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CHANGES IN CHEMICAL CONTENT AND YIELD OF HERRING (*CLUPEA HARENGUS*) AND BLUE WHITING (*MICROMESISTIUS POUTASSOU*) UNDER DIFFERENT METHODS OF SALTING

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ABSTRACT

Salting is a traditional method for preserving fish in Sri Lanka. In recent years fish salting has diminished because of little progress in the salting technique, and improved freezing techniques. A study was conducted to obtain a better understanding of various physical and chemical properties of fish muscles during salting. Samples of herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*) were salted in different brine concentrations (10%, 15%, and 20%) and different fish to brine ratios (1:1 and 1:1.6), which was followed by dry salting and storage.

Herring had more yield than blue whiting at the end of storage but there was no difference in yield among treatment groups within each species although differences were observed after brine salting. After rehydration the results were the same.

The effects of salt uptake, weight changes and chemical changes on the fish during the salting process was observed. Differences in salt uptake were not detected at the end of the process for different salt concentrations or fish to brine ratios.

Both species gained salt nearly to the same level at the end of the process, despite different fat and water content of the muscles. These results may not agree with the results of other research on other species (using different methods), which show that fat and water content influence salt uptake. This should be an issue for further study.

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1. INTRODUCTION

Salting fish is one of the oldest methods of food preservation. Salt is used both as the primary preserving ingredient and in combination with other methods such as drying and smoking.

Since ancient days there have been three basic methods used in salting fish. In most countries these methods are distinguished as dry salting, wet salting and mixed salting. The fish being salted with dry crystalline salt characterizes dry salting. Wet or salt brine type of salting is a process by which the fish is salted in a previously prepared salt solution. Mixed salting is a method by which the fish is salted consecutively in brine and with crystalline salt (Voskresensky 1965).

According to Voskresensky (1965), salting of herring was already practiced on a large scale in the 12th and 13th centuries, but the Scottish were probably the first nation to salt herring in the 8th century. In other countries, like the Netherlands, Russia, Germany, and the Nordic countries, salting of herring is traditional. Already by the fourteenth century these countries had independently improved the salting method. Therefore, salting methods and salting procedures are different in each country (Zugarramurdi and Lupin 1980).

In recent years salting, as a preservation technique, has become less popular because of developments in quick freezing preservation of fish. Frozen fish has much the same flavour as fresh fish, while salted fish has a distinct flavour derived from the salting process. Its primary purpose is preservation but in southern Europe and Brazil salted cod is a traditional food, so this method is used to produce not only a traditional food but also to produce a much appreciated delicacy. A well-ripened salted fish has a soft, tender consistency and a pleasant taste and odour. Therefore, this ancient treatment is still in use today even in developed countries, either because of economic reasons owing to its low production costs or in order to satisfy consumer demands.

Many studies have been carried out on the salting of herring, cod and other species but very little has been done in terms of researching the salting of blue whiting. This study is one of the first on salting blue whiting in Iceland, by using the same salting method as for cod in the production of bacalao. Usually herring is salted in vats using a pickle salting or brine salting method. This study is conducted to look at some other possible ways of salting herring, using dry salting method and dry storage.

The main objective of this study is to compare the characteristics of fish flesh of a fatty fish, herring (*Clupea harengus*), with the lean fish flesh of blue whiting (*Micromesistius poutassou*) during and after the salting process. Further goals of this research are to get a better understanding of the changes that occur in the fish muscle when it is salt cured, i.e. in the brining of the fish. The emphasis is on observing the effects of salt uptake on weight and chemical changes on the raw material (fatty and lean).

In Sri Lanka salting has been practised for a long time as a preservation method when catches are high. Brine salting, followed by sun drying is of considerable importance. Brine salting with concentrated brine is also practised. But with the development of freezing techniques these salt curing techniques seem to be disappearing in Sri Lanka. Until now little effort has been made to develop these ancient methods. This project is an effort to improve methods of salting for the fishing industry of Sri Lanka.

