EFFECT OF RAW MATERIAL HANDLING ON SURIMI QUALITY

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ABSTRACT

This study investigates potential improvements which may benefit production of surimi products in developing countries. The study examines the quality of conventional surimi made with different times and temperatures from raw material of Saithe (*Pollachius virens*). Four experimental groups were tested: fresh fish, on ice fish, no ice fish, and extreme temperature fish. Each group was stored over time. At intervals of 0 days, 2 days, 4 days, and 7 days, evaluations were made by testing water content, gel strength, folding, colour. The results were compared to the different times and different storage condition of conventional surimi for quality.

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1 INTRODUCTION

1.1 Background

In Myanmar, the fisheries sector is one of the most important sectors fulfilling the protein requirement of the people, providing food security as well as providing employment to many fishing communities and rural areas. Myanmar is endowed with rich natural resources both in freshwater and marine fisheries (Fisheries, 2018). Surimi is made from marine fisheries resources in Myanmar. Surimi has become one of the main commodities in the Asian seafood industry because of recent innovations in production and utilisation.

Surimi production started in 2004-2005 in Myanmar and today there are three plants producing and processing surimi in Myanmar. The surimi produced from Myanmar is primarily exported to Japan (80%), with 18% exported to China and another 2% to Australia, Singapore, Taiwan (Pangsorn, Laong- Mance, & Siriraksophan, 2007). However, according to a report by the Department of Fisheries in 2018, surimi production in Myanmar has dropped drastically since 2013. In 2013-2014 and 2017-2018, total exported surimi produced in Myanmar was respectively 2,820 MT and 1,664 MT. Threadfin bream (*Nemipterus japonicas*) is the most common species used to produce surimi. Threadfin bream is a benthic species abundant in coastal waters found on mud or sand bottoms between 5 to 80 m depth, usually in juvenile schools abundant at 27 m depth. It mainly feeds on small fishes, crustaceans, mollusks, polychaetas and echinoderms (Tun, 2001).

1.2 Properties of Surimi

Surimi is a concentrated myofibrillar protein obtained by successive washing of minced fish in which sarcoplasmic proteins and undesirable substances such as fat, blood, pigment and odorous substances are removed (Eymard, et al., 2005). A successful method currently being used to refine fish muscle proteins is surimi and fish protein isolate (FPI) (Park, Graves, & Yongsawatdigul, 2014). Proteins can be divided into three major groups based on their solubility. There are sarcoplasmic proteins (water- soluble), myofibrillar proteins (salt- soluble), and stromal proteins (insoluble). Myofibrillar proteins play the most critical role during processing and are responsible for functional properties such as gel forming ability (Moosavi-Nasab, 2003).

Surimi is a useful ingredient for producing various kinds of processed foods with unique textural properties (Zhou X. , et al., 2017). During the production of surimi, both chemical and physical

denaturation of proteins must be avoided to obtain good quality surimi (Park, Graves, & Yongsawatdigul, 2014). The production of frozen surimi has been growing due to an increase in consumer demand in Asian markets. However, freezing of surimi causes denaturation and aggregation which may result in a loss of functional properties (Bueno, et al., 2013; Leygonie, Britz, & Hoffman, 2012; Shenouda, 1980).

The quality of surimi produced in Myanmar has been a major concern as the product is graded B by the countries that import it and in turn receives a low economic value. Major problems identified have been the poor handling of fish from the landing sites and the poor storage conditions in transporting the fish to the processing sites which affect the overall quality of the surimi after preparation. Grading of surimi are SSA; > 1000, SA; 700-1000, AA; 500-700, A;300-500; B;< 300 respectively, according to the Standard Test Method for Surimi Quality published by the Japanese Surimi Association.

Therefore, the need to study the effect of different temperature storage on fish samples used in surimi production and the effect of quality control is high. There is also a need to explore value-added products to improve economic returns for Myanmar producers. For this study, saithe (*Pollachinus virens*) was used because it is the species available in Iceland that is closest to Threadfin bream in Myanmar. Threadfin bream is a lean fish with water, lipid and protein content of about 77 %, 2.10 % and 18.4 %, respectively. Saithe, like threadfin bream, is a lean species with about 81 %, 0.3-0.6 % and 16.4-20.3 %, water, fat and protein content (FAO, 2004).

The objective of this study is to gain knowledge of the quality of surimi from different raw material during the storage time such as fresh and frozen fish fillet, fillet kept on ice, fillet kept without ice and fillet kept at extreme temperature (above 4 ^{o} C). Gelation properties of saithe surimi were showed by the gel strength, colour and folding test analyses.

1.3 Goal

This work is needed to study the effect of raw material handling on surimi quality to better support the quality of surimi in Myanmar which is exported to neighboring countries.

1.3.1 Objectives

a) To assess the process of making surimi from saithe of different quality.
b) To determine the physicochemical properties of the surimi processed from different raw material.

2 LITERATURE REVIEW

2.1 Saithe (*Pollachius virens*)

Saithe (*Pollachius virens*) occasionally reaches a length of 120 cm, most of the adult fish caught are from 60 to 90 cm long. Fish weighing up to 7 kg are quite common and occasionally fish weighing 10 kg or more are caught. Saithe spawns offshore in 100-200 m of water to the north-west of Britain, in the Northern North Sea, off Norway, Faroes and South Iceland. Saithe grows about 15 cm a year for the first three years, and about 10 cm a year for the next three, reaching a length of 100 cm when it is 10-11 years old. The flesh is darker and less attractive than that of related species like cod. While Saithe is a suitable table fish, it does not receive as high a price on the markets as cod and similar whitefish. This is often attributed to the darker and less desirable colour of the flesh. Saithe has traditionally been regarded as an inferior fish, its price at the ports has remained low *(FAO, 2001)*.

2.2 Surimi

The consumption and popularity of seafoods has increased and it is recognised as an important source of nutrients for human health. Seafoods have unique characteristics that differentiate them from land animals in term of protein, lipids and bioactive components (Shahidi, 1997). The main chemical components of fish meat are water, crude protein, and lipids, which together make up about 98% of the total mass of the flesh. These components have substantial impact on the nutritional value, functional properties, sensory quality, and storage stability of the meat. The nutritional value of fish protein is relatively high because of the favorable essential amino acid pattern (Sikorski, Kolakowska, & Burt, 1990a).

Surimi is derived from a traditional Japanese way of using and preserving fresh fish. The word is derived from the Japanese words ‘suru’ meaning to process and, ‘mash/mi’ meaning to meat. Surimi is a paste of minced, processed fish used in the preparation of imitation seafood. The earliest recorded surimi processing procedure was found in a Japanese cookbook written in 1528. Surimi fish paste products have been made by hand for centuries. A freezing process for surimi was invented in 1960, which allowed the markets to expand. The expansion was based mainly on vast resources of the Alaska pollock (Benoil Vidal- Giraud & Denis, 2007). The pollock fisheries for surimi began in the mid-1960s after Japanese scientists discovered the function of cryoprotectants in preserving protein functionality for frozen, washed fish mince in 1960.

In Japanese, the word surimi refers to a fish product made from inexpensive whitefish and often processed to resemble more expensive seafood (such as crab meat). People may not have heard of surimi before, but they may know it under its most popular name 'imitation' seafood. This is a misnomer, as surimi is not imitation seafood but an actual seafood (Breslouer, 2017).

Surimi is one of the options used to create value-added seafood products from minced fish. Minced fish is washed to remove water soluble proteins, then mixed with cryoprotectants to extend its frozen shelf life. It has a relatively long shelf life, which has made rapid expansion of the industry possible. It is a functional protein ingredient with good nutritional quality (Lee C. M., 1986).

Surimi is an inexpensive source of protein. Surimi is a useful ingredient for producing various kinds of processed foods due to the unique gelling properties of the myofibrillar protein. Surimi can be used to produce various kind of seafood products such as fish balls, fish sausages, breaded fish sticks and fish slices, which have become increasingly popular due to the high nutritional value of surimi (Luruena-Martinez, Vivar-Quintana, & Revilla, 2004) (Figure 1). Normally, surimi is produced from Alaska pollock. Some surimi employers changed their material from Alaskan pollock to lower priced Asian surimi. In 2014 and 2015, global surimi production was estimated at 800 000 ton (FAO, 2016). Surimi can easily be mass produced, and there is a constant supply of raw materials for its production due to the abundance of under-utilised fish species.

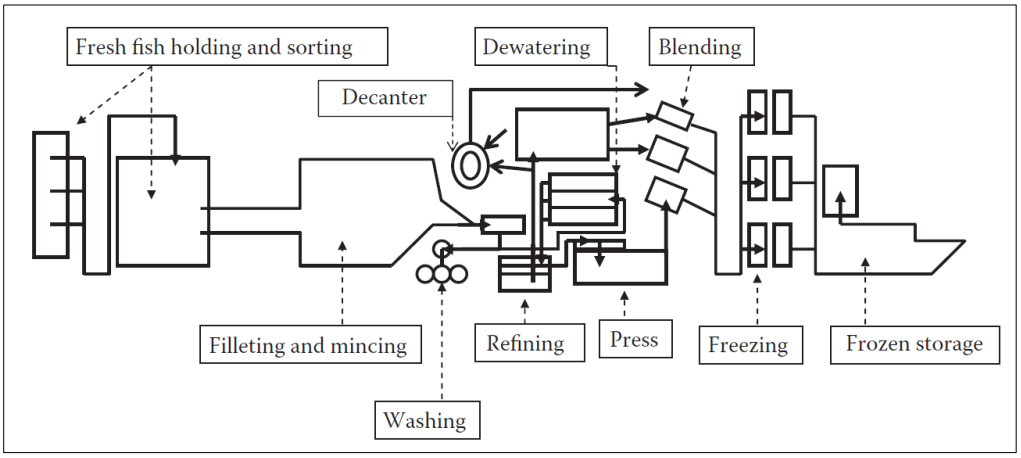


Figure 1. Flow chart of surimi manufacturing

Source: (Park J. W., Graves, Draves, & Yongsawatdigul, 2014)

2.3 Surimi physiochemical properties

Myofibrillar protein is the primary functional ingredient of surimi-based products and is very important for the gelling properties of surimi (Kong, et al., 2016). Lipids can have a negative effect on surimi gel properties and may be related to changes in surimi protein structure (Shao, Zou, Xu, Wu, & Zhou, 2011). Surimi is produced by solubilising myofibrillar proteins during the comminuting and salting stages of manufacturing (Kong, et al., 2016).

Physicochemical properties including morphology, pasting properties, and gel properties are important criteria to evaluate the quality of surimi (Luruena-Martinez, Vivar-Quintana, & Revilla, 2004). Gelation is an important step in forming desired texture for surimi-based products (Sun & Holly, 2011). Myosin and actomyosin are the main components responsible for gelation and is the most important functional property of surimi (Paker & Matak, 2015).

In the process of frozen surimi manufacturing, fish fat is usually trimmed away to increase the concentration of myofibrillar protein and to extend the storage time. To improve the physicochemical and gel properties of surimi, exogenous lipids are usually added during surimi product processing (Chojnicka, Sala, De Kruif, & Van de Velde, 2009). In 1960, all surimi used in the Japanese kamaboko industry was fresh surimi. There was no available method to control freeze denaturing until the discovery of cryoprotectants (Okada, 1990). To inhibit the negative changes during icing, freezing and frozen storage, cryoprotectant such as sorbitol, sucrose and polyphosphates, are now typically added to ensure maximum protein quality of surimi (Etemadian Y. B., 2011).

