The effects of different salting procedures on physical and chemical properties of heavily salted Atlantic mackerel (*Scomber scombrus*)

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ABSTRACT

The effects of two different salting procedures on physical and chemical properties of Atlantic mackerel (*Somber scombrus)* from two processing companies were investigated. Group I and group III were treated with single dry salting and group II and group IV were treated with pre-brined dry salting and stored in waxed carton boxes at 13℃. Samples of salted and desalted fillets from each group were taken at the beginning of storage, day 7 and day14 of storage and analysed for physical components (soaking yield, cooking yield, processing yield, and colour) and chemical components (water content, salt content, water activity, pH, TVB-N, lipid, free fatty acid, peroxide values, and thiobarbituric acid). The yield in fish treated with pre-brined dry salting was higher than of the single dry salting. The salt content in pre-brined dry salting was lower than the single dry salting. The lightness (L value) in pre-brined dry salting was higher than the single dry salting and the b value was lower than single dry salting. Pre-brined dry salting caused greater lipid hydrolysis in the mackerel muscle than the single dry salting resulting from higher free fatty acid content. In conclusion, the changes of physical and chemical properties of Atlantic mackerel depend on salting method, storage time and temperature and the quality of raw material.

Keywords: Atlantic mackerel (Scomber *scombrus)*, brining, dry salting, lipid oxidation, quality, stability

This paper should be cited as:
Phyu OO, M. 2018. *The effects of different salting procedures on physical and chemical properties of heavily salted Atlantic mackerel (Scomber scombrus).*United Nations University Fisheries Training Programme, Iceland. Final project. http://www.unuftp.is/static/fellows/document/Moe17prf.pdf

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1 INTRODUCTION

Due to its simplicity and low production cost, salting is a traditional preservation method for fish which is still used extensively in many tropical countries, including Myanmar, as well as Nordic countries. Salted cod is very popular in southern European countries such as Italy, Spain and Portugal. Salting methods can be used as a primary preservation or followed by drying and smoking or other methods to meet consumers' requirements (Berhimpon, Souness, Driscoll, Buckle, & Edwards, 1991). Most salted fish is produced in small and medium-sized traditional fish processing establishments (SME) in Myanmar. The salting and drying methods used in Iceland and in Myanmar varies considerably. Icelandic producers have used many different salting methods over the years, for example pickle salting, brining or brine injection and kench salting. When dry salting, the fish is stored in piles of salt for 10-12 days after pre-salting at 8 ℃ to minimize the risk of the growth of halophilic bacteria and oxidation without sun drying. Final products made with this method are high quality and yield. Shortening of the curing time results in higher water content and increased weight yield of salted products (Torarinsdottir, Bjorkevoll, & Arason, 2010).

In Myanmar, mackerel (*Scomber* spp) and tilapia (*Oreochromis* spp) are mainly salted. The Myanmar salt fish producers are facing problems due to poor quality of final salted products as they did not maintain the quality of raw material, hygiene and sanitation during salting, processing and storage condition. After receiving the fish material, some salt fish producers fail to maintain the quality of the raw fish material under chilled condition. The heads and viscera of the fish is removed, and the fish is washed before salting. The fish is either immersed into the brine or kept in an earthen jar alternately with salt at a 1:2 ratio of fish to salt for 2-3 days. Salting is combined with sun drying. The salt producers do not use the other drying methods due to high investment costs. During sun drying, risk of cross contamination by dust, insects, dogs, cats and birds to the final products is increased. It is difficult to implement the quality assurance for small and medium sized enterprises (SMEs) in Myanmar. In Iceland, dry salting methods without sun drying can prevent above risk factors. Using the salting methods used in Iceland without drying could possibly be suitable to replace the salting and then sun drying method in Myanmar, resulting in increased the quality, safety and stability.

Atlantic mackerel *(Scomber scombrus)* was used in present study to determine the effect of different salting procedures on the physical and chemical properties, but mackerel is one of the main species exported from Myanmar. This study aims to evaluate and compare the quality changes and shelf life of salted final products using different salting methods.

1.1 Objectives

The objectives of this study were to evaluate the effect of different salting procedures on the quality of heavily salted mackerel with reference to Myanmar, and to establish how

raw material quality affects the quality and storage stability of the final product. The following specific aims were established for this project work:

- To evaluate the physical changes of salted mackerel during storage.
- To determine the chemical changes of salted mackerel during storage.
- To compare the stability of salted mackerel depending on salting procedure.

2 LITERATURE REVIEW

2.1 Salting

Salting of fish is a preservation technique that has been used for centuries. The salting techniques have changed over the time, but several developments have been done to achieve a standardized product that meets the consumers demands (Hall, 1992). Salting can be a very simple and cheap preservation method and it has a great significance and relevance for the socio-economic system of small-scale producers.

The main aim of salting is to remove some of the water from the fish flesh and to replace it with salt, resulting in reduced water activity. Salting is therefore a fundamental mechanism to inhibit the microbial growth and to inhibit the autolytic enzymes (Saritha, Jayasantha, Aiyamperumal, & Patterson, 2012). The salting process results in important changes in composition and structure of fish muscle (Andres, Barat, Fito, & Barona, 2005). How the salt and water transfer within the fish muscle during the salting process is complicated depends on various mass transfer mechanisms. Diffusion is the important mass transfer mechanisms to diffuse sodium and chloride to the fish and water diffuse out from the fish which depends on difference in concentration and osmotic pressure between the inter-cells and salt (Akköse & Aktas, 2015).

The stability and denaturation of proteins and the physicochemical factors also depends on the salt concentration (Thorarinsdottir K. , Arason, Geirsdottir, Bogason, & Kristbergsson, 2002). The ionic strength and pH factors influence water binding of muscle proteins. In low salt concentration (2-5%), the muscle swells significantly (Sigurgisladottir, Sigurdardottir, Torrissen, Vallet, & Hafsteinsson, 2000) and above 9%, the proteins may denature, resulting in stronger protein-protein bonds, causing shrinkage of the muscle and dehydration (Thorarinsdottir K. , Arason, Geirsdottir, Bogason, & Kristbergsson, 2002). The amount of swelling depends on salt concentration. The pH values show that quality deterioration and shelf life prediction (Abbas, Mohamed, Jamilah, & Ebrahimian, 2008). Variation of pH can impact flavour, consistency and shelf life.

Salt uptake depends on many factors including species, muscle type, fish size, fillet thickness, weight, physiological state, composition (lipid content and distribution), salting method, brine concentration, duration of salting process and fish to salt ratio (Ünlüsayın, Gümüş, Erdilal, & Gülyavuz , 2011).

Salting is performed either by dry salting, brining, or injection or a combination of these methods (El-Bassir, 2015). The most common salting methods used in industrial processing has been brining and dry salting (Espe, Nortvedt, Lie, & Hafsteinsson, 2001).

2.2 Dry salting

Dry salting is a traditional salting method and has been used unchanged for millennia in many countries around the world (Gallart-Jornet, et al., 2011). When dry salting, either fish fillet or butterfly (split) fillets are stacked with alternating layers of salt and kept for weeks. Today, the fish is piled with alternating layers of salt in plastic tubs with a hole in the bottom to drain the extracted liquid from the fish. At dry salting, salt diffuses into the fish muscle and water diffuse out to the surrounding media (salt) (Thorarinsdottir K. , Arason, Bogason, & Kristbergsson, 2004). One study has shown that crude protein values in dry salted *Salmo trutta magrostigma* are lower than brine salted due to the proteins which more easily denatured during dry salting compared to brine salting and therefore were more easily lost (Bilgin, Osman Ertan, & Gunlu, 2007).

During dry salting, liquid is released from the muscle because of salt uptake and pressure and water drains away. The protein solubility in water depends on the distribution of the salt concentration. The solubility of protein increases at the low concentration where the electrostatic interactions inside the protein are reduced during the process. This reaction will influence the solubilisation of protein charge higher, called as ‘salting in’ process. However, surface tension and solubility of protein are increased when the concentration of salt is higher that can lead to interaction of hydrophobic during the process, called ‘salting out’ (Albarracin, Sanchez, Grau, & Barat, 2011). Salted cod, popularly referred to by the Spanish name ‘bacalau,’ contains 80% water and 0.3% salt in the raw material and final salted cod product contains 55-58% water and 18-12% salt (Thorarinsdottir K. , Arason, Bogason, & Kristbergsson, 2004).

2.3 Brine salting

During brine salting, fish is immersed into brine at 1:2 ratio of fish to salt which is prepared by dissolving salt in the water. The salt concentration of the brine varies, depending on producers, influencing the weight yield, water holding capacity, appearance and commercial quality of the final products. Lower brine concentration generally results in final products with higher process yields (Nguyen, Thorarinsdottir, Gudmundsdottir, Thorkelsson, & Arason, 2011). The salt diffusion rate and the extraction quantity of the protein and water are positively correlated with increasing salt concentration of the brine. The salting rate depends on initial brine concentration because during the brining process, the brine concentration decreases due to salt and water exchange between the fish muscle and the surrounding brine (Thorarinsdottir A. K., Arason, Bogason, & Kristbergsson, 2004). The advantage of brine salting is that it gives higher yield than the dry salting (Martinez-Alvarez & Gomez-Guillen, 2005). The processing yield of brine salted fish is higher compared to dry salted fish due to less water losses, salt soluble protein, and non-protein components to the salting medium (Ariyarathna, Porarinsdottir, & Arason, 2011).

2.4 Desalting

Salted fish needs to be desalted before cooking and consumption. Traditionally, the desalting process is usually carried out in the consumers' kitchens but nowadays, this process is done by the industry in line with customer demand for ready-to-eat products (Alino, Fuentes, Fernandez-Segovia, & Barat, 2011). Desalting is a rehydration process. In desalting, the salts are expelled to acceptable level for human consumption and water is rehydrated into the fish muscle and increases the weight and yield (Martinez-Alvarez, Borderias, & Gomez-Guillen, 2005) Desalting improves the fish texture. During the desalting traditionally, the fish is soaked in tap water for at least 24 hours at room temperature or under refrigeration. To improve the desalting process, water is usually exchanged one or two times. However, the result from Barat (2004) showed that the weight increased in the cod desalting process without exchange of water than the traditional desalting process and obtained economic benefits such as higher processing yield and wastewater losses. Longer desalting time gives the higher yield (Barat J. , Rodriguez-Barona, Andres, & Visquert, 2004). The thickness and fish size, water hardness, the ratio of fish to water, the influence of water management can affect the characteristics of the desalted products. The moisture content and processed condition of salted fish also affects the desalting process (Andres, Rodriguez-Barona, & Barat, 2005).

2.5 Quality Indicators

Measurements for lipid degradation and water activity were used as quality indicators for salted fish in this study.

2.5.1 Lipid Degradation

Fish and fishery products are highly susceptible to oxidation because of high content of polyunsaturated fatty acids (Guizani, Rahman, Al-Ruzeiqi, Al-Sabahi, & Sureshchandran, 2014). Lipid oxidation is the major cause of quality deterioration in food (Mariutti & Bragagnolo, 2017) . Oxidation occurs due to enzymatic or non-enzymatic reactions. Non-enzymatic oxidation can occur by two mechanisms that are auto-oxidation and photo-oxidation. Auto-oxidation occurs in the presence of triplet oxygen and the photo-oxidation occurs in the presence of single oxygen (Mariutti & Bragagnolo, 2017). Lipid degradation can occur enzymatically by lipolysis and results in forming free fatty acid, which will be easily oxidized (Ghaly, Dave, Budge, & Brooks, 2010). Thus, free fatty acid can be used as a measurement for determination of enzyme activity. The free radical mechanism of lipid auto-oxidation involves initiation, propagation, and termination steps. The rate and intensity of lipid oxidation are influenced by many factors such as pre-slaughter conditions (e.g injuries, stress), post slaughter condition (e.g. pH, carcass temperature, killing method), the composition and quality of the raw material, presence of pro-oxidants, anti-oxidants and additives, processing condition (e.g. heating or cooking), type of packaging, storage and distribution conditions among other factors (Mariutti & Bragagnolo, 2017). Lipid oxidation results in the development of off-flavors, loss of liposoluble vitamins, other

bioactive compounds (Mariutti & Bragagnolo, 2017) and in the development of off-odor and protein denaturation and texture changes (Yanar, Celik, & Akamca, 2006).