2. LITERATURE REVIEW

2.1 Raw material

2.1.1 Herring (*Clupea harengus*)

Geographically, herring can be found from the Bay of Biscay in the south, to Greenland and Spitzbergen in the north and from Cape Cod on the American coast to the mouths of the rivers Ob and Jenisei in the east. According to Kiesvaara (1975), a sub-species, *C. harengus pallasii*, is found in the northern part of the Pacific Ocean. Herring vary considerably in size and in chemical composition due to life history and seasonal variations. The amount of available herring varies from year to year due to variation in stock size and catchability.
Juvenile herring grow rapidly in the coastal waters to which they are carried as larvae. By late summer or early winter they will have reached a length of 8-14 cm and they begin then to move away from the coast into deeper waters. The feeding areas of the one year old and older fish are the regions where zooplankton is abundant during the spring and summer months (MAFF 1981).
In Iceland only one stock (a summer-spawning herring) is now caught. Before 1970 the stock called Norwegian spring-spawning herring was caught, but this stock disappeared almost completely from the traditional fishing grounds due to over fishing (Kiesvaara 1975). Now, the stock is recovering. It is increasing progressively due to good recruitment (FAO 1994). In 1998, the Icelandic landings of Norwegian spring-spawning herring were about 198 thousand tons. Landings in the 1998/99 season from the Icelandic summer-spawning herring were about 87 thousand tons (MRI 1999) (Appendix 12).

2.1.2 Blue whiting (*Micromesistius poutassou*)

The blue whiting is a gadoid species closely related to the whiting (*Merluccius bilinearis*). It is recognized by its bluish colour, long slender shape and lack of barbel. Blue whiting is a pelagic, mainly oceanic fish, usually found in waters around 200 – 400 m depth on and beyond the edge of the continental shelf (Ryan 1979). Its distribution extends from the Mediterranean to the Barents Sea and Iceland. Spawning takes place in the spring on the edge of the shelf west of Britain and Ireland. After spawning they migrate northwards between Norway and Iceland to the feeding grounds where they over-winter.
The fishery for blue whiting became fully established in 1977 and landings peaked in 1979-80 at more than 1 million tons. Since then the total catch has decreased to 356,000 tons in 1991. The stock was heavily over-fished in the late 1980s. Since 1986, the stock has been increasing and is considered within safe biological limits (FAO 1994). International catches of blue whiting in 1998 were 1.125 million tons in the Northeast Atlantic. Landings in recent years from Icelandic waters have been low, in 1996 catches

were 500 tons, in 1997 it increased to 10.5 thousand tons and in 1998 it was 65 thousand (MRI 1999).
Most of the blue whiting caught in the North Atlantic has until the last decade been used for fishmeal, although blue whiting products for human consumption have been used in the former Soviet Union (Ryan 1979).

2.2 Chemical composition of raw material

Seasonal variations associated with the nutritional status and maturation of the fish may affect characteristics such as chemical composition. The herring season (for the summer spawning herring) in Iceland lasts only for a few months, from September to January when the fat content of herring is high (Figure 1).
Analysis was carried out on whole-ungutted fish intended for fishmeal production (Figure 2). The results do not agree with data of other researchers (Bussman 1977 and 1978) especially on fat content. The fat content of fish caught at different times of the year varies. The difference in fat content may partly be due to the liver, which varies in size and oil content and acts as an energy reserve for the fish, or it may be attributed to prey organisms in the fish's stomachs. The flesh is rather lean, although it contains somewhat fatter than cod and haddock (Dagbjartsson 1975).
The protein content of blue whiting fillets is almost identical to that of cod fillets, and fat, salt and water contents are also in good agreement with those of cod fillets (Table 1).
The most promising application of the blue whiting seems to be the minced block or fillet block. Headed and gutted fish has been brine salted and dried in the Icelandic Fisheries Laboratories. That product was very similar to the salted cod (Dagbjartsson 1975). One possible export outlet for blue whiting is to Japan as surimi, an intermediate product in mince form used there for the manufacture of Kamaboko, a speciality product of high value. Several trials have been made at the Torry Research Station UK, to produce batches of surimi to the Japanese specification (TRS 1980).
Blue whiting could possibly be marketed in smoked form, either as split whole fish, cold smoked like kippers, or as hot smoked snacks after removal of the head, guts and belly flaps.

Table 1: Chemical composition of blue whiting and cod fillets (Dagbjartsson 1975).