Myofibrillar protein is the main factor affecting meat quality deterioration during frozen storage (Zayas, 1997). If myofibrillar proteins in surimi denature, it will have an impact on the quality of surimi-based products produced. The denaturation of myosin can lead to a decrease in surimi gel-forming ability (Pan, Shen, & Luo, 2010). During surimi processing, solubilisation of myofibrillar protein occurs during the washing process and this is an important step to ensure maximum gelling as well as colourless and odourless surimi. Minced fish meat contains approximately two thirds myofibrillar proteins. The remaining one third consists of blood, myoglobin, fat and sarcoplasmic proteins (Lin, Park, & Morrissey, 1995). Surimi containes myosin heavy chain (MHC) and actin as the major proteins (Singh & Benjakul, 2017).

Gel-forming ability of surimi is the most important functional requirement of good quality surimi-based products. The gel formation of surimi by heating at low temperature is called setting (suwari)

that plays a major role in strengthening surimi gel (Saeki, Iseva, & Seki, 1995). But some of the surimi from poor quality material may be the weak gel with low acceptability (Singh & Benjakul, 2017). The properties of surimi gel depend not only on their properties but also on their degree of denaturation. The gelation process begins with the denaturation of myosin, which consists of a myosin heavy chain (MHC) and light meromyosin (LMM) (Nunez-Flores, Cando, Borderias, & Moreno, 2018).

The functional property of fish is also dependent on its composition, and the fish composition is a factor that affects surimi quality. Compositional properties of fish vary as the fishing season changes (Anchorage, 1992). Generally, fish harvested during the feeding period produce the highest quality surimi. During this period, fish muscle has the lowest moisture content and pH, as well as the highest total protein. Therefore, fish harvested during and after the spawning season produce the lowest-quality surimi (Anonymous, 1984). Also, surimi quality is affected by the harvesting conditions. Several factors in the actual capture of fish can also affect final product quality.

During the production of surimi, both chemical and physical denaturation of proteins must be avoided to obtain good quality surimi (Park, Graves, & Yongsawatdigul, 2014). The freshness of fish is the most important quality parameter and primarily depends on time and temperature during processing. Denaturation of protein developed during rigor mortis.

In surimi processing, water to mince ration, washing time and washing cycle are the basic stages in the creation of surimi, which determine the quality by removing fat and undesirable substances. A large amount of water is used in washing the mince fillet with chilled water in surimi production to remove the sarcoplasmic proteins, blood, pigments, fat, and other nitrogenous compounds and finally increase the concentration of myofibrillar protein (Paker & Matak, 2015). Texture, colour and odour of the final product improve significantly when the impurities are removed by washing. The number of required wash cycles depends on species, condition, type of wash, and the desired quality of the surimi end product (Carvajal, Lanier, & Donald, 2005).

Time and temperature of the fish between capture and processing can be considered as two of the most important factors that affects surimi quality. Earlier research has reported that the functional properties of surimi quality can be affected by different species and quality of raw material during storage time. The length of time that fish can be held on ice or refrigeration, before processing, varies depending on the species (Ablett, Bligh, & Spencer, 1991).

Factory trawlers have the advantage of processing at sea and usually produce a final product within 12 hrs. In Myanmar, after the fish is caught, arrival time at the plant is always between 3-4 days after which the surimi is prepared.

2.4 Surimi Gelation Properties

The surimi production process usually involves frozen surimi being thawed well and then chopped, then followed by addition of salt and water and mixing into a paste. Addition of salt (usually sodium chloride) during the gelation process is done to break ionic linkages and assist in dispersion of the proteins. Salt plays an important role for the development of an elastic structure in the heat-set gel (Niwa, 1992). Myosin and actin are soluble in mild salt (NaCl) solution (1–8%) but are largely insoluble in water of lower ionic strength (~0.05 to ~0.5%). In preparing the meat for gel formation by cooking, salt is added to enhance the solubility and thus aid dispersion of the proteins (Sato & Tsuchiya, 1992). Gelation of protein is an important step in forming the desired texture. During the heating treatment, the formation of the protein network especially sarcoplasmic proteins, is accelerated via covalent interactions and non-covalent bonds such as hydrogen bonds, electrostatic interaction, and hydrophobic interactions (Totosaus, Montejano, Salazar, & Guerrero, 2002).

Different gel textures of surimi product can be divided into two categories, which are achieved through different cooking processes. One is direct heated gels, which are produced by heating the surimi at high temperature, and form a less hard texture. The other category is two-step heated gels, which are produced by heating the surimi at a temperature below 40 ^{o}C (suwari heating), changing its rheological properties from sol to gel. After heating at high temperature following suwari heating, the surimi shows high gel strength due to the formation of a strong gel network structure (Okazaki & Kimura , 2014). This gelation and textural strengthening of salted surimi paste at low temperature is termed “setting” (Lanier, 1986). During this two-step heated gel process, water can be easily held in such strong network, resulting in higher water holding capacity than direct heated gels (Kimura, et al., 1991). In the manufacture of Japanese traditional kamaboko (Itatsuke kamaboko), suwari heating is typically conducted commercially at temperatures ranging between 30 ^{o}C and 35 ^{o}C (Jia, et al., 2019).

Surimi gel is a three-dimensional myofibrillar protein network in which water and other components are trapped. In general, surimi moisture content ranges between 72% and 76% after mixing with cryoprotectants and plays as a key role in gelation (Park & Lin , 2005). As a result, a viscoelastic gel is obtained (Sanchez-Gonzales, et al., 2008). The gel properties can be affected by various physical conditions during gelation (Shitole, Balange, & Gangan, 2014). The quality of surimi gel and price of surimi products are evaluated by the texture formed by heat-induced gelation of myofibrillar proteins as well as appearance and flavors (Zhou X. , et al., 2017).

Colour is another important characteristic of surimi seafood. The three-colour hue values commonly measured in the surimi and surimi seafood industry are CIE L*, a*, and b*. In this space, L* indicates lightness, while a* and b* are the colour coordinates. a* is the red/green axis ("+" being toward the red and "–" being toward the green). Similarly, b* is the yellow/blue axis ("+" being toward the yellow and "–" being toward the blue). Colour quality is often determined by whiteness. Two different indices are used to ascertain whiteness. Whiteness II uses all components of the colouring fraction, while Whiteness I, uses L* and b*, but does not use a*. The a* values of pollock and whiting gels were consistent regardless of cooking/setting conditions, moisture contents, sample size, or frozen storage (Park J. W., 1995).

$$Whiteness = L - 3b$$

$$Whiteness = 100 - \sqrt{(100 - L)^2 + a^2 + b^2}$$

3 MATERIAL AND METHOD

3.1 Material

Saithe (*Pollachius virens*) fillet fish was collected from a local processing plant in Reykjavik, Iceland. Surimi was prepared from four different groups of raw material condition (Figure 2). As a starting point, for all groups surimi was made directly on arrival of the fresh fillet. The first group was stored on ice in a cold room, group two was also kept in a cooler room but with no ice. The third group was kept in a cooler at 7°C (extreme) and finally the fourth group was kept in freezer and frozen at -18°C until used for surimi preparation.

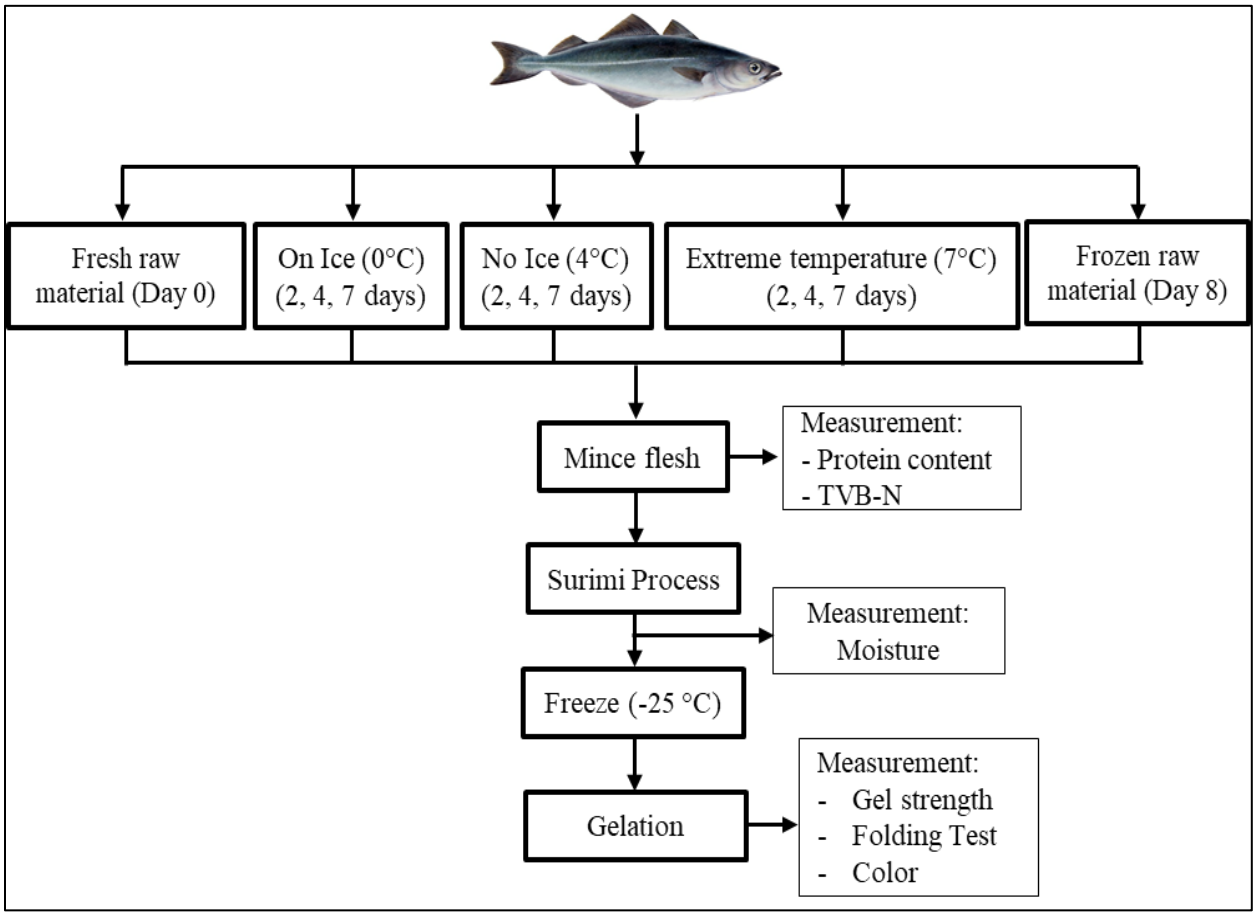


Figure 2. Experimental design: Different times and storage conditions of saith fillets prior to surimi preparation used in the project, sampling and measurements.