The development of lipid oxidation can be followed by the primary products of fatty acid oxidation, such as hydroperoxides and conjugated dienes, or secondary oxidation products such as pentanal, hexanal and malonaldehyde. Malonaldehyde is usually determined colorimetrically as thiobarbituric reactive substances (TBARS) (Mariutti & Bragagnolo, 2017).

The colour of salted final product is a very important for marketing. The colour of final salted fish mainly depends on the pH and many factors such as water, protein, lipids, muscle pigments and their interactions. Lightness (L value) changes depend on moisture content in the fish muscle. The relationship of lipid oxidation and pigment oxidation is significant (Cheng, Wang, & Ockerman, 2007). Lipid oxidation increases the yellowness (b value) of fish fillets (Bras & Costa, 2010) . The redness (a value) depends on the presence of oxymyoglobin (Pearson & Dutson). The oxidation of haemoglobin at low pH increase the redness (a value) of herring fillets (Ari111).

2.5.2 Water activity

Water activity is the critical factor for determining of storage stability and food quality. The relative humidity is a means to measure the freely available water for microorganisms to grow; measuring value is called water activity value. Water activity is defined as the ratio between the vapor pressure in food itself and the vapor pressure of pure water at the same temperature. It is sometimes also defined as free bound or available water. A portion of water content present in a product is strongly bound to specific sites such as hydroxyl groups of polysaccharides, the carbonyl and amino groups of proteins and other polar sites in the products (David, 2006). It effects undesirable reactions such as non-enzymatic browning, fat oxidation, vitamin degradation, enzymatic reactions, protein denaturation, starch gelatinization and starch retrogradation. The water activity is a fundamental mechanism to inhibit the microbial growth and to inhibit the autolytic enzymes and results effect on changes of the color, taste and aroma. By measuring the water activity, it is possible to predict which microorganism will and will not be potential sources of spoilage (Abbas, Saleh, Mohamed, & Lasekan, 2009). The water activity and pH also consider as a control measures in the Hazard Analysis Critical Control Point (HACCP) for food safety (USFDA-Fish and Fishery products Hazard Guidance). The water activity increases with temperature. The water activity is expressed as decimal.

2.6 Characteristics of Mackerel (*Scomber scombrus*)

Mackerel fish is a fatty fish, pelagic fish and fast swimming (Figure 1). Their distributions are from North-west Africa to Iceland and northern Norway in the eastern North Atlantic, including Black Sea, Mediterranean and western Baltic, and from North Carolina to Labrador in the western North Atlantic. Common size is 35 to 45 cm when caught, though it can reach 60 cm in maximum length. Mackerel feeds on a variety of pelagic animals (North Atlantic Seafood Report, 2013). The mackerel is a valuable pelagic fish and it is now primarily processed for human consumption. Atlantic mackerel

is mainly caught with purse seine. Other fishing gears are trolling lines, gillnets, traps, beach seines, and midwater trawls (FAO, 2014).

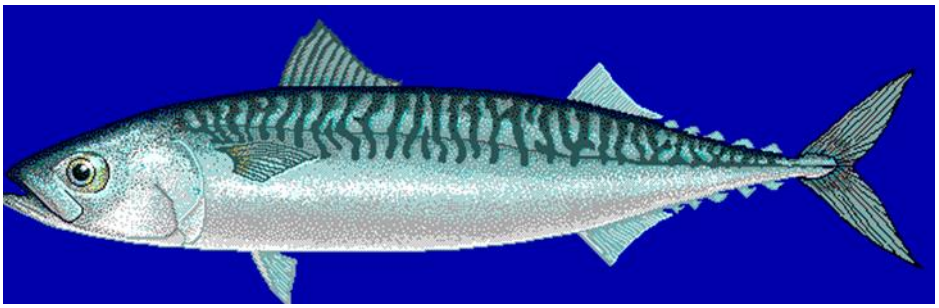

Figure 1. Atlantic Mackerel (Scomber scombrus) (FAO, 2017)

The chemical composition of Atlantic mackerel, including relative values of protein, fat, and water are outlined in Table 1 below.

Table 1. Chemical composition of Atlantic mackerel (*Scomber scombrus*) (FAO, 2014)

Component	Values (%)
Protein	18-20
Fat	6-23
Water	56-74

3 MATERIALS AND METHODS

3.1 Experimental setup

Frozen whole mackerel (*Scomber scrombrus)* of different quality were used in this study. Frozen whole mackerel of different quality were purchased from two different processing plants. These whole mackerel were transported to the laboratory. Upon arrival, the whole mackerel were thawed for 24 hours at 4°C before filleting. The fish were headed, eviscerated and filleted by hand, then washed and salted. The sample groups from two different processing producers were divided into two group: Producer I and Producer II. The quality of raw materials between Producer I and Producer II are different. The raw mackerel fillets from Producer II had a sour smell. When the mackerel were compared between Producer I and Producer II by GC analysis, the quality of fish from Producer I was better than Producer II. The TVB-N results of raw material quality from Producer I and Producer II showed 19.1 mgN/100 g and 20.05 mgN/ 100g respectively. The main reason was that Producer II used the large chilled room to keep the fish after catching in fishing vessel, and resulting the fish were not immediately cooled down.

Salting methods used were brine salting and dry salting method applied to each producer. After applying these salting methods, the mackerel fillets were packed in waxed carton boxes and kept at 13°C for 14 days. The average weight of raw fillet was 200-300 g. Industrial crystal salt of commercial grade was used for brine and dry salting. Waxed carton boxes for storage of salted fish were food grade. All material used for chemical analyses were of analytical grade. The flow chart of the experiment for evaluation of the effect of

different salting procedures on physical and chemical properties of Atlantic mackerel are shown in Figure 2.

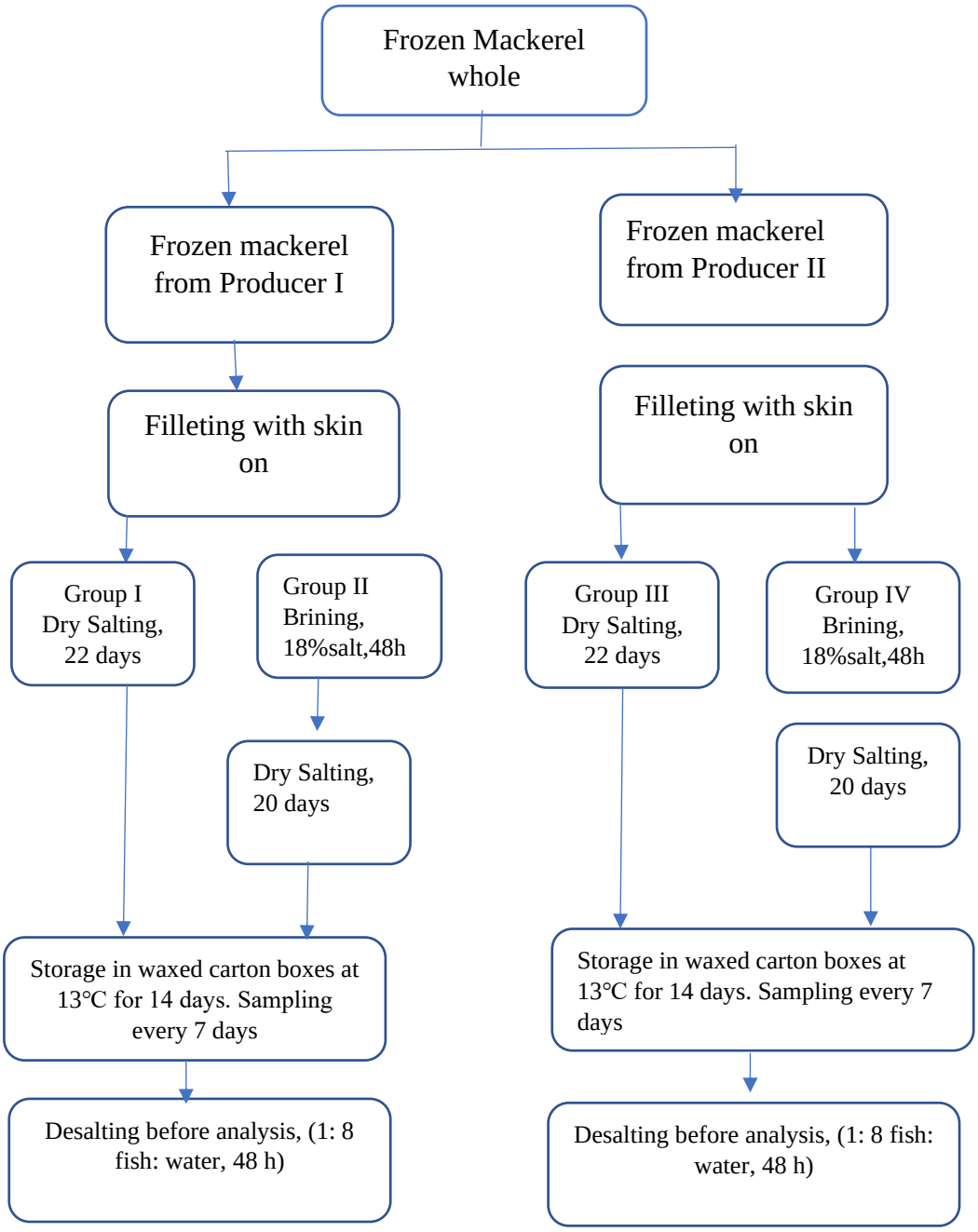

Figure 2. Flow chart of the experiment for evaluation of different salting methods of mackerel fillet with skin on

3.2 Dry Salting

Dry salting was carried out using 1:2 ratio of fish to crystal salt. Fillets for each producer were run by inserting a crystal salt with a fish layer in the plastic boxes and kept at 12.6℃ ±0.2 for 22 days (Figure 3).

Figure 3. Dry Salting of mackerel fillets (Experimental Group I and III)

3.3 Brine Salting

In brine salting, the fillets for each producer were salted in 18% brine solution at the ratio 1:1 salt to fish in plastic boxes. The salting process was carried out 2℃ for 48 hours. After removing the fillets from the brine, the fillets were stacked with alternating layers of crystal salt at a ratio 1:2 fish to salt in plastic box and kept at 12.6℃ ±0.2 ℃ for 20 days (Figure 4).

Figure 4. Brine Salting of mackerel fillets (Experimental Group II and IV)

3.4 Sampling Plan

For each experimental group, samples were collected after thawing, brine salting, dry salting and every 7 days after dry salting during storage. 3 fillets for each group, at each sampling time, were used for evaluation of cooking yield and colour. 3 fillets were used from each group, at each sampling were to evaluate chemical and physical properties. Samples were desalted prior to analysis except the raw mackerel fillets. During desalting, the salted fish is soaked in the water at a ratio 1:8 fish to water for 48 hours.

3.5 Physicochemical Analysis

The analysis performed were the salt content, water content, water activity, pH, total volatile basic nitrogen (TVB-N), lipid content, free fatty acid (FFA), thiobarbituric acid reactive active substances (TBARS), peroxide value (PV), NIR and NMR analysis, processing yield, soaking yield, storage yield and cooking yield.

3.5.1 Colour analysis

Colour was analyzed using Minolta Chroma meter CR-400 (Minolta Co., Ltd; Osaka, Japan). Colour measurements include; the L value, lightness on the scale of 0 to 100 from black to white; a value, (+) red or (-) green; b value, (+) yellow or (-) blue. The colour was measured at three points laterally from the head to the tail on the fish.

3.5.2 Salt content

The NaCl content was determined by the volumetric method of Volhard (Horwitz, 2000) . The salt content was calculated as gram per 100 g wet muscle.