Constituent	Blue whiting (%)	Cod (%)
Water (Moisture)	80.5	81.1
Protein	18.1	18.1
Fat	0,8	0,2
Ash (minerals)	1,2	1,0
Salt	0,1	0,2

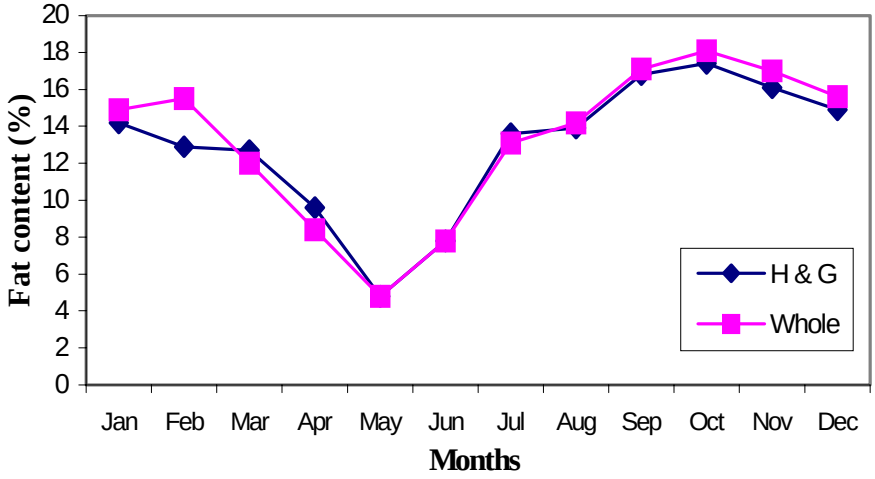


Figure 1: Fat content in whole and headed and gutted herring caught at different times during the years 1979-1987 (Einarsson 1988).

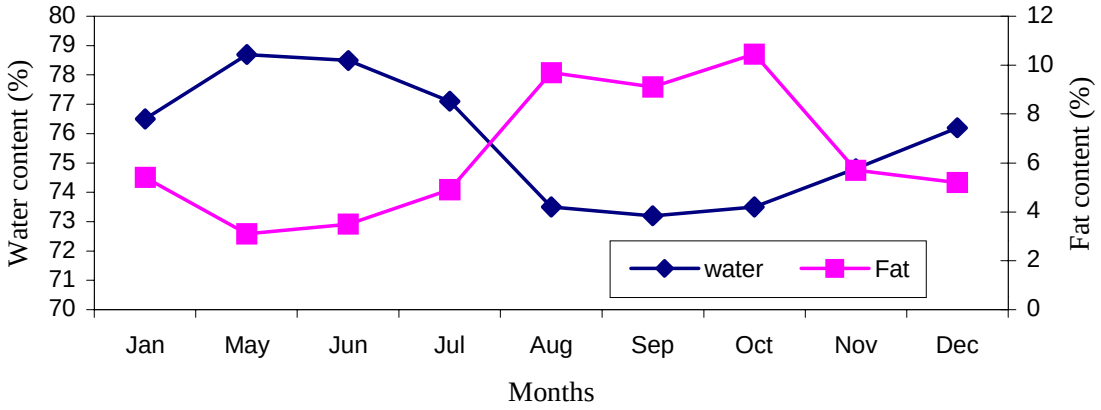


Figure 2: Water and fat content of whole ungutted Blue whiting caught at different times (Dagbjartsson 1975).

2.3 Salt curing of fish

Salting is a method of preservation, and is governed by various physical and chemical factors such as diffusion, osmosis, and a series of complicated chemical and biochemical processes associated with changes in various constituents (mainly protein) of the fish.

2.3.1 Salt uptake

As soon as fish comes in contact with salt, the salt starts to penetrate into the flesh and the salt penetration ends when all the fish has reached the same concentration as the surrounding brine. Voskresensky (1965) divided the salting process into three stages. At stage one, the fish is exposed to a high osmotic pressure. The salt diffuses into the fish tissues, but at the same time water moves by osmosis from the fish at a high speed into the surrounding brine and the fish declines in weight. At this stage no profound chemical changes have occurred and the fish has the taste and odour of raw fish. At stage two, salt and water still diffuse as in stage one, but at the same rate so no weight changes take place. The salt concentration in the surface layer of the fish tissue reaches equilibrium with that of the surrounding brine. At stage three, minor salt quantities move into the fish tissue and as a result the fish increases slightly in weight. All parts of the fish have reached the same concentration as the surrounding brine and the raw taste and odour has disappeared.

