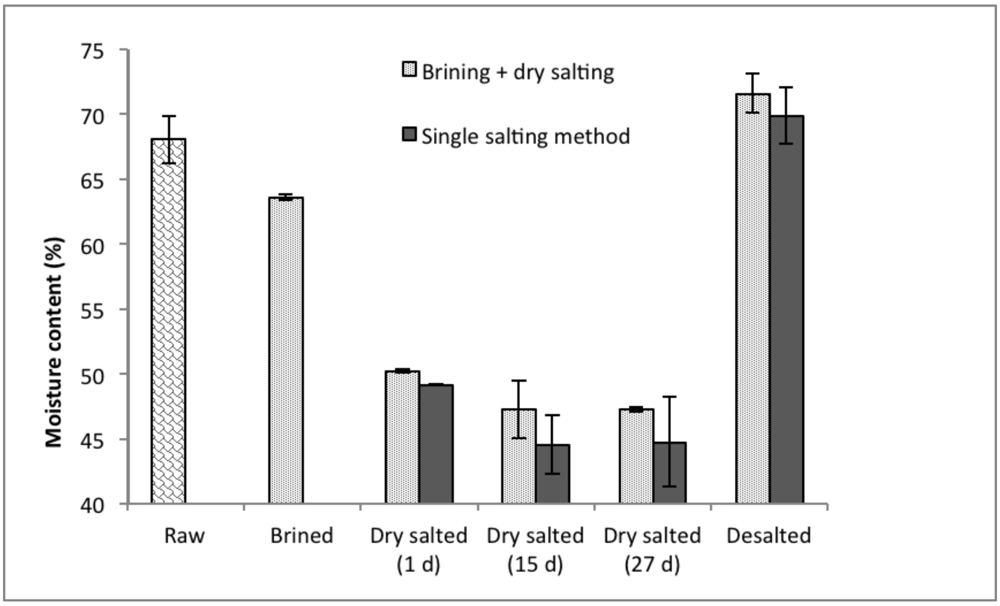


Figure 3: Changes in moisture content of herring fillets (n = 3) during single dry salting, brined (one day ) followed by dry salting, and desalting for two days (average ± standard deviation).

The moisture level of single dry salted and pre-brined dry salted fillets increased to 69.9% and 71.6% respectively, after two days of desalting in 10 L of water for every kg of fillet. Reduction of moisture after 27 days of dry salting and absorption of water after two days of desalting was not significantly affected by salting procedures ($p>0.05$).

### 4.3 Salt content (%)

The salt content in the raw fillets was 0.6 ± 0.1% (Figure 4) and increased to 8.5 ± 0.8% during brining. The salt content increased to 11.2 ± 0.3% and 17.7 ± 0.8% in single dry salted and pre-brined fillets respectively, after one day of dry salting. After 27 days of dry salting salt content of the two treatments were not significantly different. Salt percentage of single dry salted herring fillets increased to 17.2 ± 0.3% while pre-brined herring fillets increased to 18.1 ± 0.8%. After desalting, salt levels of single salted fish fillets and pre-brined fish fillets were reduced to 4.6 ± 0.34% and 2.8 ± 0.55%. The difference between groups was significant ($p<0.05$).