3.5.3 Water content

The water content was determined according to (ISO 6496:1999). About 5 g of sample were placed and weighed in a crucible. The water content was calculated as the loss in weight, after drying in the oven at 103℃ for 4 hours. The dish cooled to ambient temperature in a desiccator for about 15 minutes. The water content was expressed as grams per 100 g wet muscle. The water content of the material was calculated as follows:

$$\boldsymbol{W=} \frac{\boldsymbol{m_1-(m_3-m_2)}}{\boldsymbol{m_1}} \boldsymbol{*} 100\%$$

Where:
W= water content
m_1= weight of the sample (g)
m_2= weight of the crucible(g)
m_3= total weight of the sample and crucible after drying (g)

3.5.4 Water activity

Water activity was determined by using the water activity meter (Aqua Lab). About 2 g of minced sample were placed in a disposable cup and put it in the Aqua Lab. To reach the final reading, read time takes about 5 minutes or less and the water activity read at a measuring temperature 24±0.9℃.

3.5.5 Cooking yield

The cooking yield represents the amount of water lost during cooking. The sample weighing was done before cooking with no more than 105 g of each fillet. If the fillet weighed more than 105 g, the sample was cut on both head and tail part of the fish. The samples were cooked in a steaming oven (Convotherm Elektrogerate GmbH, Eglfng, Germany) at 90℃ for 10 minutes. After cooking, the samples were left for about 10 minutes to drain the water and weighed. Calculate the cooking yield as follows:

$$\boldsymbol{CY} = \frac{\mathrm{W}_{cooked}}{W_{raw}} * 100\ \%$$

Where:
W_{cooked} = the weight of cooked sample
W_{raw} = the weight of sample before cooking

3.5.6 pH measurement

The pH of the samples was measured using a digital pH meter (Knick-Portamess 913 pH, Berlin, Germany) after calibration using standard buffer solutions of pH-4, pH-7 and pH-10. The pH value was the average of two readings.

3.5.7 Total volatile basic nitrogen (TVB-N) analysis

The TVB-N was evaluated according to the method of Malle & Poumeyrol (1989).

3.5.8 Lipid Content

Total lipids were extracted according to the Bligh and Dyer methods (1959) using a chloroform/methanol/0.88% KCl (aq) (80±1% water). Lipid content was determined gravimetrically and expressed as g lipid / 100 g of the sample.

3.5.9 Free Fatty Acid

The free fatty acid content (FFA) was determined according to the method of (Lowry & Tinsley, 1976) with modification from (Bernardez, Pastoriza, Sampedro, Herrera, & Cabo, 2005). About 3 mL of the lower phase resulting from lipid extraction was added in a screw cap culture tube. Any solvent present was removed at 55℃ using a nitrogen jet. After cooling down, 3 mL of cyclohexane were accurately added by 1 ml of cupric acetate-pyridine reagent and vortex for 40 seconds. After centrifugation at 2000 rpm for 10 min at 4℃, the upper layer was read at 710 nm in spectrophotometer. The FFA concentration in the sample was calculated as µmol oleic acid based on a standard curve spanning a 2-14 µmol range.

3.5.10 Peroxide analysis

Peroxide value, a first stage of oxidation was analyzed according to Decker (1994). About 5 g of samples were mixed in a disposable plastic tube with 10 mL ice-cold chloroform: methanol (1:1) solution, containing 500 ppm BHT to prevent further peroxidation. 5.0ml of sodium chloride (5 M) was added into mixture and homogenized for at 6000 rpm for 10 seconds before centrifuging at 5100 rpm for 5 min at 4℃ (TJ-25 Centrifuge, Beckmann Coulter, USA). The chloroform layer was collected (50 µL) and completed with 950 µL chloroform: methanol solution. A total amount of 5 µL of ammonium thiocyanate (4 M) and ferrous chloride (80 mM) mixture (1:1) was finally added. The samples were incubated at room temperature for 10 min and read at 500 nm. A standard curve was prepared using cumene hydroperoxides. The results were expressed as mmol lipid hydroperoxides per kg of wet muscle.

3.5.11 Thiobarbituric acid reactive substances (TBARS)

The secondary oxidation product was evaluated according to the method of Lemon (1975) with some modification used. A sample (5.0 g) was homogenized with 10.0 ml of trichloroacetic acid (TCA) extraction solution (7.5% TCA, 0.1 propyl gallate and 0.1% EDTA mixture prepared in ultrapure water) using a homogenizer at maximum speed for 10 seconds (Ultra-Turrax T-25 basic, IKA, Germany). The homogenized samples were then centrifuged at 5100 rpm for 20 min (TJ-25 Centrifuge, Beckmann Coulter, USA). Supernatant (0.05 ml) was collected and mixed with the 0.95ml thiobarbituric acid (0.02M) and heated in a water bath at 95℃ for 40 minutes. The samples were cooled down on ice and immediately loaded into 96-well microplates (NUNC A/S Thermo Fisher Scientific, Roskilde, Denmark) for reading at 530 nm. A standard curve was prepared using tetraethoxypropane. The results were expressed as µmol of malomaldehyde diethylacetal per kg of wet muscle.

3.5.12 Statistical analysis

The data were subjected to analysis of variance (ANOVA). Comparison of means was carried out by Duncan’s multiple range test (Steel & Torrie, 1980).

4 RESULTS

4.1 Soaking Yield (%)

The soaking yield of the brined and dry salted and single dry salted mackerel fillets from Producer-I at day 0 were 111.84% and 112.08% respectively (Figure 5) and from Producer-II at day 0 were 112.6% and 112.53 respectively (Figure 6). The soaking yield in group II are higher than the group I for Producer-I. The soaking yield in group III is higher group IV except the end of storage. At the end of storage, the single dry salted maintained the higher yield for both Producers. No significant differences were observed in soaking yield with regard to raw material, storage time nor salting method.

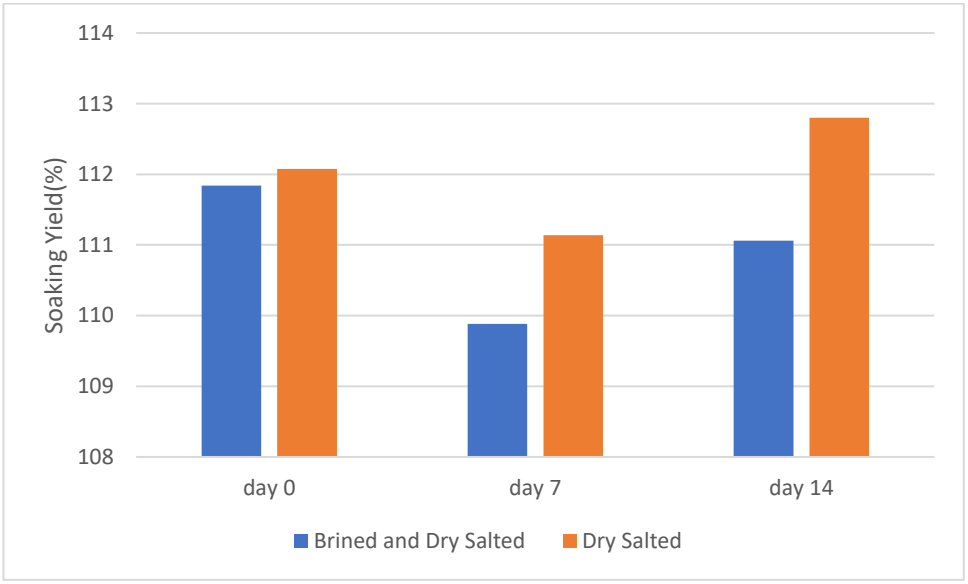

Figure 5. Soaking Yield (%) of brined and dry salted and single dry salted mackerel fillets from Producer- I during 2 weeks of storage at 13°C

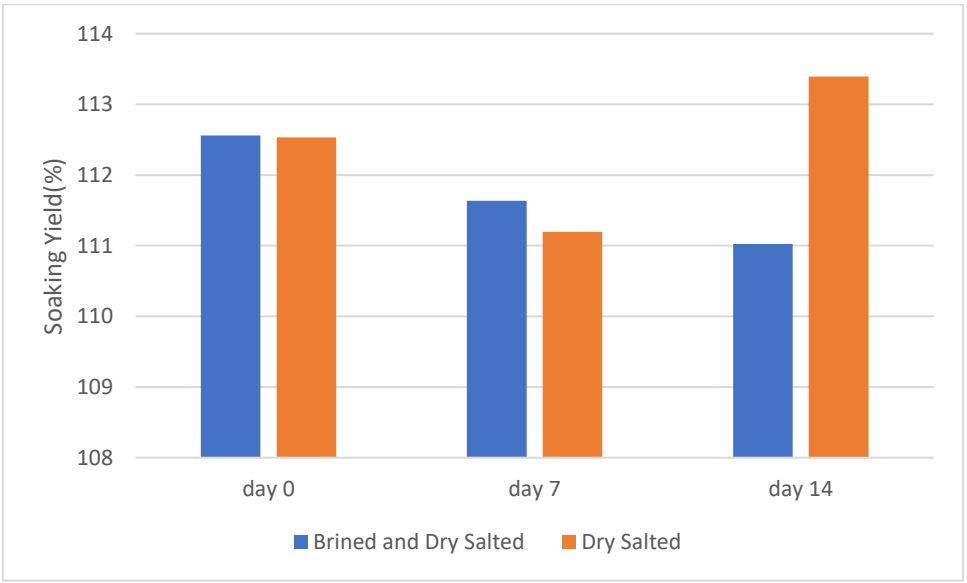

Figure 6. Soaking Yield (%) of brined and dry salted and single dry salted mackerel fillets from Producer II during 2 weeks of storage at 13°C

4.2 Processing Yield (%)

The processing yield (%) in group I and group II are shown in Fig 7 and Fig 8 for group III and group IV. The processing yield after brined salted increased than the brined and dry salted and single dry salted for both Producers. When compared between the brined and dry salted and single dry salted, the yield from brined and dry salted is higher than the single dry salted and there was significant different ($p<0.05$) for both Producers.

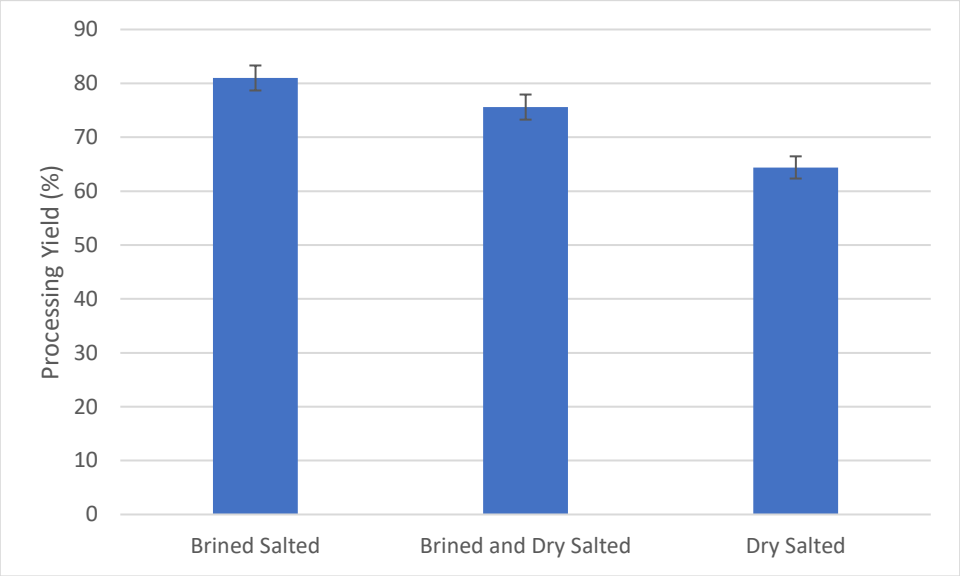

Figure 7. Processing yield (%) of desalted mackerel fillets in brined salted, brined and dry salted and dry salted from Producer I during 2 weeks storage at 13℃