3.2 Surimi production

Traditional method of surimi production technique was preferred for the production according to the method of (Chaijan, M; Benjakul, S; Visessanguan W & Faustam, C;, 2004) with slight modifications. Firstly, the bones were manually removed with a sharp knife, and the filleted fish samples were cut into small pieces and minced to uniformity using a meat grinder. Minced flesh was washed with cold water (4 °C) using a water/mince ratio of 3:1 (v/w). The mixture was stirred gently for 10 min in a cold room (5°C) and the washed mince was filtered with a layer of nylon screen. The process of washing and dewatering was repeated two times and during the second washing, 0.5% salt was added to the water and stirred as above. The washed mince was filtered with a layer of nylon screen and later squeezed using a cheese cloth. To the squeezed mince, cryoprotectant (4% sucrose, 0.3 % phosphate and 4% sorbitol) were added, mixed well with a mixer (Stephan UMC 5 electronic mixer), and frozen at -25° C overnight using the Matis quick freezer. Samples were kept in freezer at -25°C until used (Figure 3).

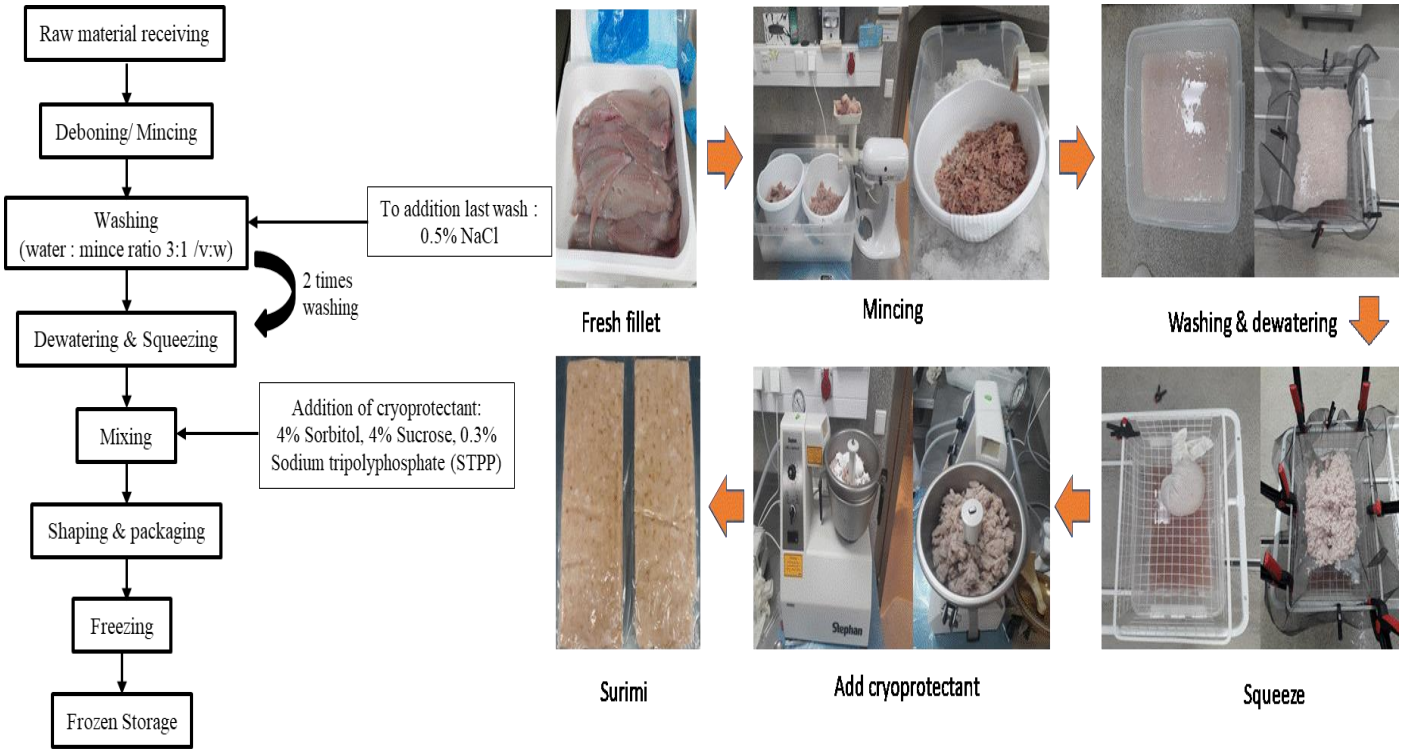


Figure 3. Flow diagram of surimi processing and the process in pictures.

3.3 Surimi Gels Preparation

Frozen surimi was thawed at room temperature (22°C to 23°C) for 3 to 4 hours. After thawing surimi samples were transferred into the Stephan mixer, mixed gently and 3% salt was added. It was then slightly mixed for 3 min at high-speed grinding setting, and the vacuum pump attached to the Stephan mixer. The mixer was put for an additional few minutes under bar pressure to remove air bubbles in the surimi. The homogenous surimi sol was stuffed into cylindrical metal tube (30mm in diameter and approximately 20 cm in length) and at least two sausages of each type of surimi was made. The tubes closed at both ends and cooked for 30 minutes in water bath at 90°C with or without prior setting for 2 hours at room temperature. Upon cooking, the samples were immediately cooled on ice and then kept overnight in fridge before evaluation (Figure 4).

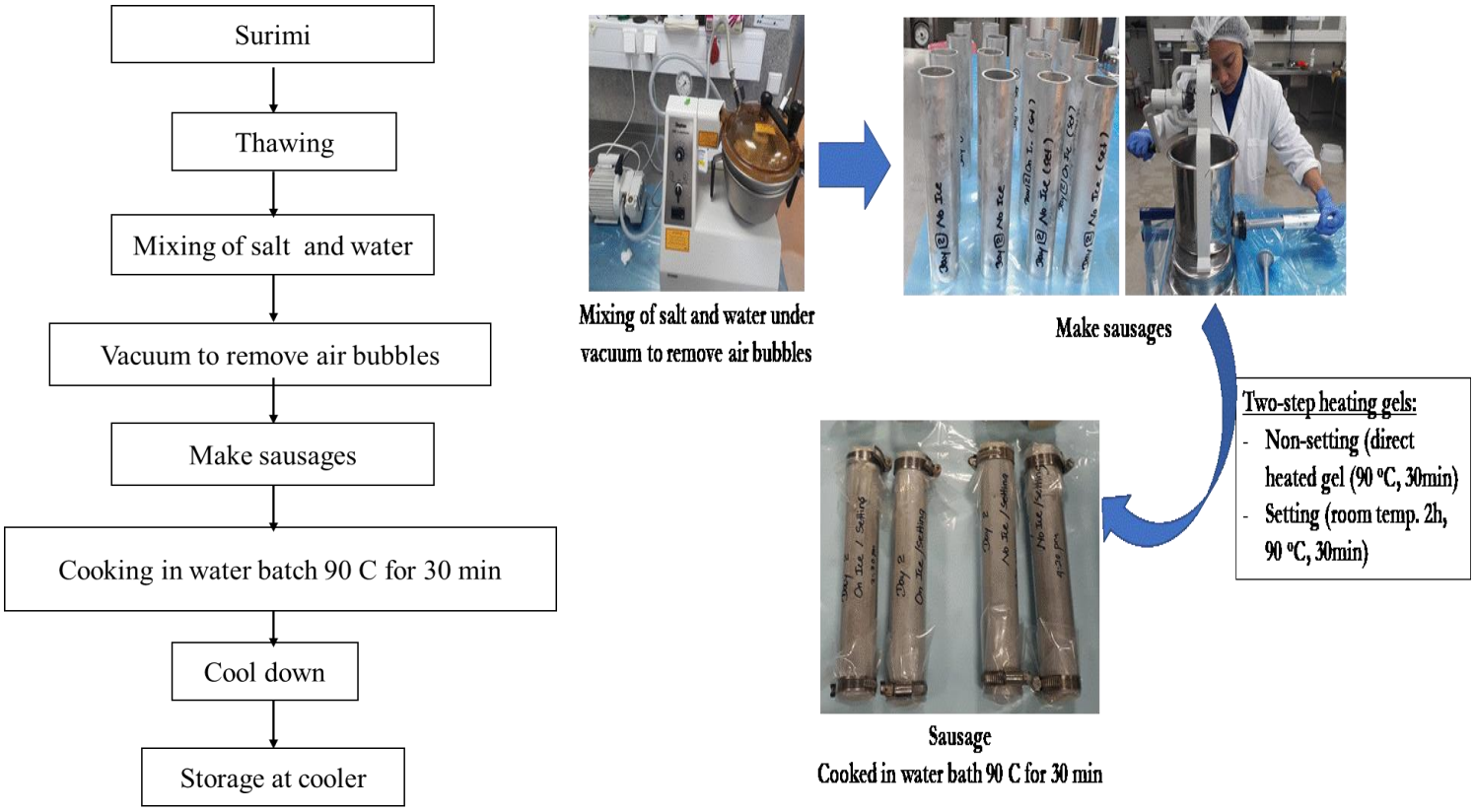


Figure 4. Flow diagram of gelation process and the process in pictures.

3.3.1 Protein content and TVB-N analysis

The moisture content, crude protein content and TVB-N analysis were determined for saithe mince flesh. Crude protein of mince flesh was determined by Kjeldhal and expressed as g/100g (dry and wet weight basis (AOAC, 1995). The measurement of total volatile basic nitrogen (TVB-N, mg/100g) of saithe mince flesh was performed according to the method described by Etemadian, et al., (2011).

3.3.2 Water Content

An appropriate portion (2 to 5 g) of the fresh surimi samples from each group was taken after squeezing and before freezing. Water content measured using oven method (GALLENKAMP, Hot box Oven with fan) at 105°C until a constant weight was reached. The moisture content values were calculated. The result unit are %.

$$\text{Water content (\%)} = \frac{weight\ before\ drying\ (g) - weight\ after\ drying\ (g)}{weight\ before\ drying\ (g)}\ x\ 100$$

3.3.3 Determination of Colour

The saithe surimi gels were sliced with a knife into ~25 mm thickness and colour properties were measured by placing samples on top of the Minolta CR-300 chromameter. L*, a* and b* measurements of the samples was recorded and calculated. The L* variable represents lightness (L= 0 for black and L= 100 for white). The magnitude of a* and b* both vary between -300 and 299, which the variable represents the red/ green dimension (a > 0 for red and a < 0 for green) and the b* variable represents the yellow/ blue dimension (b > 0 for yellow and b < 0 for blue). Whiteness of saithe surimi gels were calculated by the following equation (Tahergorabi, Beamer, Matak, & Jacynski, 2012).

$$Whiteness = L - 3b$$

$$Whiteness = 100 - \sqrt{(100 - L)^2 + a^2 + b^2}$$

3.3.4 Determination of Gel-Forming Ability

Saithe surimi gels were kept for 3 hours at room temperature prior to evaluation. A texture analyser with a plunger diameter of 1 cm (Probe 0.5S) and 0.5 mm (Probe 0.25S) (Stable Micro Systems, Surrey, UK) was used. About 25mm of the surimi sample was placed so that the centre was directly

under the plunger of the texture analyser. The penetration force in g and the deformation in mm at breakage was measured for each different day.

Gel strength (g * cm) = Force (g) * deformation (cm)

3.3.5 Folding test

Surimi samples of 1 – 2 mm were cut and folded into half and possibly into another half. The folded surimi was held for five seconds and signs of structural failure was monitored and changes in shape were graded on a five-stage merit mark. Evaluation was performed at six slices per sample. Five grade system as follows (Table 1).