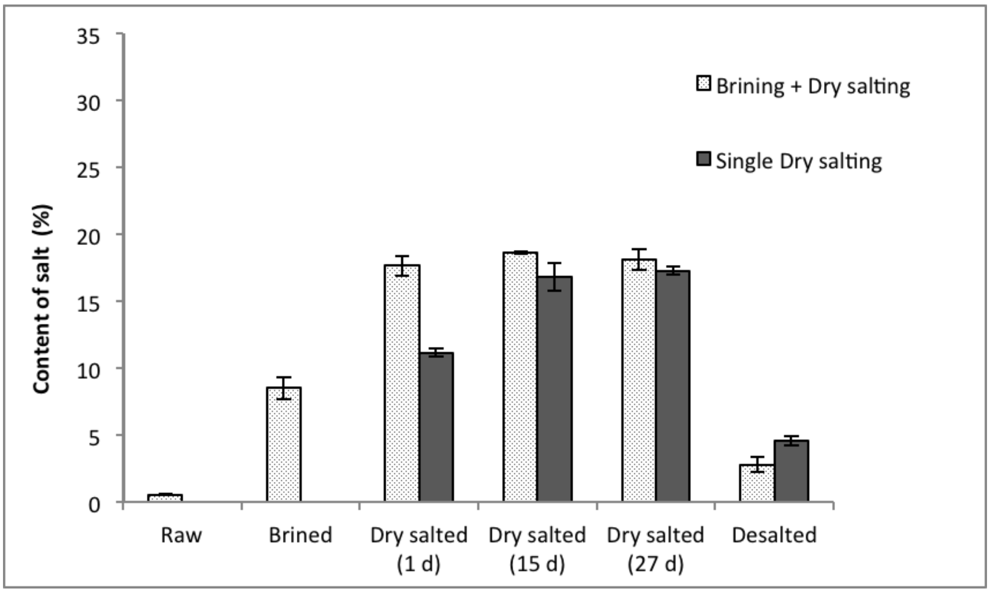


Figure 4: Changes in salt content of herring fillets (n = 3) during single dry salting, brined (one day) followed by dry salting, and desalting for two days (average ± standard deviation).

## 4.4 Water activity ($a_w$)

Water activity decreased from 1 in raw fillets (Figure 5) to 0.947 ± 0.009 during brining. After 24 hours of dry salting water activity in pre-brined fish fillets decreased to 0.768 ± 0.007, which was significantly lower ($p<0.05$) than for the single dry salted fillets 0.856 ± 0.019. Water activity in both groups decreased further during the dry salting period. At the end of the dry salting period, single dry salted fish fillets had significantly lower water activity ($p<0.05$) (0.737 ± 0.003) than the fish fillets, which were brined and dry salted (0.747 ± 0.003). Water activity of both groups increased during desalting to 0.971 ± 0.017 and 0.993 ± 0.008, for single salted and pre-brined groups respectively, without significant difference ($p>0.05$).

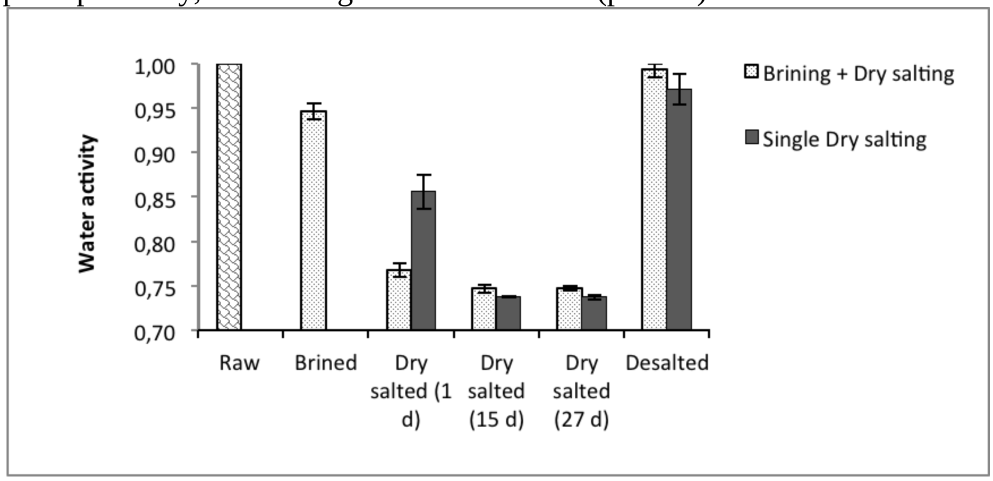


Figure 5: Changes in water activity of herring fillets (n = 3) during single dry salting, brined (one day) followed by dry salting, and desalting for two days (average ± standard deviation).

### 4.5 pH level in herring (flesh)

The pH of fresh herrings fillets was close to neutral, 6.8 ± 0.2, and decreased to 6.0 ± 0.1 after brining and dry salting causing a significant initial decrease in pH ($p<0.05$), but a subsequent gradual increase during dry salting period was observed (Figure 6). After 27 days of dry salting, single salted and pre-brined dry salted fillets had a pH of 6.3 ± 0 and 6.1 ± 0.1 respectively. After desalting, pH values of the single dry salted fillets had increased to 6.5 ± 0. The pH of pre-brined salted fillets were significantly higher 6.8 ± 0.2 ($p<0.05$).