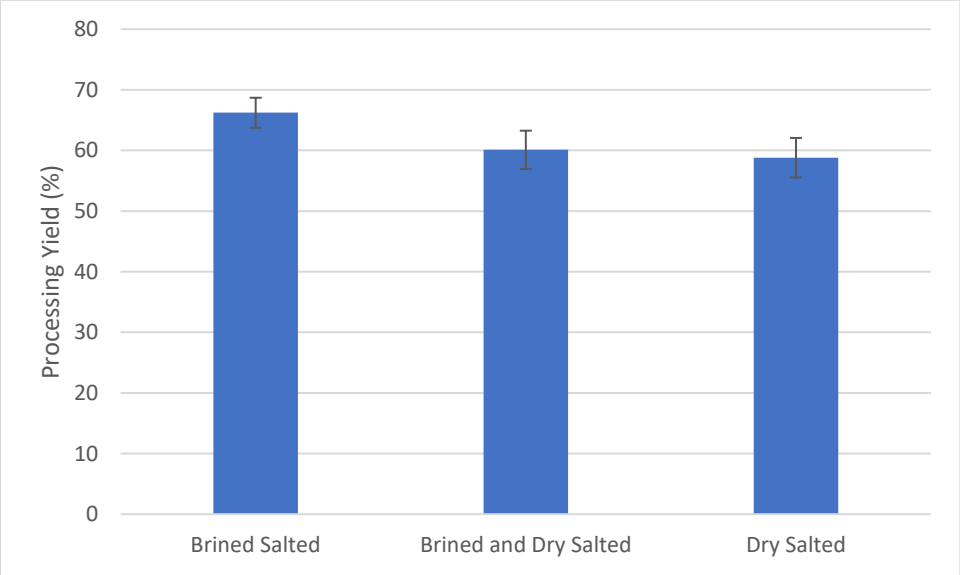

Figure 8. Processing Yield (%) of desalted mackerel filler in brined salted, brined and dry salted and single dry salted from Producer II during 2 weeks storage at 13℃

4.3 Water Content

The changes of water content in mackerel fillets during salting, and 2 weeks of storage at 13℃ from Producer I and Producer II are shown in Figure 9 and Figure 10. The water

content in raw mackerel fillets from Producer I and Producer II were 54.1±0.28 and 53.85±0.78 respectively. The water content in mackerel fillets during salting process decreased in all groups. After desalting of 48 hrs, the water content increased again and there were significant different ($p<0.05$) between pre-brined dry salting and single dry salting for both Producers. The water content in all groups decreased gradually during storage and there were significant different($p<0.05$) during storage in group I and group II, group III and group IV.

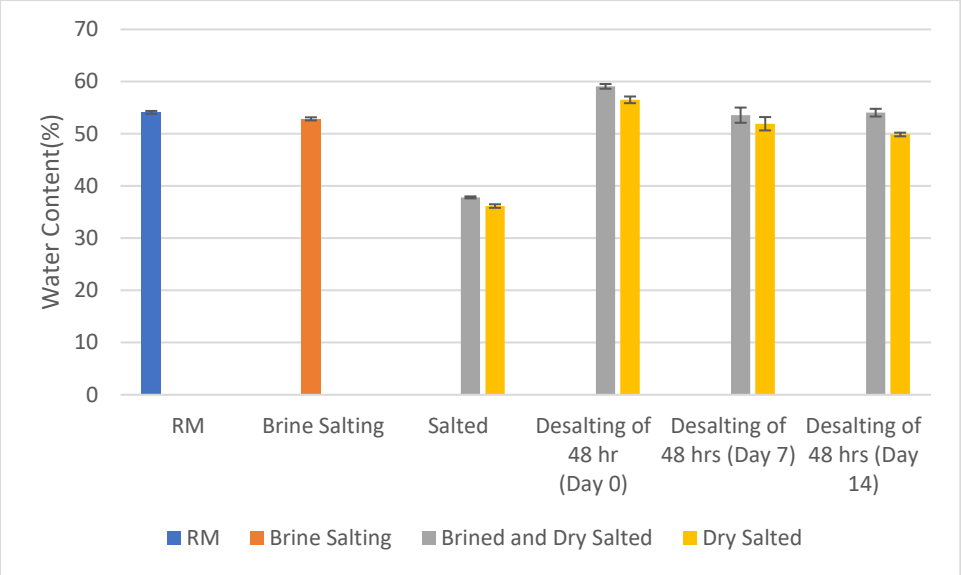

Figure 9. Changes of water content (%) in mackerel fillets from Producer I during processing, and 2 weeks of storage at 13℃

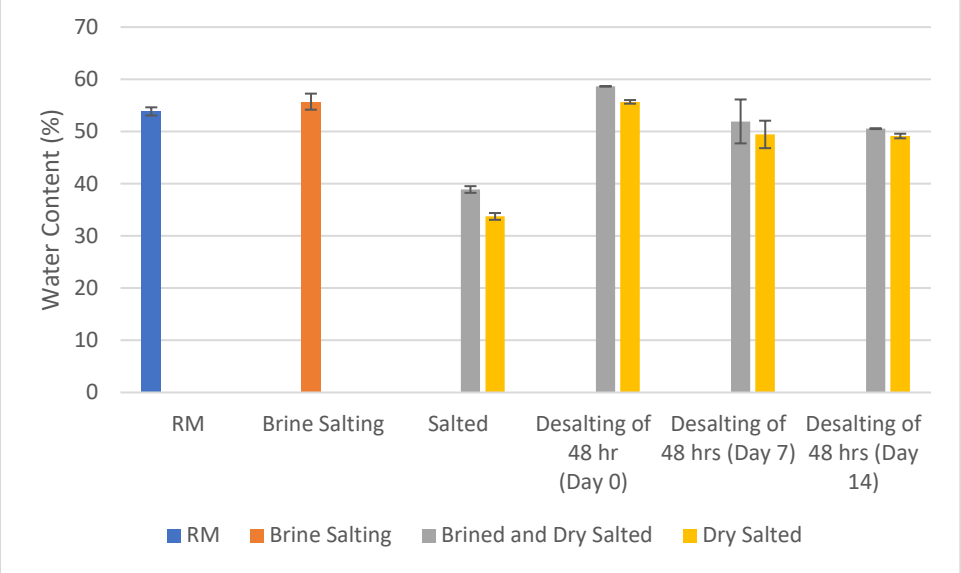

Figure 10. Changes of water content in mackerel fillets from Producer II during processing, and 2 weeks of storage at 13℃

4.4 Salt Content

The salt content in raw mackerel fillets from Producer I and Producer II were 0.45±3% and 0.45±3% and increased 5.1 ±3% and 6.35±3% during brine salting respectively (Figure 11 and Figure 12). The increased salt content was found in pre-brined dry salting and single dry salting. The salt content in pre-brined dry salting is lower than the single dry salting for both Producers and there were not significantly different ($p<0.05$). After desalting of 48 hrs, the salt content of pre-brined dry salting and single dry salting from Producer-I decreased 3.195±3% and 3.295±3% respectively and the Producer-II were 2.69±3% and 3.7±3% respectively. There was a significant difference between different groups for both Producers.

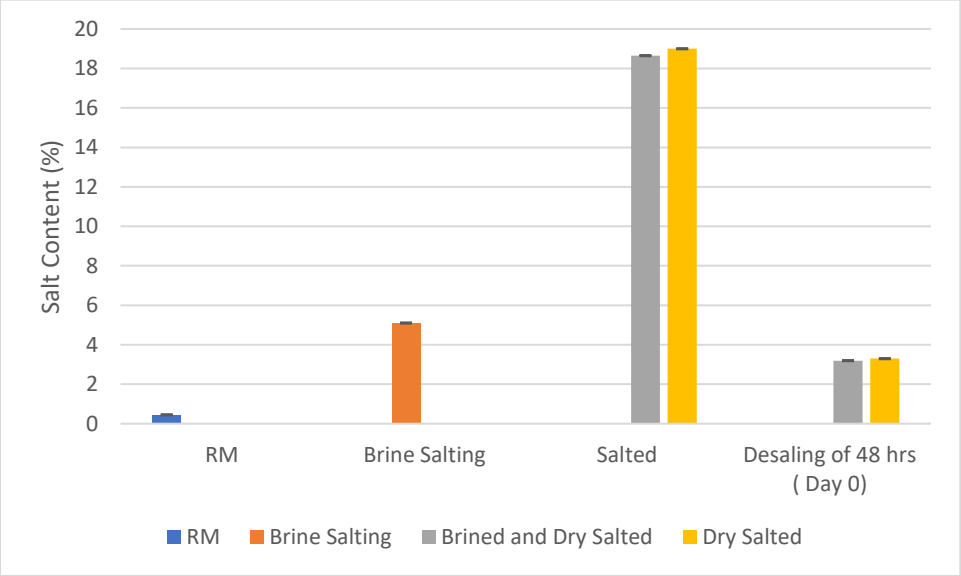

Figure 11. Changes of salt content in mackerel fillets from Producer-I during the salting and desalting process

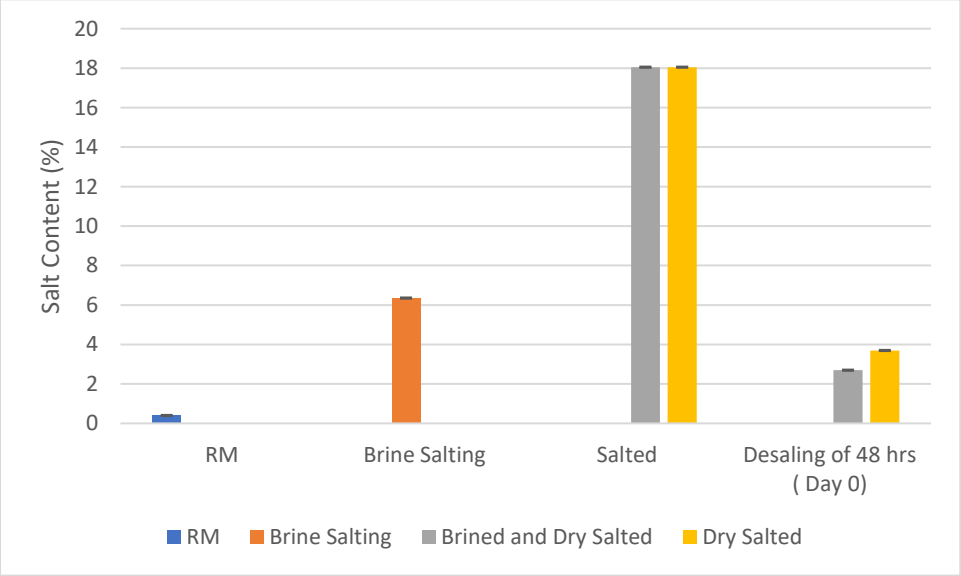

Figure 12. Changes of salt content in mackerel fillets from Producer-II during the salting and desalting process

4.5 Cooking Yield (%)

The cooking yield of salted mackerel fillets from Producer I and Producer II in brined dry salted after desalting at day 0 was 90.85% (Figure 13) and 85.64% (Figure 14) respectively. The result showed that the cooking yield decrease with the end of storage time in all groups. When the cooking yield are compared between the brined and dry salted and single dry salted, the single dry salted are higher than the brined and dry salted for both Producers. There were no significant different ($p<0.05$) in the brined and dry salted and single dry salted during storage for producer I.