Table 1. Folding Test Score

Score	Characteristics
5	No crack occurs even if folded in four
4	No crack occurs if folded in two, but a crack occurs if folded in four
3	No crack occurs if folded in two, but splits if folded in four
2	Cracks if folded in two
1	Split into two if folded in two

According to Jae W. Park (Surimi and Surimi Seafood).

3.4 Statistical Analysis

Analysis were done in triplicate (n=3) and results expressed as mean ±SD. It was not possible to run further statistical analysis on the results due to lack of time, but SD was used to indicate possible significant difference.

4 RESULTS AND DISCUSSION

4.1 The effect of different raw material storage time and temperature on saithe surimi

4.1.1 Assessment of raw materials properties

Prior to observation of the effect of condition and storage time of raw material on surimi, TVB-N and protein content values of mince from saithe fillets were measured (Table 2). Batch 1 and Batch 2, the contents of TVB-N increased day by day. Day 7 extreme temperature gave highest TVB-N value. Frozen fish TVB-N content was lower than unfrozen samples from day 4 to day 7. Some fluctuations were found in protein content of the raw material where highest protein content was found in the frozen fish (Batch 1) and lowest in samples from day 4 in Batch 2. Most probably this was due to different moisture in the fish (see 4.1.2).

The shelf life of fish is defined by the level of TVB-N. According to European Union regulations (1995) the freshness limit is 25-35 mg N/100g. Comparing to this standard, only the saithe kept on ice was acceptable for consumption after 7 days (**Error! Reference source not found.**). It is apparent from the TVB-N value that the raw material for batch 2 was not as fresh as batch 1.

Table 2. TVB-N and protein content of saith after different storage times (Batch 1 and Batch 2).

Batch 1	TVB-N [mg N/ 100g]	Protein %
Fresh Fish (day 0)	11.8	18.50
On ice (day 4)	21.2	-
No ice (day 4)	31.1	-
On ice (day 7)	31.4	18.8
No ice (day 7)	66.5	19.3
Extreme (day 7)	110.7	-
Frozen Fish (day 8)	19.9	19.9

Batch 2	TVB-N [mg N/ 100g]	Protein %
Fresh Fish (day 0)	16.8	18.60
On ice (day 4)	16.5	18.20
No ice (day 4)	16.2	18.20

4.1.2 Moisture content after washing

In this study, moisture content of saithe surimi was lower when the raw material used had been stored for longer time and at higher temperature. The moisture content of surimi after repeated

washing from raw material kept in ice and extreme temperature decreased from 84% to 82%, but more stable in surimi from raw material kept without ice. Whereas, water content of surimi from frozen material was decreased to 80.8% (Table 3, Figure 5). It should though be kept in mind that the changes are not big taking the standard deviation into account. The excess water which is essentially needed to be removed from surimi before adding the cryoprotectant, typically ranges between 80% and 84% (Park J. W., Graves, Draves, & Yongsawatdigul, 2014). The lower water content indicates that the proteins had denatured during storage due to microbial activity or freezing resulting in lower water holding capacity, making it easier to remove water in the process.

Table 3. Moisture content after washing - Batch 1.

Raw material condition	Day 2	Day 4	Day 7	Frozen
On Ice	84.9±0.31	83.3±1.47	82.7±0.16	
No Ice	84.3±0.36	83.6±0.16	84.7±0.21	
Extreme temp.	84.4±0.25	84.1±1.81	82.8±0.27	
Frozen				80.8±0.19

*Mean values ± SD (n=3).

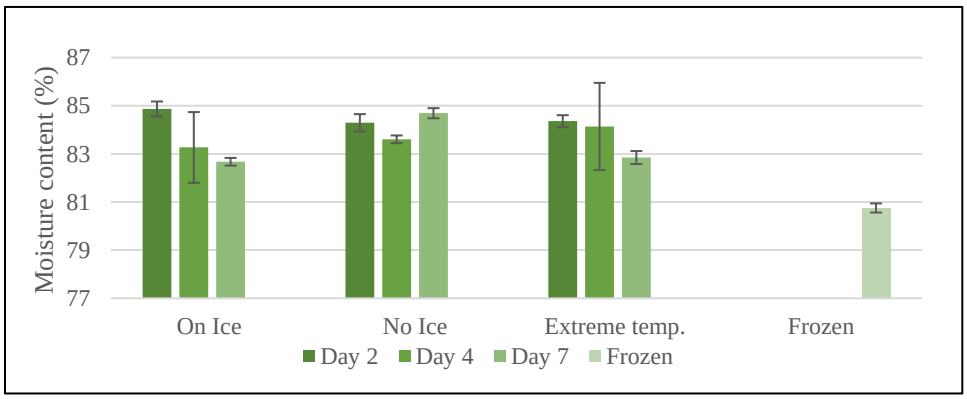


Figure 5. Moisture content of saith mince after washing - Batch 1.

4.1.3 Moisture content of saithe surimi

The moisture content of saithe surimi from raw material kept on ice decreased in the early stage of storage time and slightly increased at day 4. Both water content of saithe surimi from raw material kept without ice and extreme temperature were higher than the fresh raw material. Water content reduced during storage time at day 4 to 7 for both treatments. Frozen raw material (day 8) produced lower content moisture surimi product compared to the fresh material (Table 4, Figure 6). Standard deviation was lower for those results and clearly indicate significant difference in water content for the samples kept at extreme temperature and the frozen sample. The water

content is also a critical factor in surimi products and suggested that the standard water content of surimi is 78% during mixing. Adequate water content, high protein and myofibrillar were required to make a high-quality surimi (Jin, et al., 2007).

Surimi processed from frozen fish had lower water content than other samples (Figure 6) indicating that the proteins of the saith had undergone changes due to freezing. During freezing and frozen storage, protein of fish muscle can change resulting in loss of quality including less water holding capacity (Sotelo, Pineiro, & Perez-Martin, 1995).

Table 4. Moisture content of saithe surimi – Batch 1.

Sample	Day 0	Day 2	Day 4	Day 7	Frozen
On Ice	77.8±0.16	77.4±0.15	77.6±0.26	77.1±0.15	-
No Ice	77.8±0.16	78.2±0.79	77.2±0.08	77.5±0.06	-
Extreme temp.	77.8±0.16	78.6±0.29	77.4±0.23	76.0±0.16	-
Frozen	-	-	-	-	75.7±0.13

*Mean values ± SD (n=3)

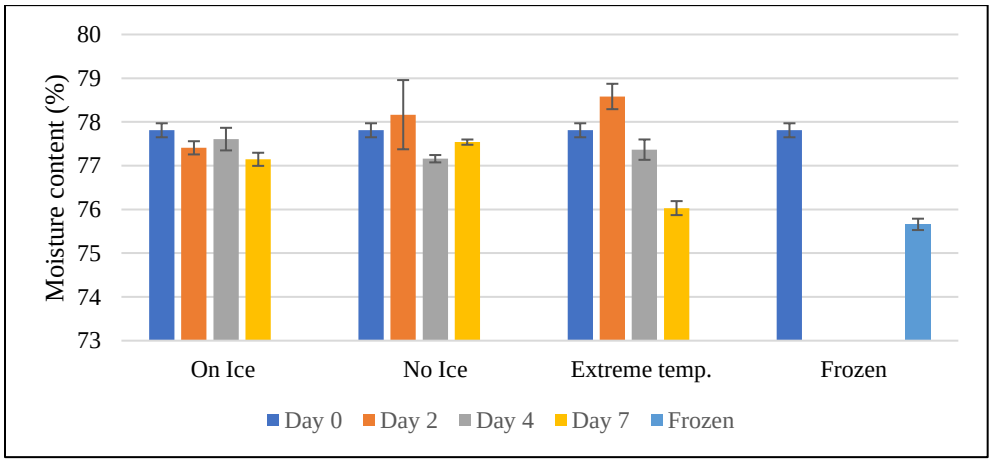


Figure 6. Moisture content of saithe surimi made from raw material after different storage time (with setting time) -Batch 1.

4.2 The effect of different raw material storage time and temperature on saithe surimi gel

4.2.1 Colour properties (Batch 1)

Color parameters and whiteness of surimi gels are shown in table 5 and table 6. To confirm the changes in colour, surimi gels from different sources of raw material were assessed for their Hunter colour values. The moisture content of the surimi has been found to be directly linked to change of the colour hue of the gels (Park, Ooizumi, & Hunt, 2014). That connection was not found here.

The L* and whiteness of the composite gels prepared from the same washing treatment, but different heating processed showed similar results. The values of whiteness of surimi from raw material kept in ice and without ice did decrease somewhat during storage time but most probably not significantly. Otherwise, the whiteness of surimi gels where raw material kept in extreme temperature increased somewhat with storage time of the raw material, but again probably not significantly. This result indicates that gels obtained from different cooking processes did not affect the whiteness of the gels. Whiteness might be affected by washing process among all raw material conditions during setting and heat treatment. Washing could remove impurities like blood, pigments, etc., improving the colour properties of surimi gel (Pan, et al., 2018). Since the raw material was not measured alone, this cannot be confirmed for this test, but when comparing figures of the starting raw material over to the surimi, change in colour can be observed from red/gray fish to more yellowish surimi (Figure 7-8 and Figure 9-10).

Table 5. Whiteness of surimi gel from different raw material storage times (without setting time).

		Value Non- Setting			
Storage Time		**On Ice**	**No Ice**	**Extreme**	**Frozen**
0 day	L*	71.2±2.67	71.2±2.67	71.2±2.67	
	a*	-2.3±0.19	-2.3±0.19	-2.3±0.19	
	b*	6.1±0.59	6.1±0.59	6.1±0.59	
2 days	L*	69.2±0.74	69.7±0.75	67.6±1.99	
	a*	-2.3±0.15	-2.2±0.37	-2.2±0.34	
	b*	4.3±0.29	5.3±0.25	6.3±1.0	
4 days	L*	69.3±0.09	68.2±0.83	68.9±1.23	
	a*	-2.3±0.14	-2.2±0.10	-1.8±0.38	
	b*	5.9±0.50	5.6±0.47	5.3±0.42	
7 days	L*	68.1±0.40	66.3±1.77	69.7±0.82	
	a*	-2.2±0.11	-1.7±0.24	-1.8±0.14	
	b*	5.1±0.45	5.5±0.24	5.0±0.35	
Frozen	L*				69.31±1.05
	a*				-1.8±0.14
	b*				6.0±0.46

*Mean values ± SD (n=3)

Non-Setting								
	Whiteness I				Whiteness II			
Storage Time	**On ice**	**No Ice**	**Extreme**	**Frozen**	**On Ice**	**No Ice**	**Extreme**	**Frozen**
0 day	53.0±3.8	53.0±3.8	53.0±3.8		70.5±2.6	70.5±26	70.5±2.6	
2 days	56.3±1.4	53.8±1.5	48.8±4.7		68.8±0.7	69.1±0.8	66.9±2.1	
4 days	51.7±1.6	51.5±1.3	53.1±2.0		68.7±0.9	67.7±0.8	68.4±1.2	
7 days	52.8±1.5	49.9±2.6	54.8±1.1		67.6±0.4	65.8±1.7	69.2±0.8	
Frozen				51.3±0.9				68.7±0.1