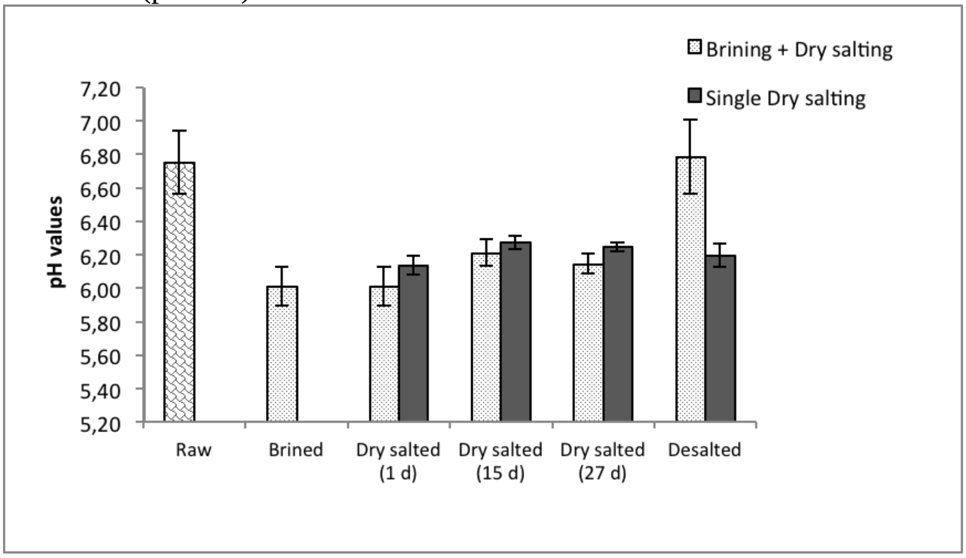


Figure 6: Changes in pH values of herring fillets (n = 3) during single dry salting, brined (one day ) followed by dry salting, and desalting for two days (average ± standard deviation).

### 4.6 Protein yield in fish fillets (protein in 100 g of fillets)

After brining the protein yield dropped to 93.18% (Figure 7) ($p<0.05$) and continued to decrease during the dry salting period. Protein yield of single dry salted fish fillets were significantly lower than the pre-brined dry salted fish fillets ($p<0.05$) throughout the dry salting period. Protein yield of single dry salted fillets decreased from 86.8% to 77.7% ($p<0.05$) as a result of desalting. Protein yield of pre-brined dry salted group also decreased to 92.5% during dry salting period and decreased further to 87.9% after desalting, resulting in a significant change ($p<0.05$). After desalting, protein yield of single dry salted fillets were significantly lower than the pre-brined dry salted fish fillets ($p<0.05$).

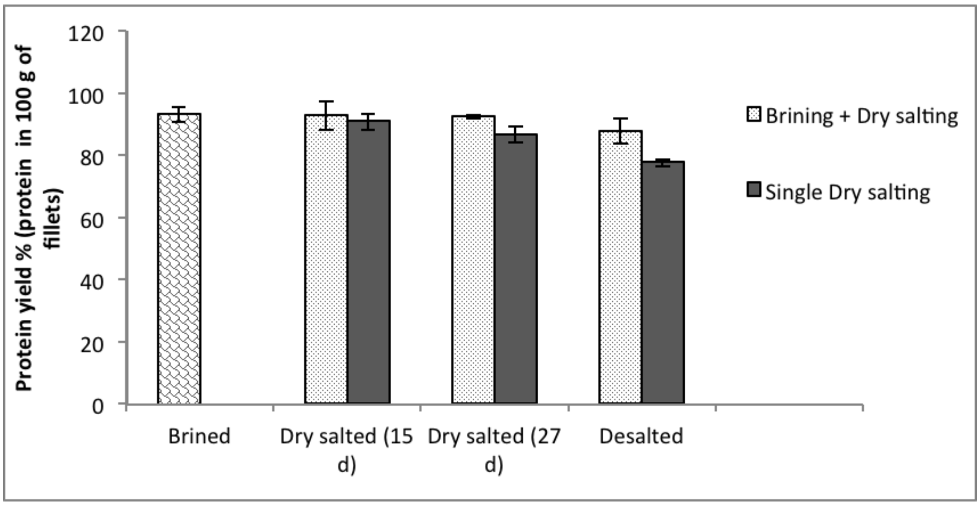


Figure 7: Changes in protein yield of herring fillets (n = 3) during single dry salting, brined (one day ) followed by dry salting, and desalting for two days (average ± standard deviation).

## 4.7 Colour measurements

The initial mean L* value of thawed herring fillets was 56.63 ± 2.0 (Figure 8) and decreased significantly ($p<0.05$) to 48.57 ± 2.0 during brining. The L* value gradually decreased during the dry salting period in both groups to 45.82 ± 4 and 52.23 ± 2.0, in single dry salted and pre-brined and dry salted fillets respectively. However, single dry salted fish fillets had lower L* value than the pre-brined dry salted group ($p<0.05$), during the dry salting period. The L* values of fish fillets increased again during desalting. Differences between groups were not significant ($p>0.05$) after desalting .