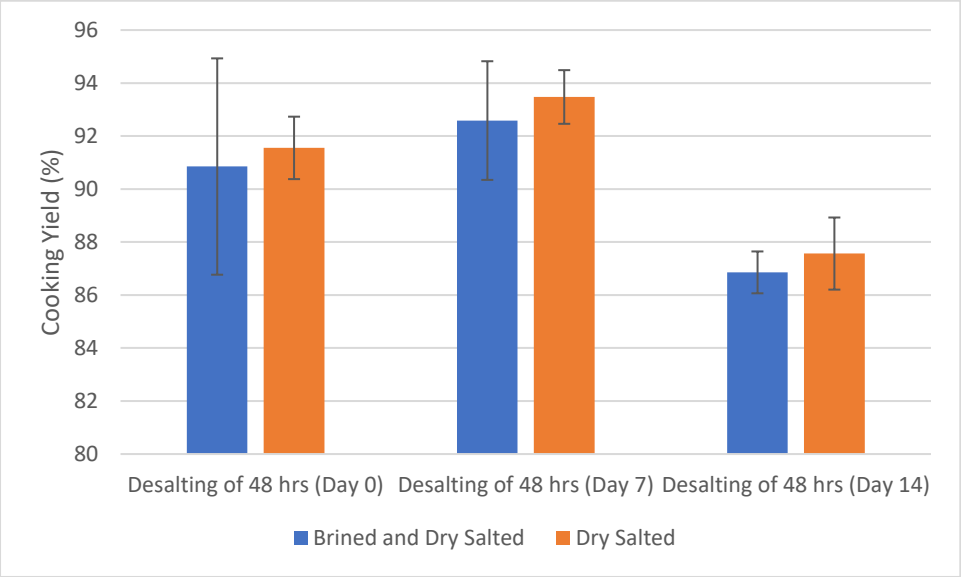

Figure 13. Cooking Yield (%) of desalted mackerel fillets in brined and dry salted and single dry salted from Producer I during 2 weeks of storage at 13°C

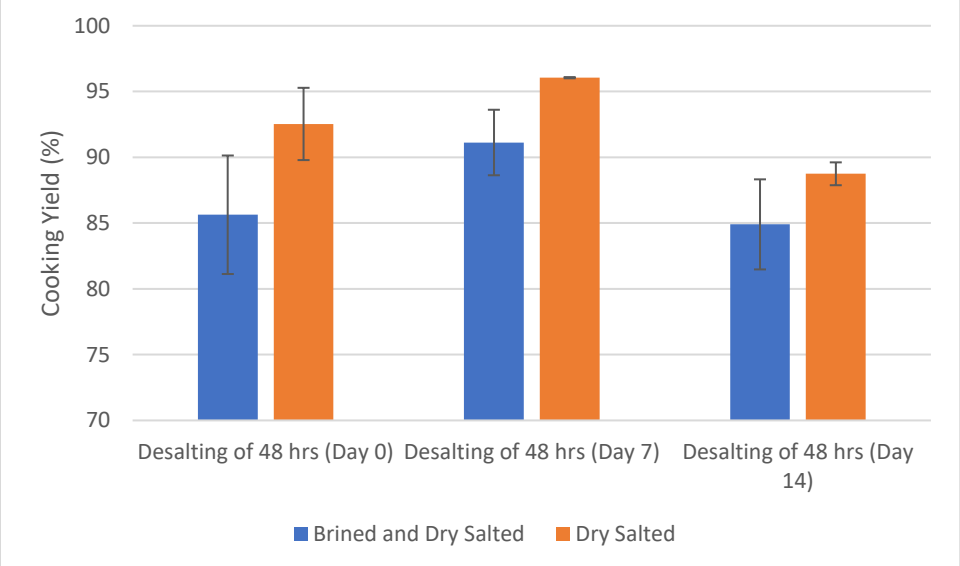

Figure 14. Cooking Yield (%) of desalted mackerel fillet in brined and dry salted and single dry salted from Producer II during 2 weeks of storage at 13°C

4.6 Colour

The lightness (L value) of the raw mackerel fillets from Producer I and Producer II were 55.79 ± 3.29 (Figure 15) and 62.24±3.29 respectively (Figure 16). The L value in brined and dry salted is higher than the single dry salted for both Producer. The L value decreased in all groups after salting process. However, the L value increase after desalting in all groups. There were no significant different ($p<0.05$) between difference groups after desalting. During storage, the L value increased again.

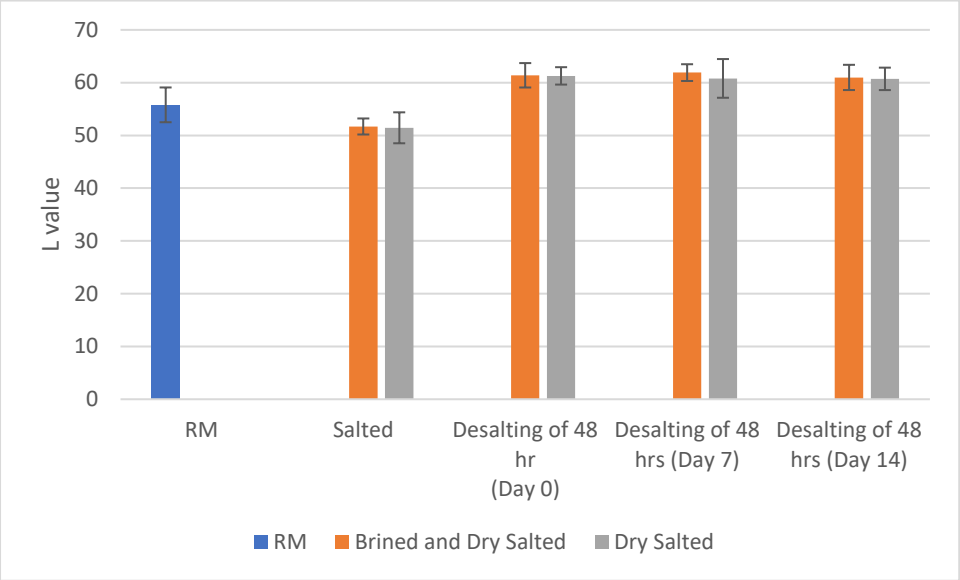

Figure 15. Changes of Lightness (L value) in salted mackerel fillets from Producer I during processing, and 2 weeks of storage at 13°C

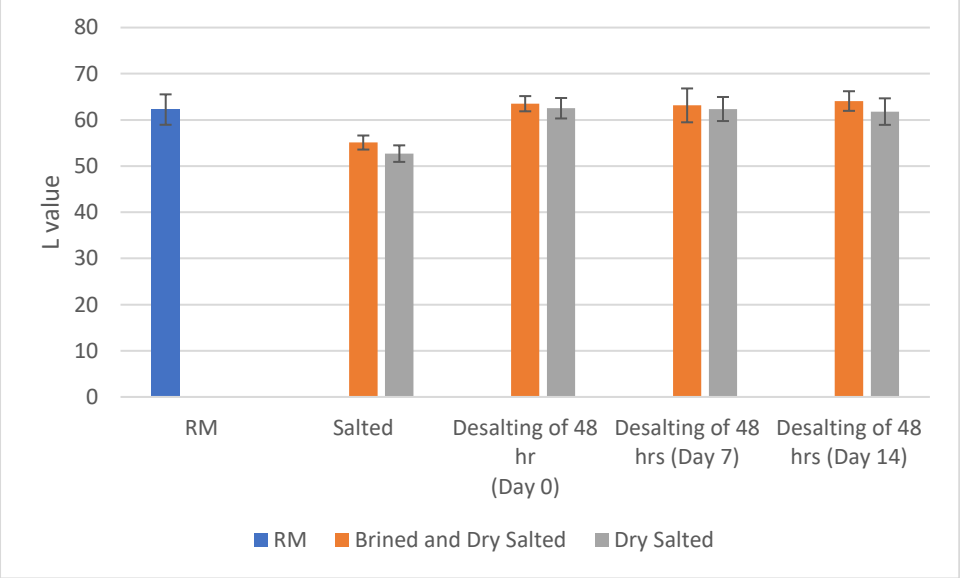

Figure 16. Changes of Lightness (L value) in salted mackerel fillets from Producer I during processing, and 2 weeks of storage at 13°C

The redness (a value) of salted mackerel fillets in pre-brined dry salting, single dry salting and desalting during storage are shown in Figure 17 and Figure 18. The a-value

of raw mackerel fillets from Producer-I and Producer-II were 7.56±1.63 and 4.53±2.12 respectively. The a-value in all groups decreased during the salting processing and desalting.

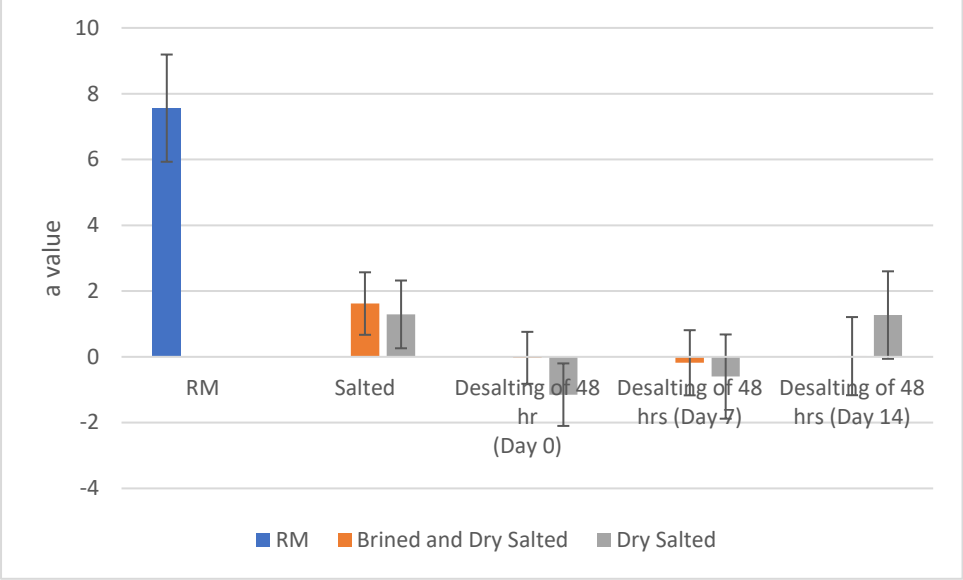

Figure 17. Changes of redness (a value) in salted mackerel fillets from Producer I during processing, and 2 weeks of storage at 13℃

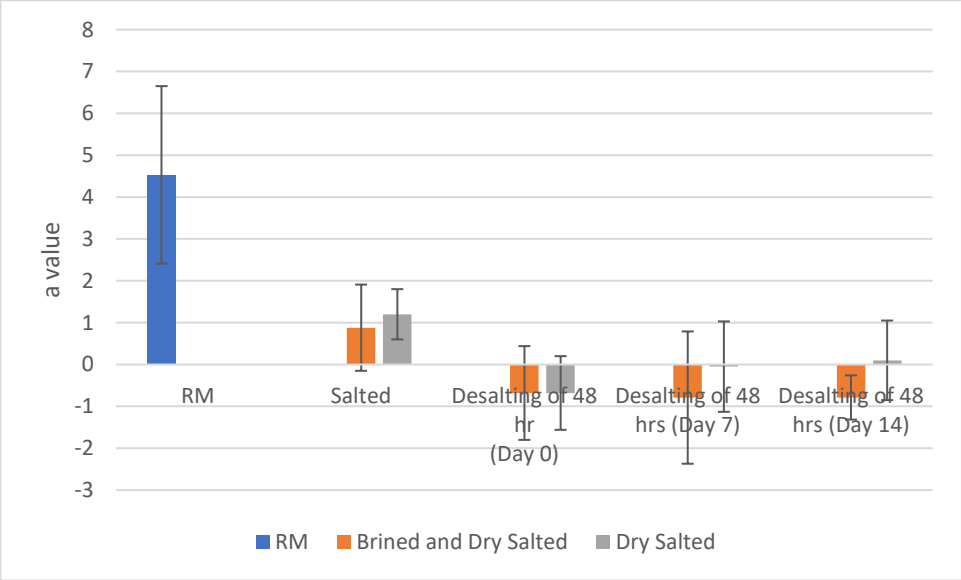

Figure 18. Changes of redness (a value) in salted mackerel fillets from Producer II during processing, and 2 weeks of storage at 13℃

The yellowness (b value) in mackerel fillets of pre-brined dry salting and single dry salting, desalting during storage from Producer I and Producer II are shown in Figure 19 and Figure 20. The yellowness (b value) in raw mackerel fillets from Producer I and Producer II were 5.53±1.14 and 6.3±0.89 respectively. The b value in all groups increased during the salting process and 2 weeks of storage at 13℃. The b value in single dry salting is higher than the pre-brined dry salting in both Producers and there were significantly different ($p<0.05$).