*Mean values ± SD (n=3)

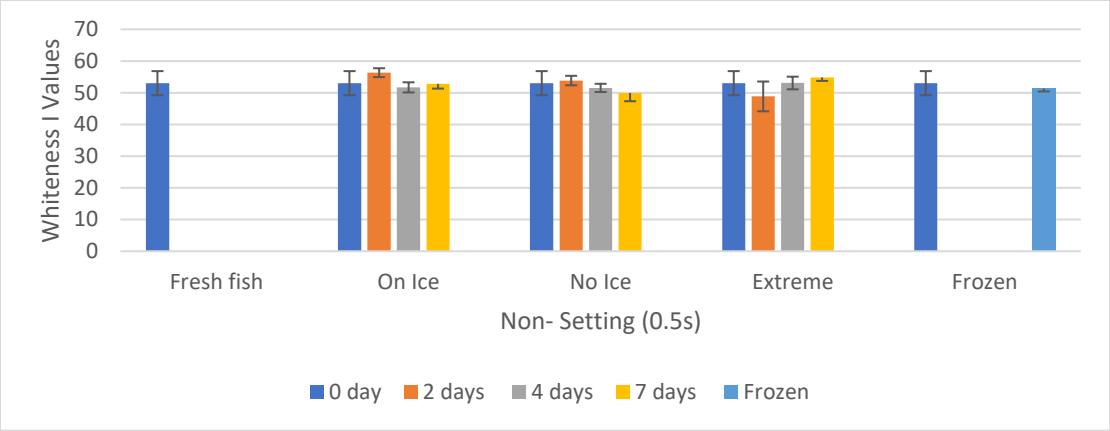


Figure 7. Whiteness I of surimi gel from different raw material storage times, direct heating (without setting time) - Batch 1.

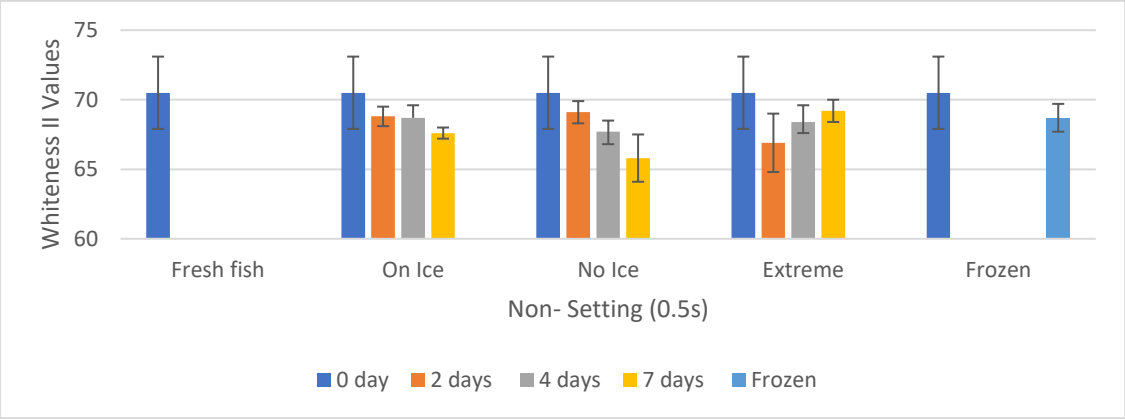


Figure 8. Whiteness II of saithe surimi gels from different raw material storage times, direct heating (without setting time).

Table 6. Whiteness of surimi gel from different raw material storage times (with setting time).

		Values Setting			
Storage Time		**On Ice**	**No Ice**	**Extreme**	**Frozen**
0 day	L*	71.6±1.39	71.6±1.39	71.6±1.39	
	a*	-2.2±0.28	-2.2±0.28	-2.2±0.28	
	b*	5.9±0.37	5.9±0.37	5.9±0.37	
2 days	L*	69.0±0.83	70.8±0.87	68.1±0.97	
	a*	-2.3±0.05	-2.4±0.09	-2.4±0.22	
	b*	3.9±0.22	5.1±0.25	6.1±0.39	
4 days	L*	69.0±0.61	67.9±0.87	69.5±0.44	
	a*	-2.2±0.32	-2.1±0.31	-2.0±0.2	
	b*	5.7±0.88	5.9±0.85	5.3±0.87	
7 days	L*	68.3±0.31	67.9±0.99	69.9±0.69	
	a*	-2.1±0.29	-1.9±0.23	-1.6±0.24	
	b*	4.9±0.44	4.4±0.86	4.6±0.26	
Frozen	L*				69.0±1.2
	a*				-1.8±0.16
	b*				6.3±0.59

*Mean values ± SD (n=3)

	Setting							
	Whiteness I				**Whiteness II**			
Storage Time	On Ice	No Ice	Extreme	Frozen	On Ice	No Ice	Extreme	Frozen
0 day	53.9±2.1	53.9±2.1	53.9±2.1		70.9±1.4	70.9±1.4	70.9±1.4	
2 days	57.3±1.1	55.6±1.2	49.8±2.0		68.7±0.8	70.2±0.9	67.4±1.0	
4 days	51.9±3.1	50.2±3.1	53.5±2.8		68.5±0.7	67.3±0.9	69.0±0.5	
7 days	53.4±1.5	54.6±3.3	56.1±1.1		67.8±0.3	67.6±1.0	69.6±0.7	
Frozen				50.2±2.0				68.3±1.2

*Mean values ± SD (n=3)

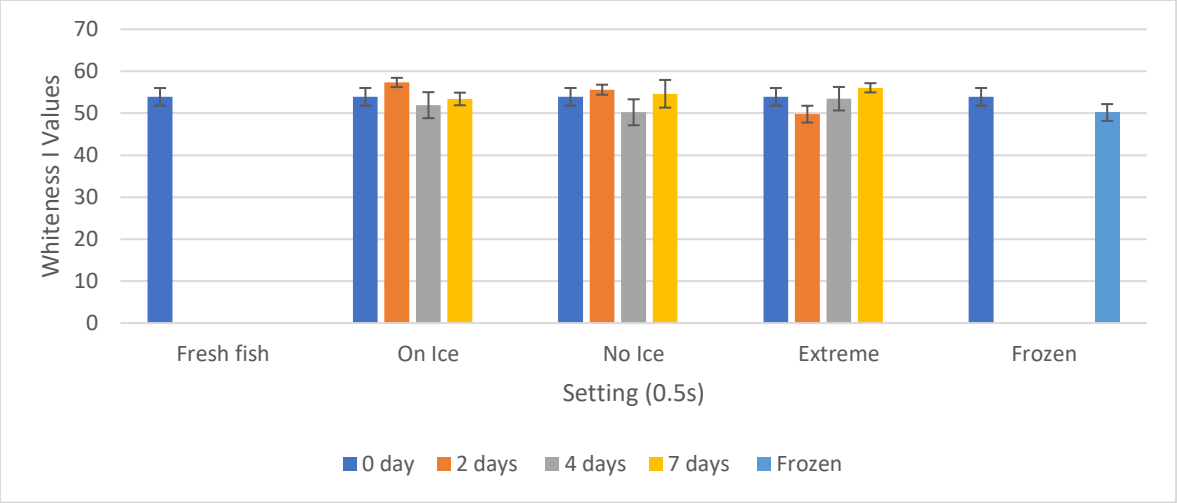


Figure 9. Whiteness I of surimi gel made from raw material after different storage times (with setting time).

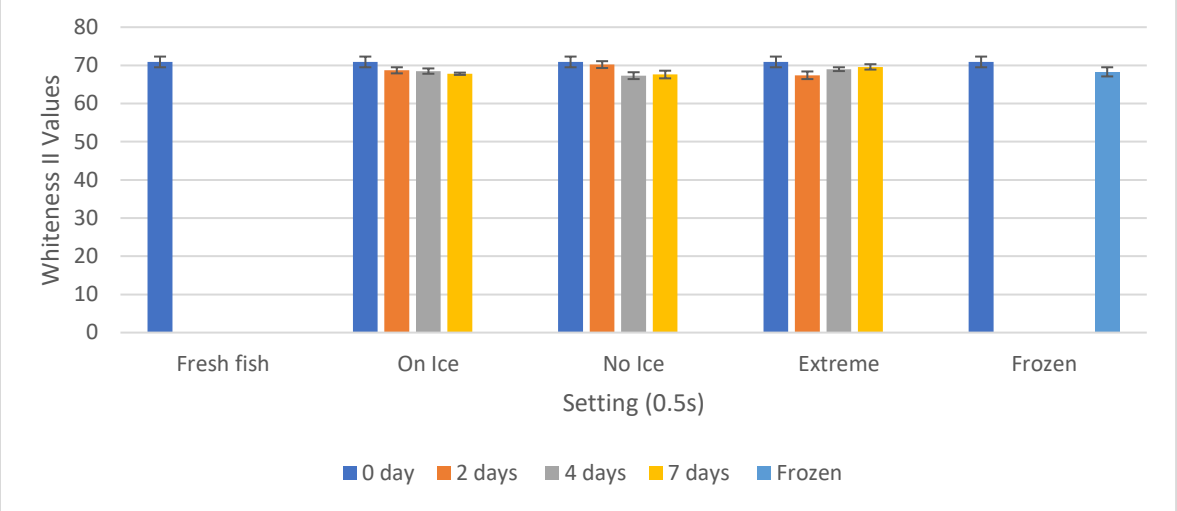


Figure 10. Whiteness II of surimi gel made from raw material after different storage times (with setting time) -Batch 1.

4.2.2 Effect on gel strength and folding test of surimi (Batch 1)

The force and distance needed to rupture surimi gels were impacted by different time and storage condition of the raw material used (Figure 11 & 13). Saithe surimi gels treated with setting time presented higher gel strength values that of direct heated gels (without setting time). However, gels prepared from different raw material had lower gel strength during storage than fresh raw material. In case of raw material condition, an increase in gel strength during storage time was observed from raw material kept on ice and extreme temperature. Folding test score decreased for

all groups during storage both with and without setting (Fig 12 & 14). Gel strength of samples kept on ice was lower than from no ice; it could be due to fish meat samples kept in storage in the cooler room for a long time with ice.

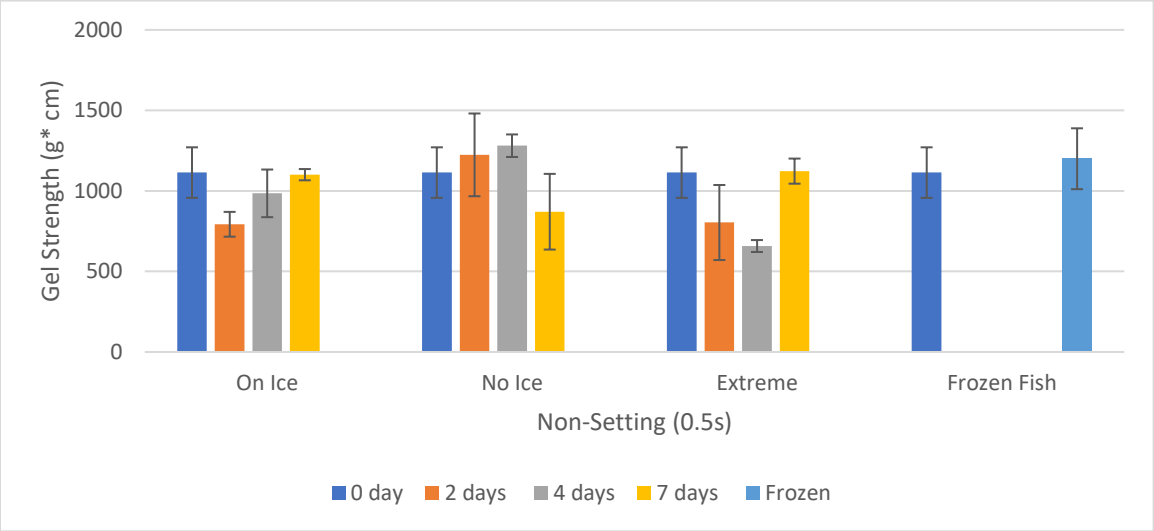


Figure 11. Gel strength of surimi made from raw material after different storage times (without setting).