The rate of salt penetration depends upon the following factors; chemical composition of the fish, specific surface and shape of the fish body, concentration and temperature of the brine, salting method, chemical composition and the fineness of the salt used.

Deng (1977) indicates that the change in rates of salt penetration closely follows changes in extractable actomysin (actin and myosin) in muscle, indicating a dependence of the change on the degree of denaturation of fish muscle proteins. In his study on effect of freezing and frozen storage on salt penetration, he observed that the salt penetration into mullet muscle decreased gradually with 1-5 week storage. However after 5 weeks storage there was no further decrease in salt penetration. The protein content could also influence the rate of salt uptake as salt penetration decreases with increasing total protein (Zugarramurdi and Lupin 1980).

Fat plays a passive role in the process of salting as it reduces the area where salt and water diffusion takes place, and slows down the salting process (Zaitzev et al. 1965). A report of Torry Research Station (Burgess and Bannerman 1963) shows that increasing fat content of the fish reduces the uptake of salt. But in a later publication Aitkin and Baines (1969) indicate that the fat content and the size of the fish plays a minor role in salt uptake as compared with other factors affecting the salt uptake. However they indicated that salt diffuses only into the aqueous system. With increased oil content, water volume will be reduced, resulting in lower salt uptake.

Bohdan et al. (1987) reported in their study on herring that decrease in salt uptake with increase in fish size reflects the effect that fat content exerts. Their study showed a high positive correlation ($r = 0.9762$) between the length of the fish and the fat content.

The brine temperature has little effect on salt uptake (Aitken and Baines 1969) and was too small to be detected in their experiment. Crean (1961) had previously noticed the same effect of brine temperature. Bohdan et al. (1987) also reported that salt uptake was slightly higher in brining with 10°C as compared to 0°C. Similar observations were made by Ravesi and Krzynowek (1991) during their study on three species of fish fillets (cod *Gadus morhua*, blackback flounder *Pseudopleuronectes americanus*, and ocean perch *Sebastes marinus*) using three brine temperatures. They suggested that temperature changes over the 14°C range had no effect on the amount of sodium absorbed by fillets.

2.3.2 Denaturation of proteins

Denaturation of proteins implies a change in the structure of the protein molecule. Increased temperature can cause denaturation of proteins. But salt has been shown to denaturize proteins also. Van Klavern and Legrendre (1965) studied a process in cod muscle in which soluble proteins are gradually reduced during salting. The denaturation process stopped after 18 days when reduction equilibrium was reached. The hydration of proteins is about the same for most fish. As salt penetrates the tissue, it alters the colloidal properties of the proteins and changes the nature of the water/protein relationship (Zaitzev et al. 1969). Duerr and Dyer (1952) reported denaturation of cod muscle protein at salt concentration of 8-10% in the muscle. While the rapid denaturation of cod muscle occurred, they observed that water loss and salt uptake had been increased.

2.3.3 Changes in weight

Salted fish usually changes in weight during brining and storage. The change in weight during brining is the net effect of salt uptake and change in water content of the fish. Previous work on cod at the Torry Research Station (1962) suggested that the brine strength would most influence the weight change. Later Aitken and Baines (1969) showed that there was highly significant linear relationship between weight change and brine strength. Deng (1977) reported that when the brine concentration was low, 12-15%, mullet fillets absorbed water and gained weight and when it was more than 20%, water was extracted from the fillets.

2.4 Common methods of salting

The main prerequisite for successful salting is to ensure that the whole surface of the fish is in contact with the salt solution. Fish may be kept in contact with salt by mixing them with salt crystals, or by immersing them in a salt solution (brine), or by mixing them with salt crystals and topping the mixture with brine.
The curing of salted fish may be done in several ways, which are basically variations of pickling/brining and staking (kenching). In kench salting, split fish are piled into stakes where fish and salt layers alternate. As the fish muscle absorbs salt, water diffuses from the flesh and a pickle forms that is allowed to drain off. In pickle salting the fish is also salted with dry salt but the fish is kept in vats so that the water which diffuses from the fish forms strong brine as the salt dissolves in it (van Klaveren and Legendre 1965). In brine salting the fish is immersed for 1-5 days in brine which usually has a salt concentration of 16-18%. A new method of salting is salt injection, were needles are used to inject brine into the fish muscle. Brine salting and the brine injection give the best utilization of salt but brine injection is more sensitive to contamination and temperature. The brine salting method has been used increasingly in Iceland. After brine salting/pickle salting the fish is usually dry salted for 10-12 days and then packed and stored. Before consumption, the fish is soaked in water for rehydration and desalting.