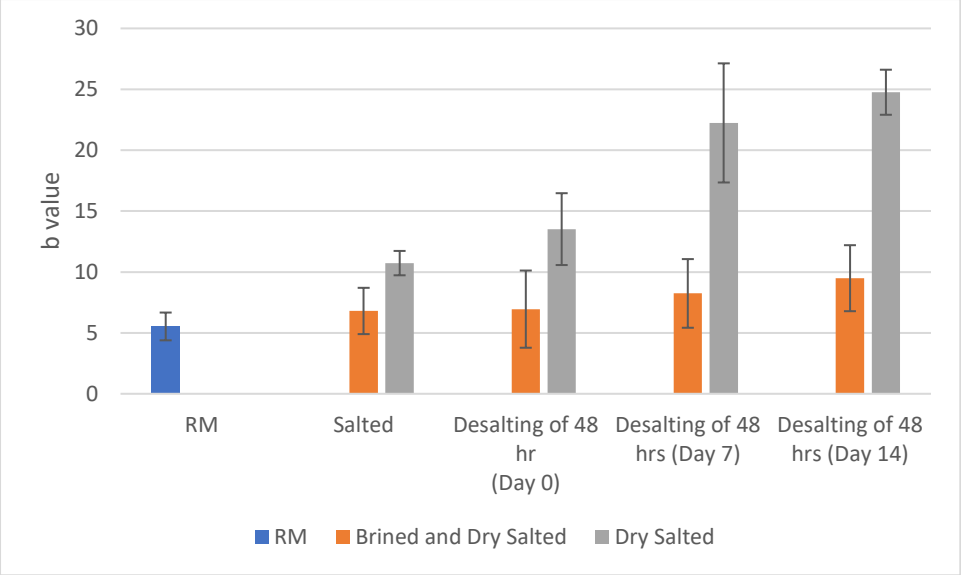

Figure 19. Changes of yellowness (b value) in mackerel fillets from Producer I during processing, and 2 weeks of storage at 13℃

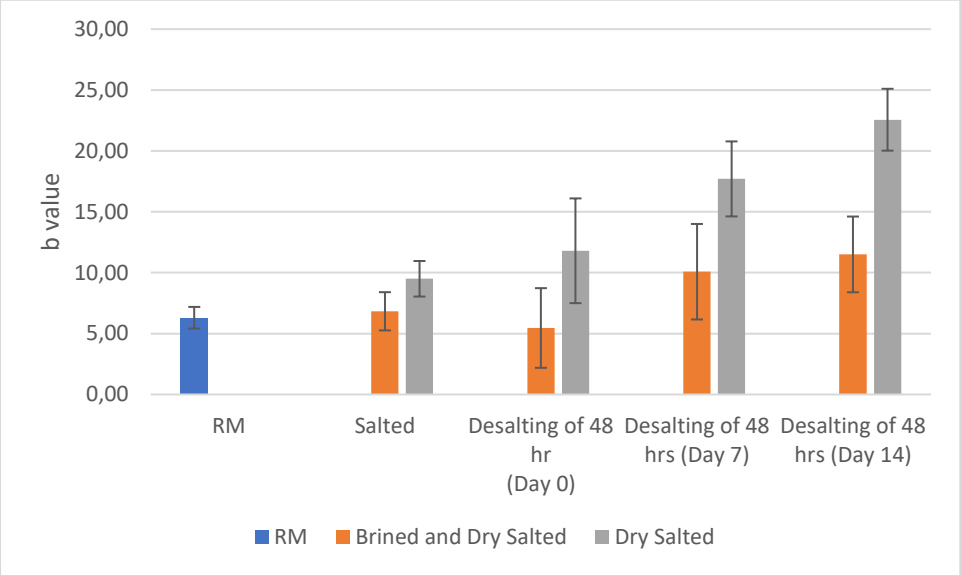

Figure 20. Changes of yellowness (b value) in mackerel fillets from Producer II during processing, and 2 weeks of storage at 13℃

4.7 pH

The pH values in all groups are shown in Figure 21 and Figure 22. The pH values in mackerel fillets from Producer I and Producer II are 6.44±0.031 and 6.23±0.11 respectively. The pH values from Producer I and Producer II decreased in brined salting, and there were 6.34±0.094 and 6.17± 0.06. The pH values from Producer I and Producer II in pre- brined dry salting are higher than the single dry salting. During dry salting, the decreased pH value between the pre-brined dry salting and single dry salting was significant different ($p<0.05$) in Producer-I. After desalting of 48 hrs, the pH values in all groups increased again. However, the pH values in mackerel fillet samples in all groups decreased gradually during the storage period.

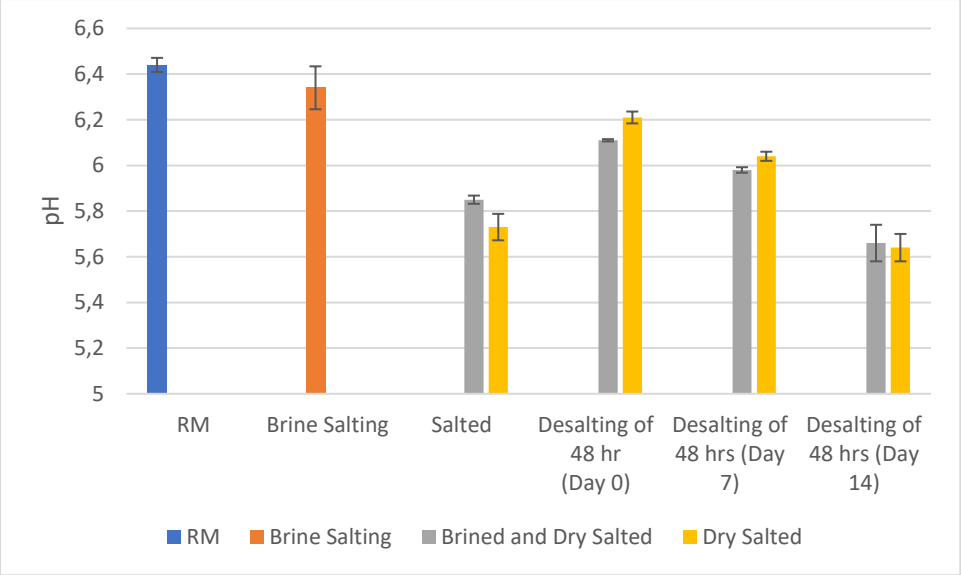

Figure 21. Changes of pH in mackerel fillets from Producer I during processing, and 2 weeks of storage at 13℃

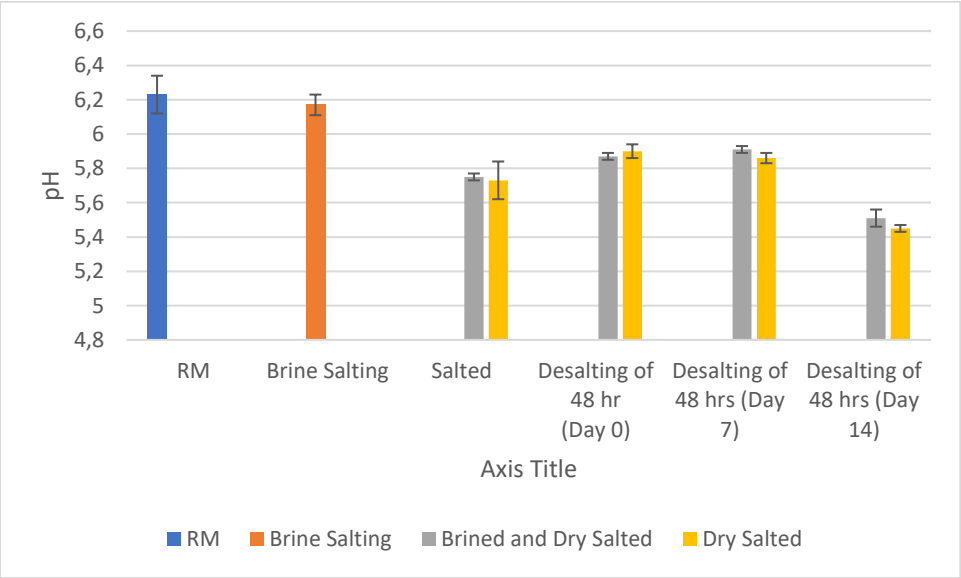

Figure 22. Changes of pH in mackerel fillets from Producer II during processing, and 2 weeks of storage at 13℃

4.8 Water activity

The water activity of raw mackerel fillets from Producer I and Producer II was 0.99 and 0.98 respectively (Figure 23). The water activity during pre- brined dry salting decreased to 0.746 and during single dry salting was 0.741 (Figure 24). The water activity in the pre-brined dry salting are higher than the single dry salting for both Producers. There was no significant difference ($p<0.05$) between these two groups. After desalting, the water activity increased again in all groups. The water activity of pre-brined dry salting and single dry salting after desalting increased to 0.959 and 0. 958 from Producer I and 0.961 and 0.958 from Producer II. At the end of storage, there are a little decreased in all groups.

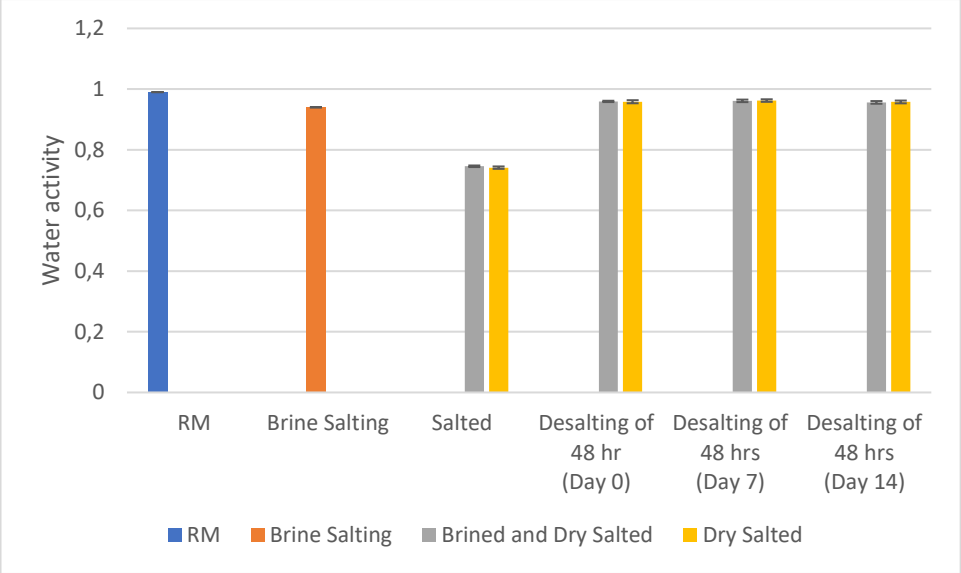

Figure 23. Changes of water activity in mackerel fillets from Producer I during processing, and 2 weeks of storage at 13℃

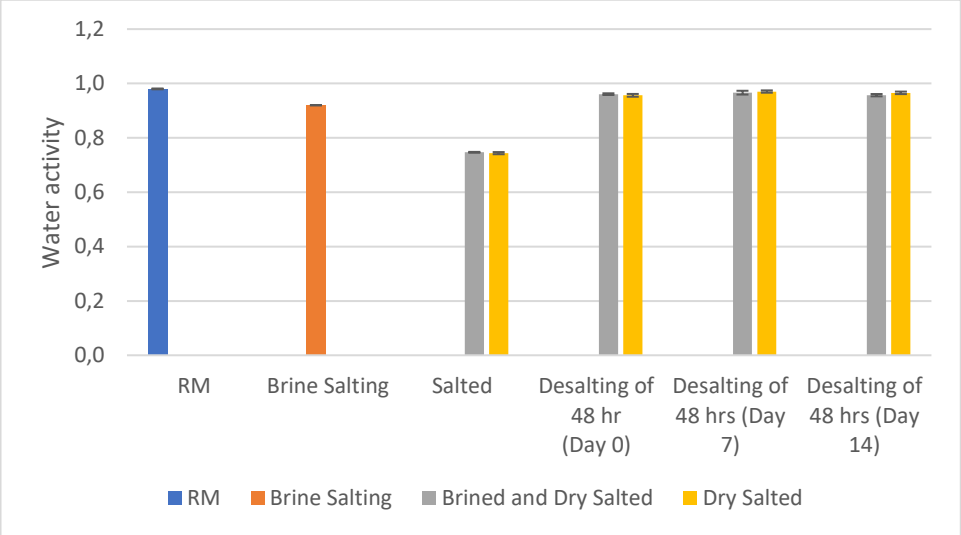

Figure 24. Changes of water activity in mackerel fillets from Producer II during processing, and 2 weeks of storage at 13℃

4.9 Lipid Content

The changes of lipid content in all groups are shown in Figure 25 and Figure 26. The lipid content in raw mackerel fillets from Producer I and Producer II were 26.42 and 26.86 respectively. The lipid content of brine salting was lower than the raw material from Producer I. There was not significant difference. The lipid content from both producers in pre-brined dry salting and desalting is higher than the single dry salting. But the lipid content in all groups gradually decreased during 2 weeks of storage.