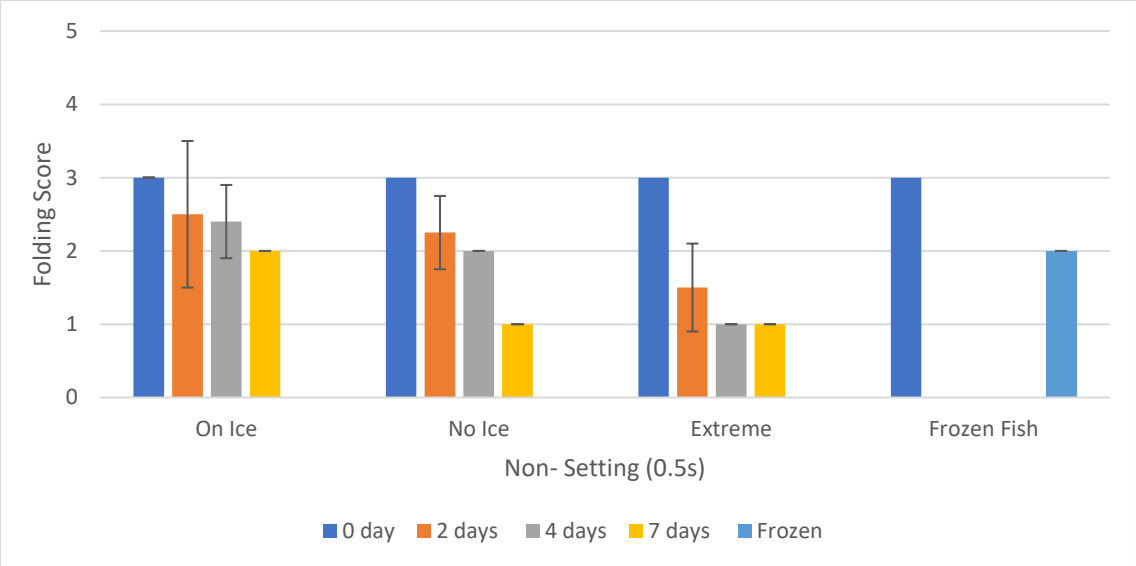


Figure 12. Folding test made from raw material after different storage times (without setting) - Batch 1.

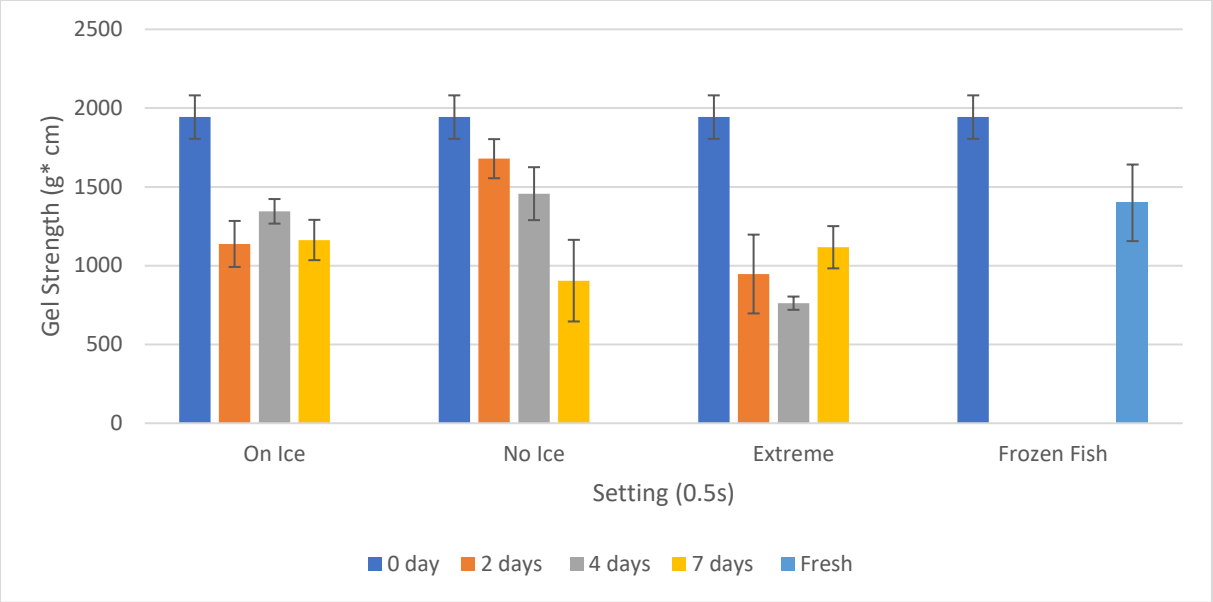


Figure 13. Gel strength of surimi made from raw material after different storage times (with setting).

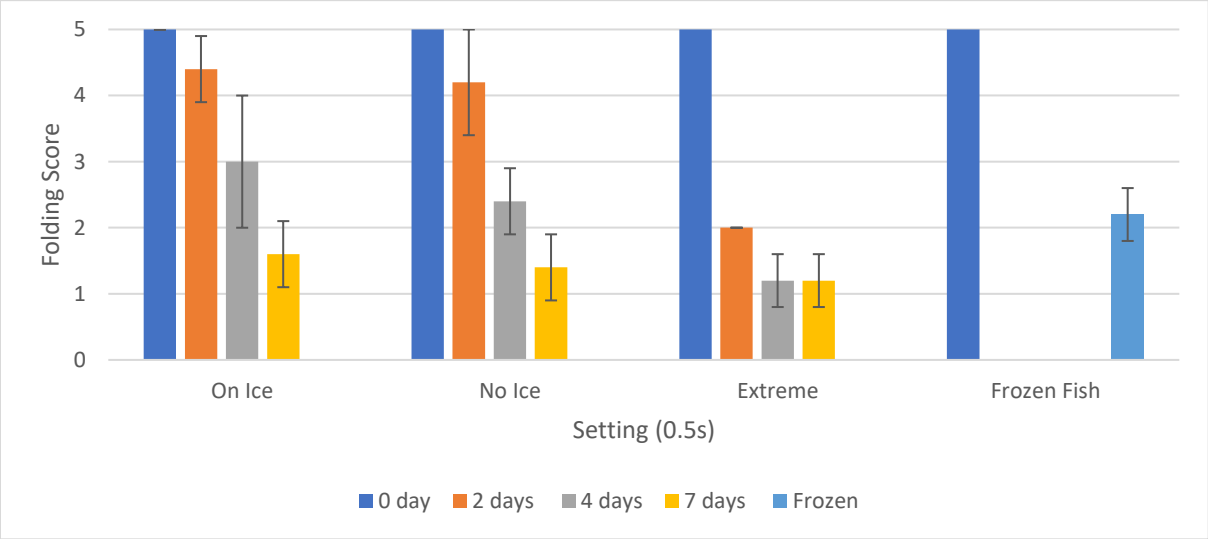


Figure 14. Folding test made from raw material after different storage times (with setting).

4.2.3 Effect on moisture content of washed saith mince and surimi (Batch 2)

Batch 2 moisture content was testing for three different times and storage conditions (Fresh fish, on ice and no ice) (Table 7 and 8). The moisture content of surimi clearly reduced with storage time of raw material. It was higher with no ice than on ice. While moisture content without cryoprotectant decreased day 0 to day 4. Moisture content value can be seen in figures 15 and 16.

Table 7. Moisture content of surimi samples made from saith after up to 4 days storage with or without ice (Batch 2).

Sample	Day 0	Day 2	Day 4
On Ice	85.5±0.1	85.0±0.03	84.5±0.21
No Ice	85.5±0.1	85.1±0.01	84.5±0.21

*Mean values ± SD (n=3).

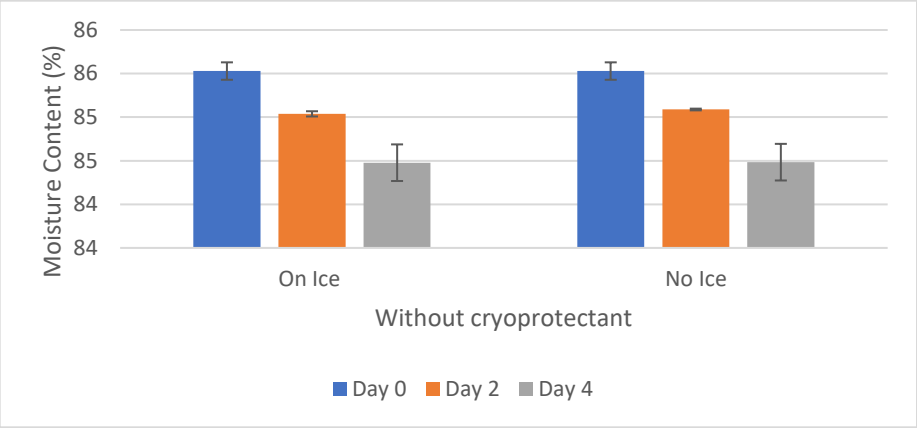


Figure 15. Moisture content of surimi samples made from saith after up to 4 days storage in a cold room with or without ice from Batch 2.

Table 8. Moisture content of surimi samples made from saith after up to 4 days storage with or without ice (Batch 2).

* Mean values ± SD (n=3).

Sample	Day 0	Day 2	Day 4
On Ice	78.9±0.11	78.3±0.18	77.4±1.51
No Ice	78.9±0.11	78.9±0.17	78.2±0.32

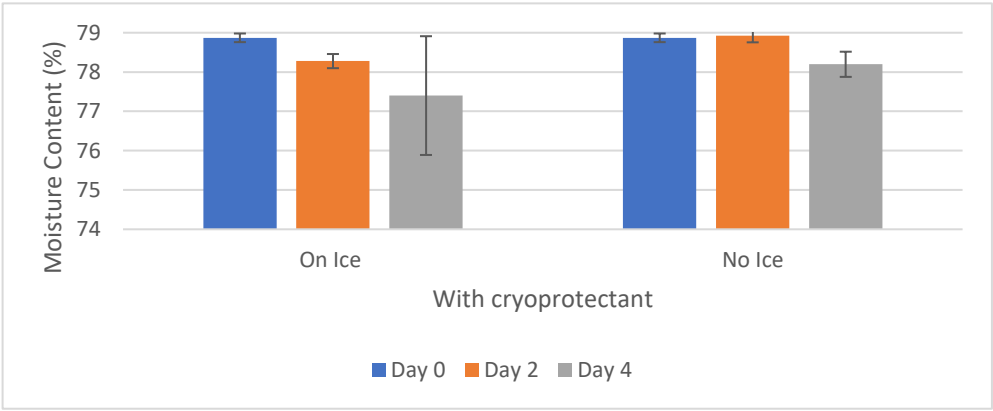


Figure 16. Moisture content of surimi samples made from saith after up to 4 days storage in a cold room with or without ice from Batch 2.