2.5 Traditional brining methods of Sri Lanka

In Sri Lanka fish is generally marketed fresh. The manufacture of dried fish with or without salting is of considerable importance. Sun drying without salting is limited to very small fish and shellfish, especially shrimp. The fish is dried whole on the hot sandy beach. Salting and sun drying are applied to all other species. The fish are gutted, split, incised, and salted. The moisture is drained off, and the product is washed in seawater and sun dried for 3-5 days.

Eviscerated fish with gills removed and washed in 10% saline solution are satisfactorily kept in saturated brine if 2% citric acid (using lemon juice) was added to control pathogenic microbes and to aid in the initial salt penetration (Gunasekara et al. 1956). Salting and wet curing with ultimate sun drying are also practised. Whole small fish and scaled, eviscerated, and filleted large fish are placed in barrels of concentrated brine, to which dried pericarp of goraka (*Garcenia gambogia*) is added. This ingredient decreases the sharp taste of the salt in the cured product. Salt is added repeatedly. In dry weather, small fish are removed from the brine and sun dried during the day and returned to the brine at night.

Maldives fish, especially skipjack tuna (*Euthunnus pelamis*), are gutted and cut into thick chunks. A broth is made by boiling with goraka in half diluted seawater. The chunks of fish are placed in the boiling broth for 10 minutes, removed, rolled in wood or coconut leaf ash, smoked for a few days and sun dried (Venkatharaman and Sreenivasan 1959). This product is called Maldives fish because this kind of processed fish is imported in large quantities from the Maldive Islands to Sri Lanka.

Until now adequate attention has not been paid to the development of these ancient methods. The tropical climate inhibited development, because spoilage is common in salting fish. The reduction of the pH of brine solution using citrus or dried pericarp of goraka (*Garcenia gambogia*) indicates that people knew how to prevent spoilage. Further development and research on salting fish in Sri Lanka should be based on the spice salting methods using natural preservatives such as goraka.

3. MATERIALS AND METHODS

3.1 Materials

The herring (*C. harengus*) used in this study was caught between the Faroe Islands and Iceland in June 1999. The fish was stored in refrigerated sea water tanks on board the vessel. The herring was filleted (butterfly fillets) at SVN in Neskaupstad, 40 hours after being caught, and block frozen at -24°C. All the fillets were similar in size. The blue whiting were caught east of Iceland in August 1999, beheaded, gutted and frozen in blocks. A minimum of 15 herring and 21 blue whiting were used for each batch (Appendix 12).

3.2 The salting

Refined marine salt (Torre salt) imported from Torrevieja, Spain, was used to salt the fish in plastic containers, which are used for experimental trials at the Icelandic Fisheries Laboratories.
Specimens of the two species, received as frozen blocks more than 5 weeks after capture, were thawed at room temperature for 10 hours before brining. The experimental process is shown in Figure 3.
Brining was carried out using 10%, 15% and 20% salt (NaCl) brine. The ratio of brine to fish was maintained at 1.6 kg for each 1 kg of fish for three groups. In addition, one further trial in 20% solution was carried out with 1:1 fish to brine ratio (Table 2).
All fillets were tagged with plastic numbers and the weight of each fillet was recorded at the end of each procedure. Fish were kept in brine in plastic containers. Approximately 2.5 kg of fillets were cured in each group. Brining was done at 5°C for 36 $\pm$ 2 hours. Brined fillets were drained for 5-10 minutes and then dredged with salt and placed in plastic boxes for 10 days for further dry salting. After 10 days, the fish were stored in cardboard boxes at the same temperature for 20 days. The temperature was the same throughout the whole process.
Two groups (20% 1:1.6 and 10% 1:1.6) from trial 1 (herring 1 and blue whiting 2) were taken for rehydration. From each group six fish were soaked in water with 1:4 fish:water ratio and kept at 0°C. Twenty four hours later the fish were drained for 5 minutes and weighed. The fish was then put in new water and soaked for another 24 hours at the same temperature.Then two samples were taken from each group for chemical analysis. Water samples were also taken for analysis after each step.