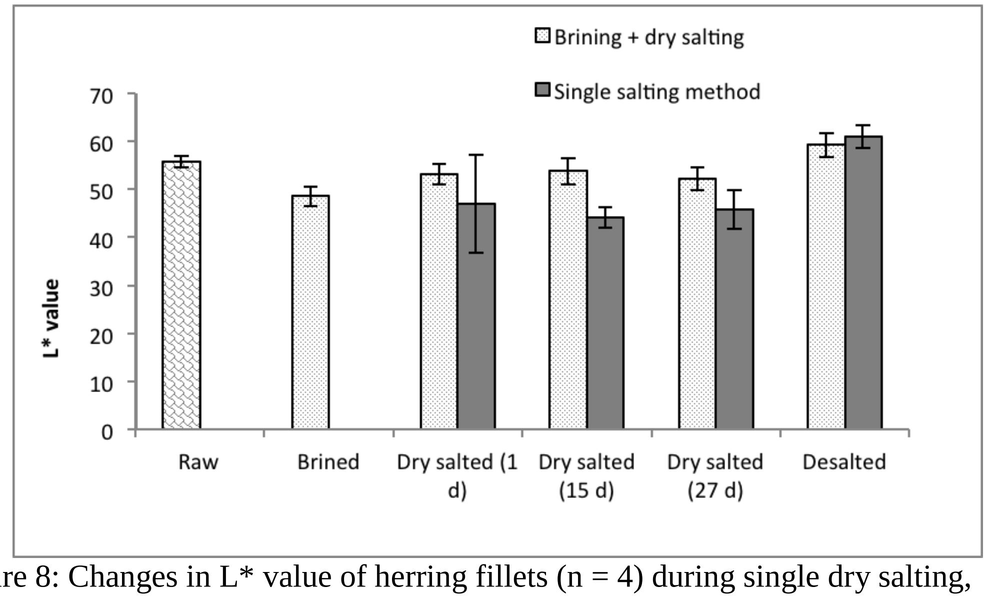


Figure 8: Changes in L* value of herring fillets (n = 4) during single dry salting, brined (one day) followed by dry salting, and desalting for two days (average ± standard deviation).

The initial mean value of a* in raw fish fillets was 1.89 ± 0.96 and decreased to 2.24 ± 0.21 as a result of brining (Figure 9). The a* values of the both groups were negative during the dry salting period and desalting step carried out for two days. Single dry salted fillets recorded lower a* values throughout the dry salting period than the brined fish fillets before dry salting. The b* value show the yellowness of fish fillets (Figure 10). The b* value of raw fish fillets decreased during brining and gradually increased during the dry salting period and desalting step. Pre-brined dry salted fish fillets had significantly higher ($p<0.05$) b* values at the end of the dry salting. However, single salted fillets reached to a significantly higher ($p<0.05$) b* values than pre-brined fish fillets after desalting.

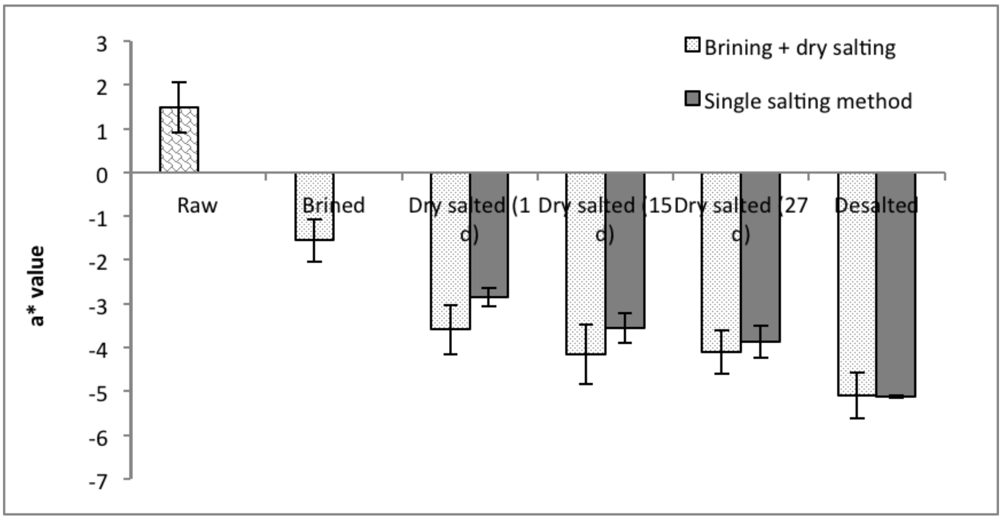


Figure 9: Changes in a* value of herring fillets (n = 4) during single dry salting, brined (one day) followed by dry salting, and desalting for two days (average ± standard deviation).