In batch 2, two different probes (0.5s and 0.25s) were used for gel strength analysis. Colour was measured in the samples used for both probes. Table 9-12 show the colour and whiteness test. No apparent significant difference was found between the samples in batch 2 (Figure 17-20).

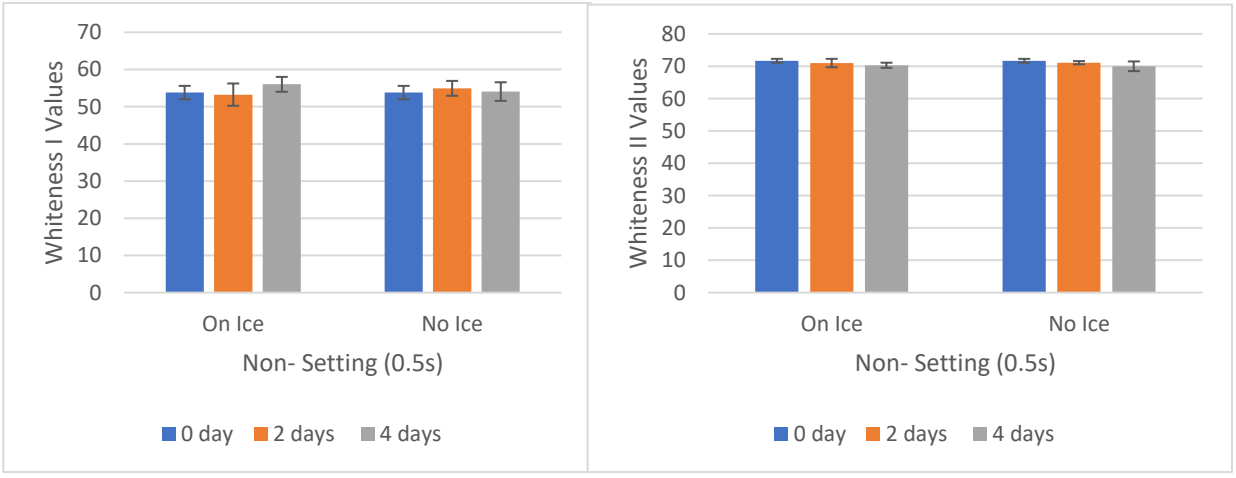
For both Batch 1 and Batch 2 colour of surimi did not change with storage of the raw material, either measured as the Lab values or calculated as whiteness. This indicates that the lipids found in saithe did not oxidise during storage.

Table 9. Whiteness of surimi gel from different raw material storage times (without setting time) (0.5s).

Non Setting (0.5s)							
		Values		Withness I		Withness II	
Storage Time		On Ice	No Ice	On Ice	No Ice	On Ice	No Ice
0 day	L*	72.5±0.53	72.5±0.53	53.8±1.8	53.8±1.8	71.7±0.6	71.7±0.6
	a*	-1.8±0.24	-1.8±0.24				
	b*	6.2±0.49	6.2±0.49				
2 days	L*	71.8±1.18	71.7±0.46	53.3±3.0	54.9±2.0	71.0±1.3	71.1±0.5
	a*	-2.0±0.11	-2.2±0.12				
	b*	6.2±0.68	5.6±0.55				
4 days	L*	70.8±0.84	70.6±1.53	56.0±2.0	54.1±2.5	70.3±0.8	70.0±1.5
	a*	-2.2±0.04	-2.2±0.21				
	b*	4.9±0.71	5.5±0.68				

*Mean values ± SD (n=3).

Figure 17-Whiteness I and Whiteness II of surimi gel made from raw material after different



storage time (without setting time) (0.5s).

Table 10. Whiteness of surimi gel from different raw material storage times (with setting time) (0.5s).

Setting (0.5s)							
	Values			Withness I		Withness II	
Storage Time		On Ice	No Ice	On Ice	No Ice	On Ice	No Ice
0 day	L*	72.9±0.76	72.9±0.76	56.2±2.5	56.2±2.5	72.2±0.8	72.2±0.8
	a*	-2.1±0.06	-2.1±0.06				
	b*	5.6±0.63	5.6±0.63				
2 days	L*	71.0±0.29	71.7±0.92	53.4±1.2	56.5±1.6	70.3±0.3	71.1±0.9
	a*	-2.1±0.06	-2.3±0.19				
	b*	6.0±0.41	5.0±0.6				
4 days	L*	70.7±1.03	70.8±0.62	57.1±1.6	52.0±2.5	70.2±1.0	70.1±0.7
	a*	-2.2±0.18	-2.4±0.15				
	b*	4.5±0.42	6.3±0.67				

*Mean values ± SD (n=3)

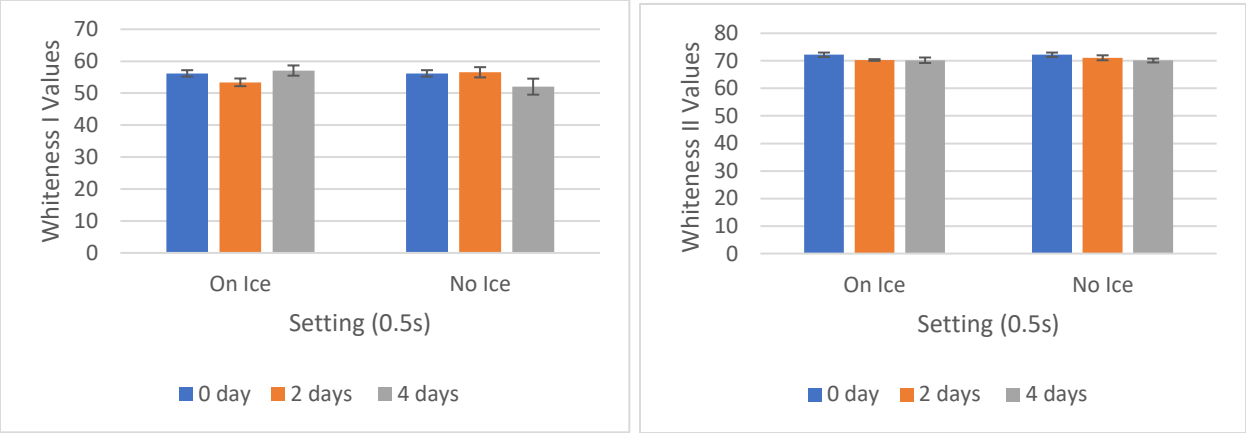


Figure 18. Whiteness I and Whiteness II of surimi gel made from raw material after different storage times (with setting time) (0.5s).

Table 11. Whiteness of surimi gel from different raw material storage times (without setting time) (0.25s).

Non Setting (0.25s)							
	Values			Withness I		Withness II	
Storage Time		On Ice	No Ice	On Ice	No Ice	On Ice	No Ice
0 day	L*	71.9±1.66	71.9±1.66	53.2±1.9	53.2±1.9	71.1±1.6	71.1±1.6
	a*	-1.9±0.21	-1.9±0.21				
	b*	6.3±0.63	6.3±0.63				
2 days	L*	71.0±1.28	71.2±1.25	52.7±2.0	55.4±2.4	70.3±1.3	70.6±1.3
	a*	-1.9±0.11	-2.1±0.24				
	b*	6.1±0.42	5.3±0.2				
4 days	L*	70.7±0.56	71.2±0.71	54.6±1.3	54.5±1.9	70.1±0.6	70.6±0.7
	a*	-2.2±0.15	-2.2±0.2				
	b*	5.4±0.4	5.6±0.51				

*Mean values ± SD (n=3).

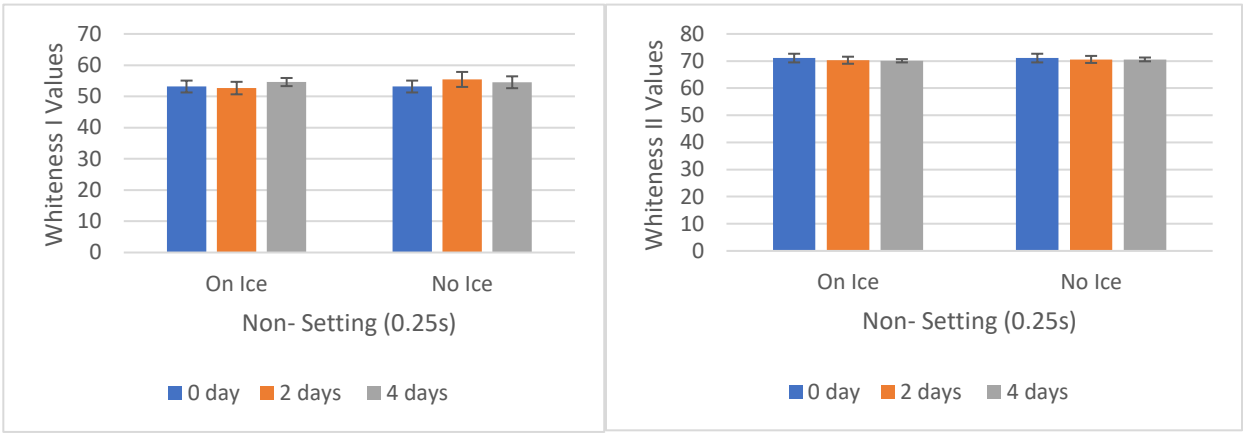


Figure 19. Whiteness I and Whiteness II of surimi gel made from raw material after different storage times (without setting time) (0.25s).

Table 12. Whiteness of surimi gel from different raw material storage times (with setting time) (0.25s).

Setting (0.25s)							
	Values			Withness I		Withness II	
Storage Time		On Ice	No Ice	On Ice	No Ice	On Ice	No Ice
0 day	L*	72.1±0.48	72.1±0.48	55.4±1.4	55.4±1.4	71.5±0.5	71.5±0.5
	a*	-2.2±0.2	-2.2±0.2				
	b*	5.6±0.46	5.6±0.46				
2 days	L*	70.5±0.75	71.5±1.43	50.9±2.1	54.7±1.3	69.7±0.8	70.9±1.4
	a*	-1.9±0.17	-2.1±0.2				
	b*	6.5±0.53	5.6±0.22				
4 days	L*	70.3±0.85	71.3±0.73	56.2±1.9	53.9±2.6	69.8±0.8	70.6±0.8
	a*	-2.1±0.14	-2.5±0.19				
	b*	4.7±0.53	5.8±0.68				

*Mean values ± SD (n=3).