In all steps of salting the yield was calculated by the formula

$$\% \text{ Yield} = \frac{\text{Weight after process} * 100}{\text{Weight of raw material}}$$

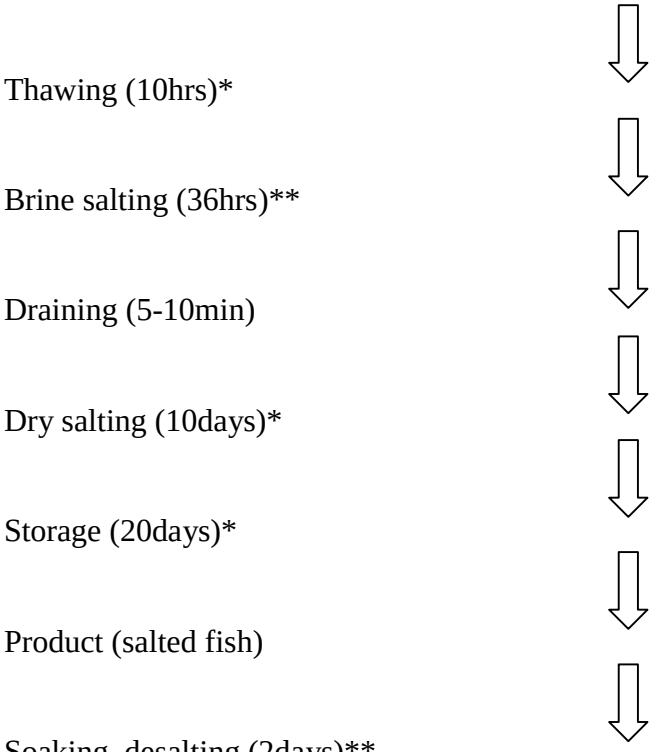
Table 2: The plan of the experiment.

		Trial 1		Trial 2	
	Ratio	Herring 1	Blue whiting 1	Herring 2	Blue whiting 2
groups	1:1.6	10%	10%	10%	10%
		15%	15%	15%	15%
		20%	20%	20%	20%
	1:1	20%	20%	20%	20%

The chemical composition, when determined as percentages can sometimes be misleading because all these results are strictly relative. In order to follow the changes in each chemical component the recovery yield (for the component) was calculated as follows.

$$\% \text{ Recovery yield} = \frac{\text{Mass of the chemical component in the sample} * 100}{\text{Mass of the chemical component in the sample of raw material}}$$

The mass of each chemical component (moisture, fat, protein and salt) was determined at the beginning of each step and during each step of the salting process. The mass of chemical matter of raw material was taken as initial mass and the reduction or increase of the mass in each step of salting was calculated as a percentage. That value gives the recovery yield.
Pairwise comparison (t-test) was used when determining differences with significant defined at the 95% confidence level ($p<0.05$) (Sokal and Rohlf 1981).



* steps, at the end of which weight should be recorded and flesh samples taken for chemical analysis
** Steps where except * , Before and after brine samples should be taken for chemical analysis

Figure 3: The flow diagram of the experiment

3.3 Sampling

Samples were collected through the whole process, from the beginning of the salting and after each processing step. Blue whiting and herring were weighed after draining the

containers. Before brining, fish samples (raw material) were checked for pH, protein, fat, salt and water contents. Samples of flesh were taken from each batch at the end of each procedure as well as 100 ml of brine solution for chemical analysis. Two whole fillets were removed from each group of samples for this purpose. The samples for the chemical analysis were frozen immediately and stored at –24°C, until the measurements could take place. Prior to storage, the samples were skinned by hand. Before the chemical analysis, samples were minced in a Braun mixer (type 4262, Germany).
When taking samples from fillets or whole fish, it is important to remember that in addition to interstitial fat deposits, herring characteristically have a layer of fat just under the skin.

3.4 Chemical analysis

3.4.1 Salt content of muscle and brine

Salt content was determined by the volumetric method of Volhard (AOAC 937 09-1990). Five grams of minced flesh were weighed accurately into a conical flask and 200 ml of distilled water added. The flask was placed on an electric shaker for 45 minutes. The supernatant was used for titration. 20 ml solution was pipetted into an Earlinmeyer flask and the chloride ions precipitated by adding 5-10 ml of 0.1N $AgNO_3$. The excess $AgNO_3$ was backtitrated with 0.1N NH_4SCN solution, a ferric indicator ($FeNH_4(SO_4)_2*12H_2O$ in diluted HNO_3) was added for determination of the end point, when a fair red brownish colour appeared. The salt content was calculated as percentage of the sample.
The salt concentration of the brine was determined by the Volhard method. A 0.2 g sample of the brine was weighed in Earlinmeyer-flasks and 5-12 ml $AgNO_3$ added. The sample was then titrated directly.