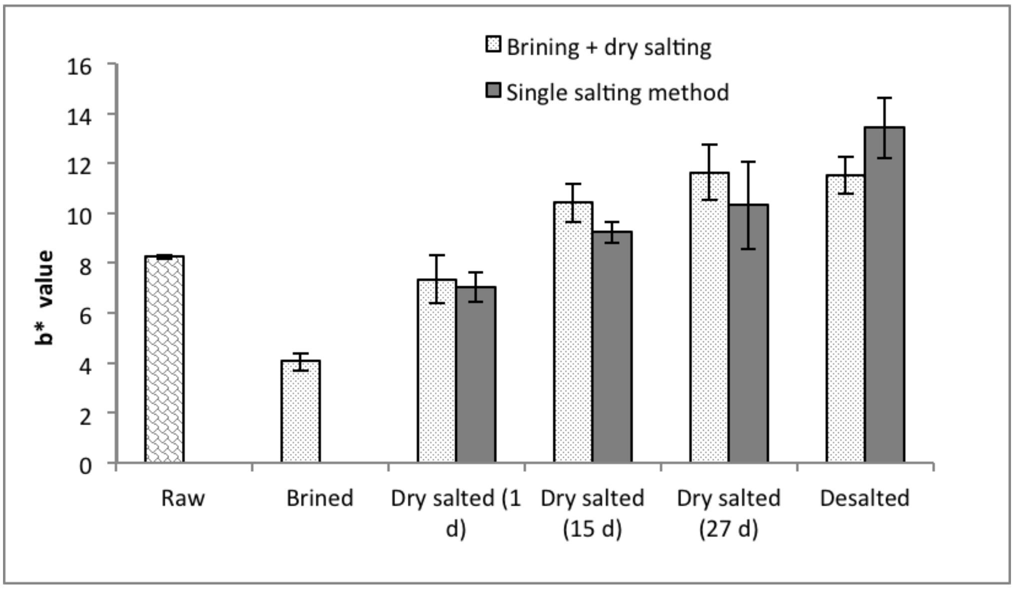


Figure 10: Changes in b* value of herring fillets (n = 3) during single dry salting, brined (one day) followed by dry salting, and desalting for two days (average ± standard deviation).

## 4.8 Sensory evaluation

According to the results of panel discussion and individual evaluations, fish fillets belonging to both groups were not significantly different ($p>0.05$) from each other. The fillets were very rich in flavour, quite salty, bitter and rancid. Both had a sweet and earthy flavour and the texture was a little tough and quite crumbly. No significant difference was seen between groups but fish fillets belonging to pre-brined before dry salting had a slightly more rancid flavour than fish fillets that were single dry desalted (marginal significance). The panel lists agreed that fish fillets belonging to single dry salted group had a darker colour and a more heterogeneous colour than fish fillets that were dry salted after brining.

# 5 DISCUSSION

Salt content in single dry salted fillets were significantly higher than in pre-brined fish fillets after one day of dry salting. This indicates the effect of concentration of the salt medium on uptake of salt. Nguyen *et al.* (2010) observed similar results. During dry salting, salt crystals covering fish fillets can create a greater difference in salt concentration between the outside and inside of fish fillets causing higher penetration rate of salt. However, salt level of both groups reached a similar level by the end of the dry salting period, most probably due to equilibrium of salt concentration inside and outside the fish fillets (Voskresensky 1965). Brining controls the uptake of salt and reduces the aggregation and denaturation of proteins as compared to dry salting. Brining at low salt concentration (6-15%) increases the water holding capacity due to salting-in effect in the beginning, but higher concentration of salt decreases the water holding capacity due to aggregation of protein (Nguyen *et al.* 2010).

Water activity in herring fillets decreased significantly ($p<0.05$) during brining and dry salting. The $a_w$ values of the brined fillets were higher than in dry salted fillets after 27 days. This may be due to the increase of salt content and decrease of water content of single dry salted fillets as described by Chaijan (2011).
The salt content and water activity in fish fillets of both groups were not significantly different after 15 days and 27 days of dry salting.Therefore, the time of dry salting can be reduced to 15 days.