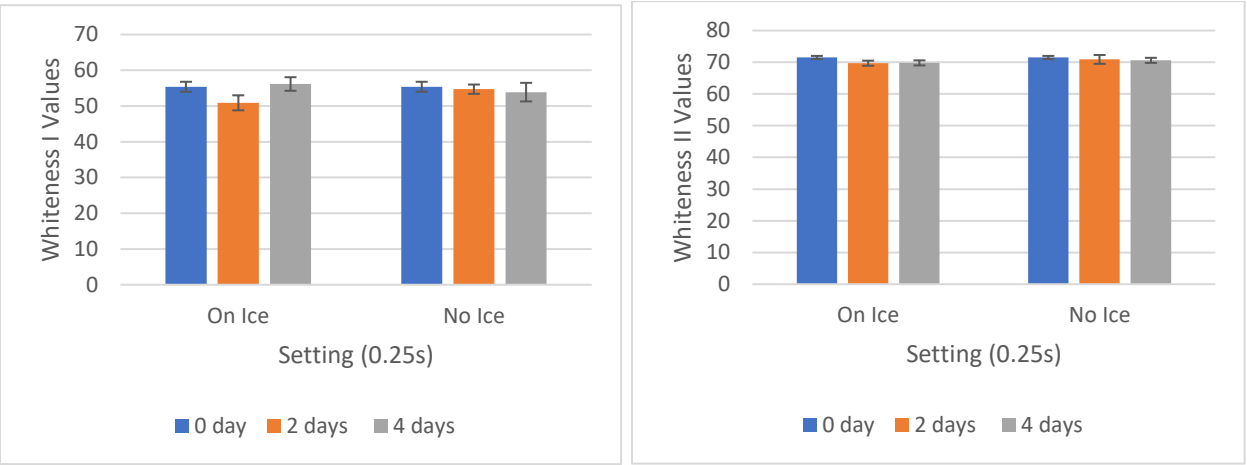


Figure 20. Whiteness I and Whiteness II of surimi gel made from raw material after different storage time (with setting time) (0.25s).

4.2.4 Effect on gel strength and folding test of surimi (Batch 2)

In batch 2, gel strengths were tested using different probes (0.5s and 0.25s). The value of surimi gel strength was impacted by different probe where smaller probe (0,25s) gave lower gel strength whereas less force is needed to penetrate the gel with the smaller head. Furthermore, there was

proportionally higher SD using the smaller probe whereas air bubbles and other defects of the gel have more effect than when using a smaller probe. (Figure 21 & 23). The result of gel strength with setting was higher than without setting using both probes. Standard deviation was rather high in the results making further comparisons difficult. Folding test values decreased from day 0 to day 4 for surimi made from saith both kept on ice and without ice.

In summary, gel strength and folding test compare batch 1 and batch 2. A decrease was observed in the folding property of surimi from the first day of the raw material storage (Table 1). Using saithe after 2 days of storage resulted in a folding score of lower than 3 indicating low quality surimi, also indicating the importance of using fresh fish kept at optimum conditions to make high quality surimi. Higher temperature and longer storage time did have a negative effect on gel strength.

Surimi gel strength values depended on probe size (Figure 23). According to the Standard Test Method for Surimi Quality published by the Japanese Surimi Association, 0.25s should be used when grading surimi (Appendix). It would have been best to use 0.25s for all analysis in the trial but due to experimental set up that was not possible.

Values presented for batch 2 in Figure 21 and 23 can therefore be compared to the grading presented on page 6, where gel strength values above 300 have grades A, AA, SA or SSA, below 300 has grade B. Surimi made from saithe kept for less than 4 days in a cooler with or without ice can be graded as A surimi (Figure 23). For this study, it was recorded that as storage days of raw material increased and it was kept at higher temperatures, the gel strength decreased (Figure 11 & 13, 21 & 23).

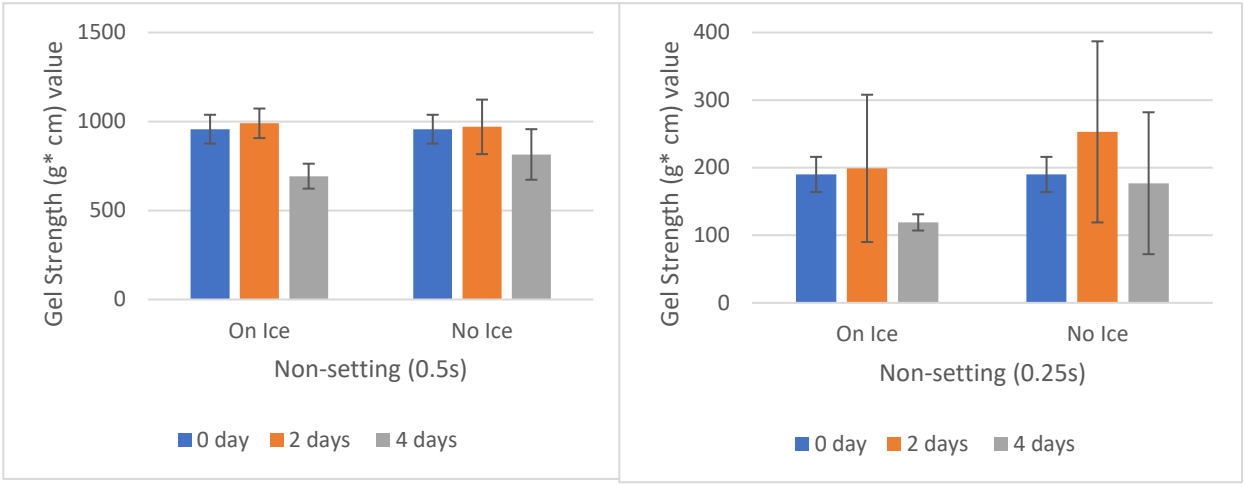


Figure 21. Gel strength of surimi made from raw material after different storage times and different probes (without setting) (Batch 2).

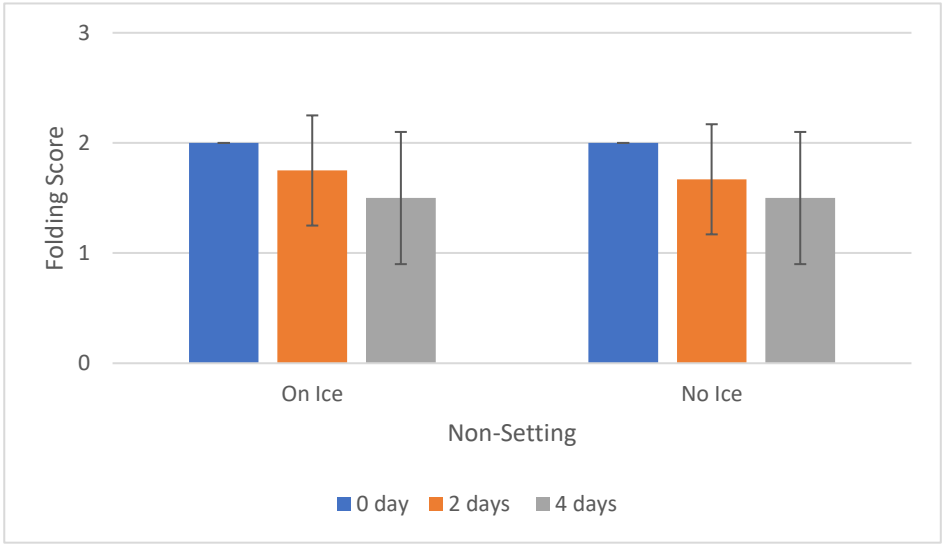


Figure 22. Folding test made from raw material after different storage times (without setting) (Batch 2).

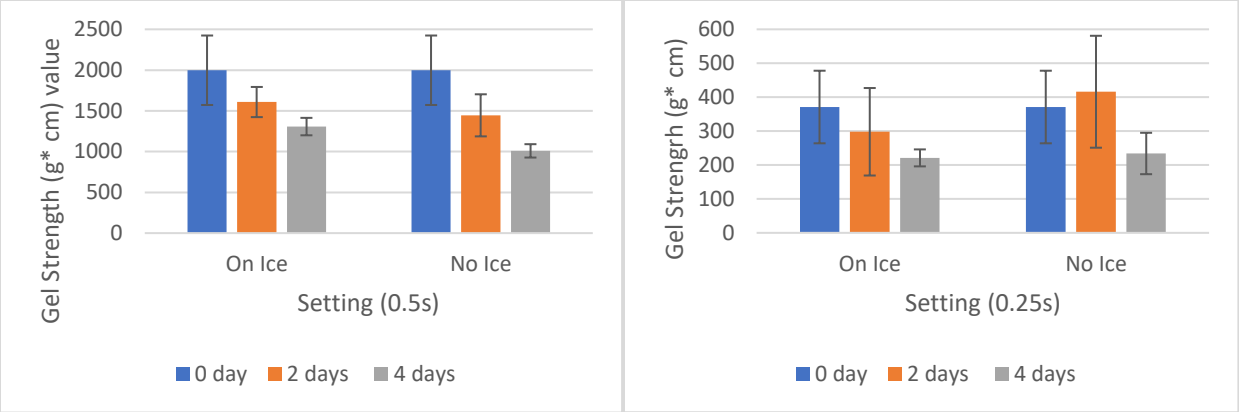


Figure 23. Gel strength of surimi made from raw material after different storage times and different probes (with setting) (Batch 2).

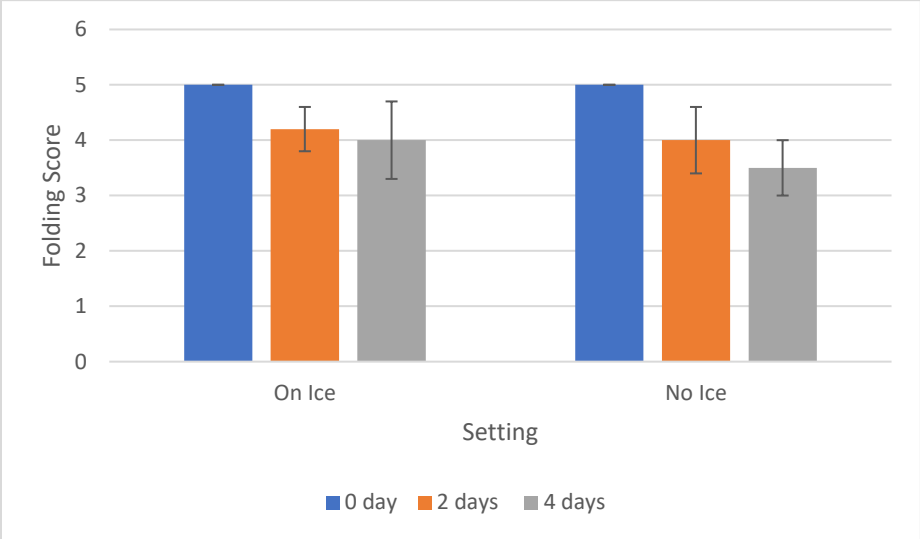


Figure 24. Folding test made from raw material after different storage times (with setting) - Batch 2.

5 CONCLUSION

This study TVB-N of raw material correlated to temperature and time but no direct correlation between TVB-N and gel strength of surimi. Raw material quality did not influence surimi colour but had an effect on gel properties. Different probes selected had an effect on results and in future work a probe with 0.5 cm diameter should be used. Freezing is not a good method to store fish to be used as raw material for surimi processing. Higher temperatures and longer storage times of the raw material had a negative effect on gel strength.

This study showed the importance of storing fish under optimum conditions and using as soon as possible from the point of catch which will result in high quality surimi.

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