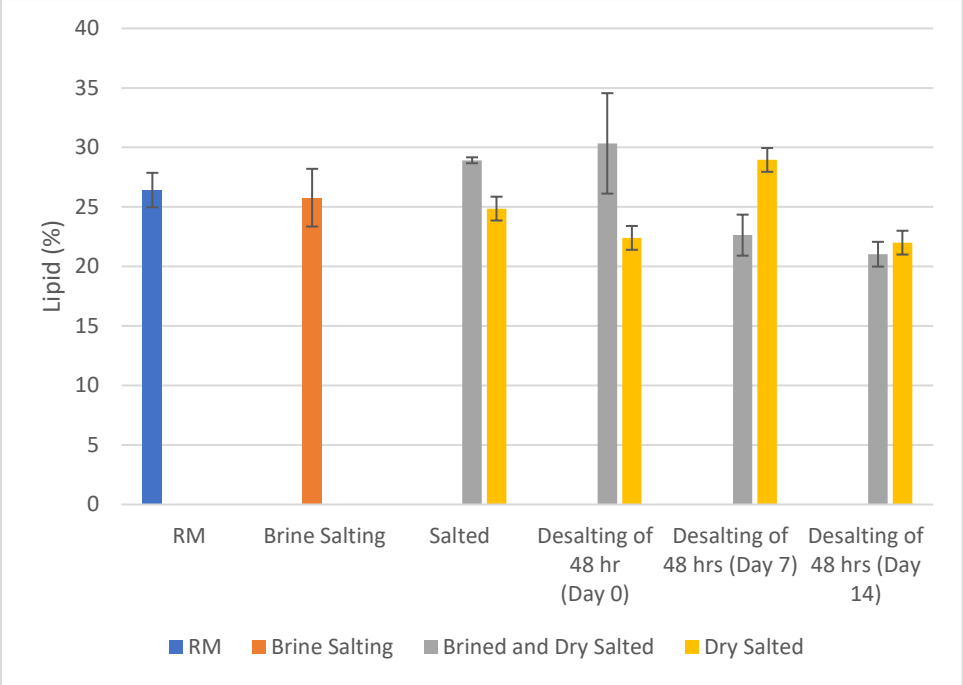

Figure 25. Changes of lipid content in mackerel fillets from Producer I during processing, and 2 weeks of storage at 13℃

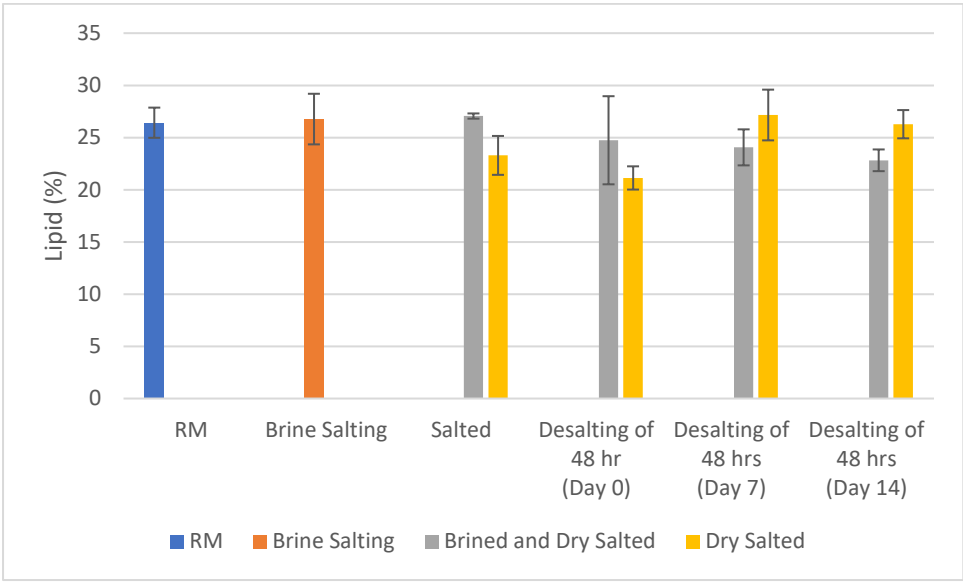

Figure 25. Changes of lipid content in mackerel fillets from Producer II during processing, and 2 weeks of storage at 13℃

4.10 Free Fatty Acid

The free fatty acid in raw mackerel fillets from Producer I and Producer II was 1.14 and 1.26 respectively. Results are shown in Figure 27 and Figure 28. The free fatty acids in mackerel fillets from Producer I and Producer II during pre-brined dry salting and desalting of 48 hours were higher than the single dry salting. The free fatty acid in pre-brined dry salting and single dry salting after desalting decreased 3.462 and 3.323 in

Producer I and 3.477 and 2.915 in Producer II. The free fatty acid in all groups increased gradually during storage.

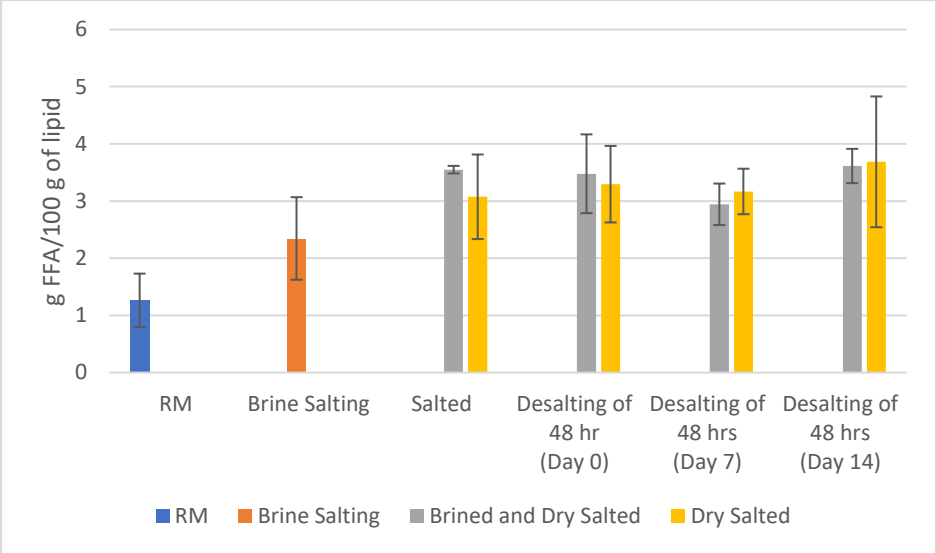

Figure 26. Changes of free fatty acid in mackerel fillets from Producer I during processing, and 2 weeks of storage at 13℃

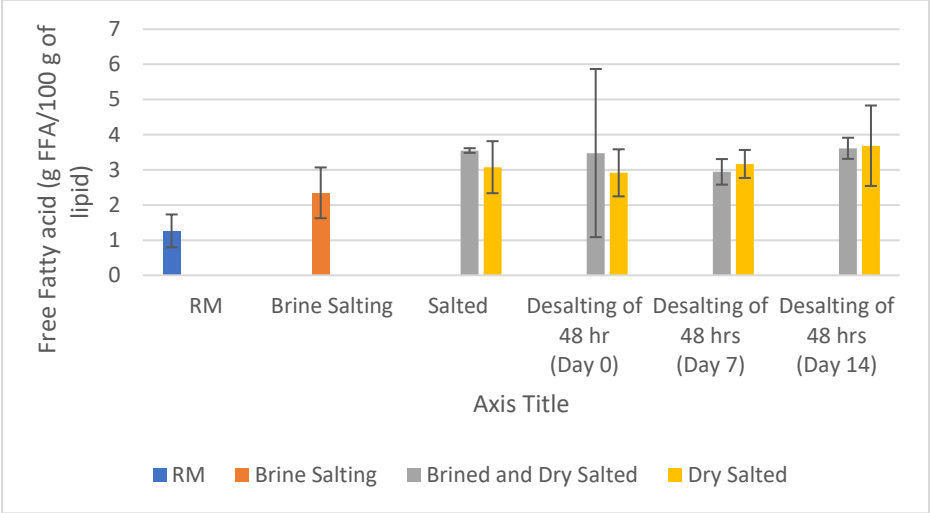

Figure 27. Changes of free fatty acid in mackerel fillets from Producer II during processing, and 2 weeks of storage at 13℃

4.11 Peroxide value (PV)

The peroxide value in mackerel fillets from Producer I and Producer II are shown in Figure 29 and Figure 30. The PV in raw mackerel fillets from Producer I and Producer II were 606.57 mM/kg and 412.166 mM/kg respectively. The PV increased in all groups in pre-brined dry salting and single dry salting. The PV in pre-brined dry salting are higher than the single dry salting for Producer I. There were significant difference ($p<0.05$) between group I and group II. After desalting, the PV values decreased in group I, II and III. At the end of storage, the PV gradually decreased in all groups.

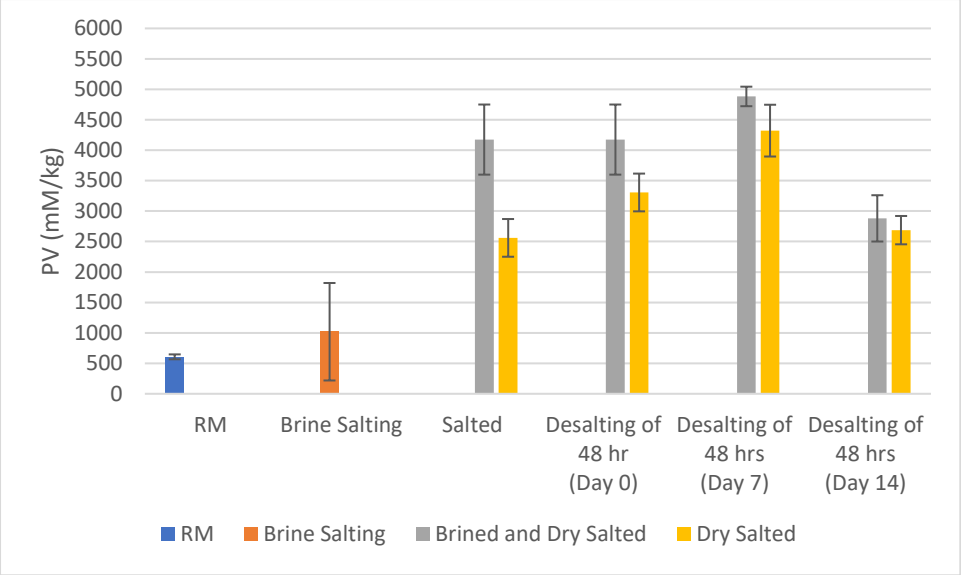

Figure 28. Changes of peroxide values in mackerel fillets from Producer I during processing, and 2 weeks of storage at 13℃

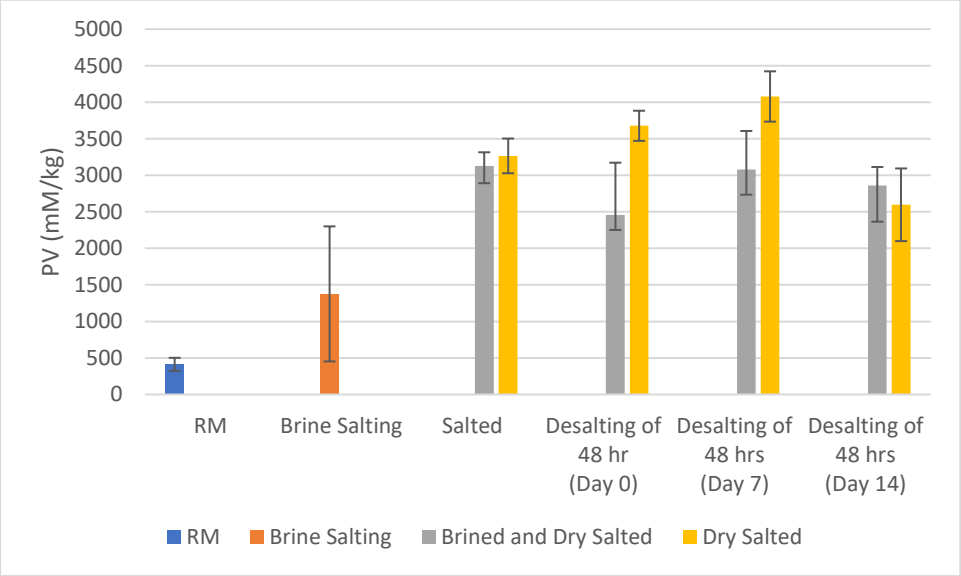

Figure 29. Changes of peroxide values in mackerel fillets from Producer II during processing, and 2 weeks of storage at 13℃

4.12 Thiobarbituric acid reactive substance (TBARS)

The effect of different salting methods on the changes of thiobarbituic acid (TBARS) in mackerel fillets from Producer I and Producer II are shown in Figure 31 and Figure 32. The TBARS values in raw mackerel fillets from Producer I and Producer II were 84.73 µmol/ kg and 38.53 µmol/kg respectively. After pre-brined dry salting and single dry salting, TBARs increased from Producer I and Producer II. TBARS in brined dry salting is lower than the single dry salting from Producer I. There was significant difference ($p<0.05$). After desalting, TBARS significantly decreased in all groups. During storage, it gradually increased in group I, group II and group IV.