The pH values of fish fillets were in the range of 6.0-6.8 during this study, which may have improved water holding capacity. The isoelectric point of protein in fish muscle is about pH 5. If pH is higher than this, water holding capacity and water absorption of the muscle can improve (Hamm, 1986).

Weight changes of fish fillets can be affected by the mass exchange between the fish muscle and the salting medium. The exchange of water and salt has the largest effect, although water-soluble proteins, salt and water-soluble non-protein nitrogen components can also have an effect. Rate and direction of movements of salt and water is controlled by a number of factors such as salt concentration, salting time, method, quality of raw material, pH of medium and temperature.

Brining of fish fillets in 20% salt solution resulted in higher yield due to increased water holding capacity and swelling of the fish muscle protein as a result of salt uptake as described by Barat *et al.*(2002) and Aitken and Baines (1969). Birkeland *et al*. (2005) recorded 10%-12% weight gain of herring fillets after brining for 24 hours at 17.5°C and 21%-28% weight gain during brining at 3.5°C in a 25.5% salt solution. Weight decrease during dry salting can be due to water loss, loss of water and salt soluble protein and non-protein component to the salting medium as observed by Szymczak (2011). However yield gain obtained during brining was maintained throughout the dry salting and desalting steps. Brás and Costa (2010) reported similar results for cod fillets (*Gadus morhua*), which were subjected to brine plus pickle salting. Results of this study also proved the positive effect of brining on weight gain of fish fillets.

Yield of protein was reduced after the brining step, during dry salting and desalting. This could be due to protein and non-protein nitrogen components diffused into the brine and the protein aggregation and denaturation as described by Szymczak (2011) and Thorarinsdottir *et al.* (2004). These results confirmed the significant effect of the salting method on protein yield in herring fillets.

Colour is an important factor from the marketing point of view. Whiteness of the fish fillets increased during the dry salting period and after desalting, which agrees with observations of Brás and Costa (2010). This could be attributed to the presence of ions such as calcium and magnesium in the salt used (Martinez-Alvarez and Gómez-Guillén 2005). Yellowness of the fish fillets in both groups increased during dry salting and desalting, which agrees with the findings of Hamre *et al.* (2003). They observed that the deterioration of colour of herring fillets did not depend on the lipid oxidation, but could be related to the changes in proximate composition of the fish muscle. According to the result of this study, there were no significant effects of the salting method on the colour changes of herring fillets during dry salting.

Sensory evaluation shows similar sensory properties of both groups. The fillets were salty and bitter. Szymczak *et al.*(2011) observed similar results for herring fillets marinated using 13-15% of brine solution. Desalting carried out in this study was not enough to reduce the salt content as indicated by sensory evaluation. Therefore, desalting time should be increased to reduce the salt level.

The dry salting method commonly used in Sri Lanka causes weight loss of about 50-65% during salting and drying, but in this experiment the weight loss of single dry salted and pre-brined and dry salted fillets were 33% and 23% respectively, after dry salting. This will be good news for processors of salted fish. If products are sold after desalting, weight loss will decrease further down to 13% and 7% for single dry salted and pre-brined dry salted fish fillets. Desalting will affect shelf life. The product then has to be refrigerated or frozen. Continued caring during dry salting outdoors, especially during rainy days, creates a lot of extra work. Salting inside provides an excellent solution for those problems and avoids cross contamination. Reducing water activity down to 0.075 after dry salting reduces microbial activities and mould growth, helping to increase and maintain quality and product stability. Good colours increase the market attraction, price and competitiveness .The amount of salt present after desalting was rather high therefore, the desalting procedure should be improved to reduce the salt content. Further studies are needed on packaging and storage conditions for desalted products. This method is simple and does not differ greatly from current practices in Sri Lanka and could be adopted without much effort. Processing indoors to control the environment and brining before dry salting and subsequent de-salting will be of benefit to both producers and consumers of dry fish in Sri Lanka.

## 6 CONCLUSION

Brining before dry salting increases the weight in fish filets compared to single salting method. The protein yield of pre-brined fish fillets was higher than the single dry salted herring fillets. Brining of herring fillets affected rapid up taking of salt during salting and decrease during desalting than for single dry salted method. Single salted method increases yellowness in fish fillets. Sensory properties (taste, texture and flavour) of herring fillets were not effect by the salting methods.

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