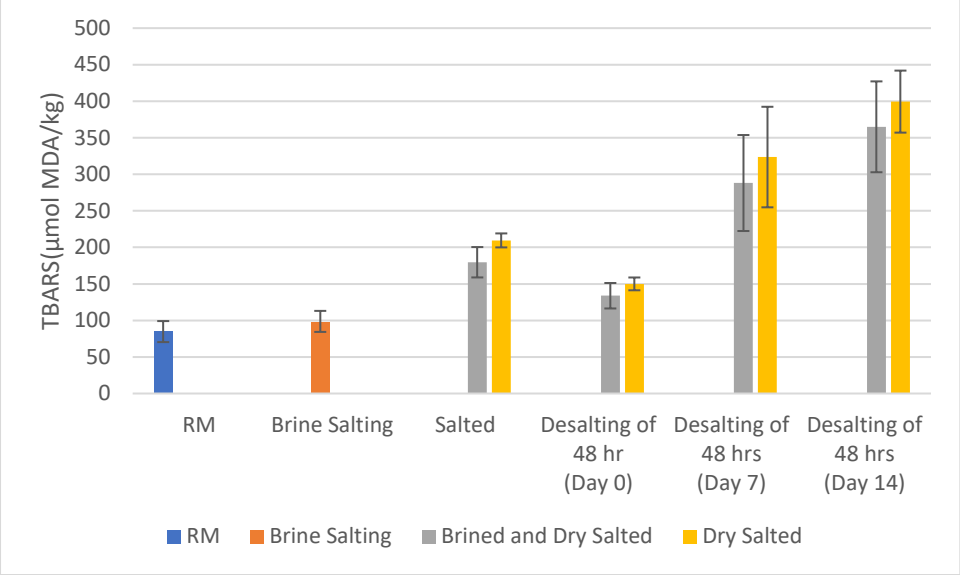

Figure 30. Changes of thiobarbituric acid (TBARS) in mackerel fillets from Producer I during processing, and 2 weeks of storage at 13°C

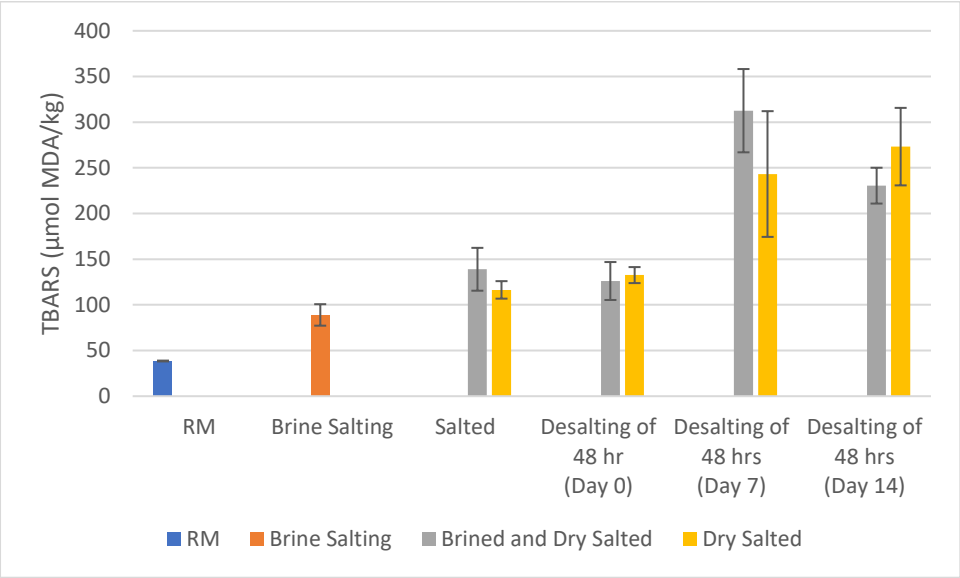

Figure 31. Changes of thiobarbituric acid (TBARS) in mackerel fillets from Producer II during processing, and 2 weeks of storage at 13°C

5 DISCUSSION

The yields in pre-brined dry salting were higher than the single dry salting which may be associated with loss of moisture content. The moisture content in the single dry salted mackerel, moisture contents were low compared to pre-brined dry salting. It was determined that the moisture loss in dry salting was higher compared to brine salting. Dry salting caused considerable moisture loss due to heavy uptake of salt (Martinez-Alvarez & Gomez-Guillen, 2005). The moisture content decreased in all groups during storage.

A positive significant correlation ($p<0.05$) between the water content and salt content is observed. The salt content in raw mackerel fillets from Producer I and Producer II were 18.65 ± 3% and 18.05±3% respectively. The salt content in the single dry salting was higher than pre-brined dry salting in all groups. In a study performed on salted tilapia (*Oreochromis niloticus*), the results showed that the salt content in dry salting is higher than in brined dry salting. During dry salting, there is a great difference in the concentration of salt between inside and outside of the fish muscle by salt covering directly and penetration effectively to the fish surface (Chaijan, 2011). The salt content in all groups decreased after desalting of 48 hrs.

The colour is very important for sensory attribution in the marketing. The changes of colour are related to the water content, pH, strong ionic force and phospholipids in the membrane of the fillets which are highly susceptible to oxidation as they contain high levels of polyunsaturated fatty acids. The reduction of water content may cause contraction of muscle surface by overlapping of actin and myosin filament and resulting the loss of transparency. The consequence is the increase of lightness (L value) (Lauritzsen, et al., 2004). The L values in all groups increased after desalting. The yellowness (b value) increased in single dry salting and desalting during storage, which agrees with (Hamre, Lie, & Sandnes, 2003). This may be due to salt uptake in single dry salting is higher than the pre-brined dry salting.

The pH value is used as an indicator of fish spoilage. The pH in fresh fish is near to the neutral. The increase in pH indicates the loss of quality (Latifa, Chakraborty, Begum, Nahid, & Farid, 2014). The increase of pH may be due to the distribution of oxidation-reduction balance by effect of enzyme or bacteria and changes in the concentration of free hydrogen and hydroxyl ions (Varlik, Uğur, Gökoğlu, & Gün, 1993). The pH of raw mackerel fillets from Producer I and Producer II were 6.44 and 6.23 respectively and there was significant difference ($p<0.05$) between the pre-brined dry salting and single dry salting for Producer I. After desalting, pH in pre-brined dry salting was lower than the single dry salting and there was significant difference ($p<0.05$). However, the lowering of pH of salted fish was found in all groups during storage. The pH decreased with the increasing salt content and decreasing water content in pre-brined dry salting and single dry salting.

The water activity in mackerel fillets decreased to 0.741 and 0.746 in group I and II and 0.743 and 0.746 in group III and IV during salting. Therefore, the water activity in pre-brined dry salting are higher than the single dry salting and there was significant difference ($p<0.05$). This may be due to the decrease of salt content and increase of water content. The result is similar with the result by Chaijan (2011). After desalting, the water activity in all groups increased, which was 0.96. During storage, there was a little change in water activity in all groups.

The lipid values in raw mackerel fillets from Producer I and Producer II were 26.42 and 26.86 respectively. The lipid content in mackerel fillets during brine salting gradually decreased in all groups. The lipid content in the pre-brined dry salting are higher than the single dry salting and there was a significant difference ($p<0.05$) between these two groups for both Producer II. During storage, lipid content in single dry salting is higher than the

pre-brined dry salting. This may be due to draining of water and removal of fat. Hydrolytic rancidity produces the free fatty acid. Therefore, the free fatty acid in pre-brined dry salting are higher than the single dry salting for Producer-I, and there was not significant difference. The FFA decreased after desalting and increased during storage in all groups.

The peroxide values and thiobarbituric acid is used as a measurement for lipid oxidation. The PV in pre-brined dry salting resulted in a higher oxidation than the single dry salting and there was significant difference ($p<0.05$) for Producer I and the PV value in single dry salting is higher than the pre-brined dry salting for Producer II. This is probably due to more restriction of oxygen access by immersion in single dry salting (Horner, 1997). At the end of storage, PV decrease in all groups. This may be due to the decomposition of hydroperoxide as described by Chaijan (2006) (Chaijan, Benjakul, Visessanguan, & Faustam, 2006). The increase of TBARS indicate the formation of secondary lipid oxidation products. The increased salt content may induce the lipid oxidation as the salt have the prooxidative activity (Kanner, Harel, & Jaffe, 1991). The TBARs value in single dry salting is higher than the pre-brine dry salting for Producer I. This may be due to the increase of salt content and loss of natural antioxidant during the salting. After desalting, the TBARS value decreased in all groups. The TBARS in all groups increased gradually during storage.

6 CONCLUSION

From this study, it can be concluded that:

- The changes physical and chemical properties of heavily salted mackerel depend on different salting procedures.
- The yield and the quality of salted mackerel fillets in Producer I were higher than Producer II in both treated with dry salting and pre-brined dry salting.
- The processing yield is a very important in the economic point and the result showed that pre-brine dry salting more improve than the single dry salting.
- Dry salting resulted in higher salt uptake associated with a decrease in water activity and it seemed to enhance the oxidation and hydrolysis of lipid more than the wet salting during storage.
- Single salted method increases yellowness in fish fillets.
- No clear effect of the different salting methods was observed on the lipid oxidation during processing was observed.
- Atlantic mackerel is a fish with high fat content, and using a fish with a lower fat value would give better results in different salting process.

7 ACKNOWLEDGEMENTS

I would like to give special thanks especially to Dr.Tumi Tomasson, Progamme Director of UNU-FTP for granting me as a fellowship in the United Nations University-Fisheries Training Programme in 2017. I would also like to thank to Mr. Thor Heidar Asgeirsson, Deputy Director of the programme, Mrs. Mary Frances Davidson, Mrs. Julie Ingham and Mr. Stefan Ulfarsson for their valuable advice, assistance, care and encouragement enabling me to complete this programme sucessfully.

I am grateful to my supervisors, Dr. Magnea G. Karlsdóttir, Sigurjón Arason and Hildur Inga Sveinsdóttir for their valuable guidance and technical advice in accomplishing this study. I would like to thanks to staff from Matis for giving me the opportunity to use the equipment in the Laboratory. My sincere thanks to Hildur Inga Sveinsdottir for lending her assistance during the experimental period.

Finally, I would like to thanks to my UNU-FTP fellows in 2017, especially the Quality Management group for their kind help and their willingness to share their knowledge and experience.

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