3.4.2 Moisture content of muscle

An inert sand and glass rod was added to a porcelain dish and weighed accurately. Approximately 5 g of fish mince were accurately weighed into the dish and mixed with the sand. Moisture content (g/100g) was calculated as the loss in weight, after drying at 105°C for 4 hours (ISO6496-1983).

$$\text{Moisture content} = \frac{\text{m (dried sample + dish +sand + glass rod) - m (dish +sand +glass rod)*100}}{\text{M(sample + dish + sand + glass rod) - M (dish +sand + glass rod)}}$$

3.4.3 Acidity (pH) of muscle and brine

The pH of both muscle and brine was determined with a combination glass electrode, pH meter at room temperature. The pH of the muscle was measured by inserting the electrode directly into the fillet mince, according to the method of Kramer and Peters (1981). Another possibility is to mix the mince with distilled water (1:4) and measure the pH in the slurry after 5-10 min equilibration (Ingólfsdóttir 1998). The pH of the brine was measured directly at room temperature.

3.4.4 Analysis of protein content in muscle and brine

The nitrogen content of the fish muscle and brine was measured with the Kjeldahl method (ISO 5983-1979) with changes for Tecator apparatus from SSF Norway. 1-2 g of minced fish and 10-12 g of brine were weighed accurately into a 200 ml digestion flask. Two catalyst tablets (each containing 0.4 g $CuSO_4$ and 3.5 g K_2SO_4) and 17.5 ml of concentrated sulfuric acid (H_2SO_4) were added and the content mixed thoroughly. The flasks were placed on a digestion system (No 2020, Tecator, Sweden) and the samples digested by heating them to 210°C in 15 min and maintaining 210°C for 30 min. Then the sample was heated to 420°C in 30 min and kept at 420°C for 2 ½ hours. After digestion the nitrogen was in the form of ammonium (NH_4^+) ions. The flasks were allowed to cool and 75 ml of distilled water added. Before being placed in the Autosampler system (Kjeldahl Autosampler system 1035, Tecator, Norway), where 90 ml of 40% sodium hydroxide solution were added into each flask. Then the distillation of ammonia (NH_3) was started in 1% boric acid (H_3BO_3). The nitrogen content was determined by an automatic titration with a 0.2N H_2SO_4.

The protein content was calculated as;

$$\% \text{ Nitrogen} = \frac{\text{ml } H_2SO_4 * NH_2SO_4 * 14 \text{ g/mol} * 100}{\text{g (mass of sample)} * 1000}$$

and

$$\% \text{ Protein} = \% \text{ Nitrogen} * 6.25$$

3.4.5 Muscle Fat

The muscle fat content was determined by the AOCS official method Ba 3-38 (1989) and by using petroleum ether, with modifications according to the Icelandic Fisheries Laboratories. First a dry Soxlet flask was weighed accurately. A 5 g sample of minced fish was dried before being placed in an Whatman cellulose extraction thimble and placed into a Soxlet extraction tube. The Soxlet extraction tube was fixed on the Soxlet flask with petroleum ether. After assembling the apparatus (soxlet flask, soxlet extraction tube and water-cooled condenser), it was placed on an electric hot plate for four hours.

The cellulose thimble was then removed and the apparatus placed on an electric hot plate to evaporate the extra ether which was collected for further usage. Only the fat remained in the Soxlet flask, which was then extracted from the sample. The Soxlet flask was placed in an oven for 20 min, and used to a sucker remove any remaining ether. Then the flask was weighed accurately.
The fat content was calculated as;

$$\text{Fat \%} = \frac{(\text{weight of flask with fat} - \text{weight of flask}) * 100}{\text{Weight of the sample}}$$

4. RESULTS

During the salting process, some changes in chemical content of the flesh occur, mainly in salt and water content, and consequently, in the weight of the fish. This chapter presents the major changes in weight, salt uptake, and the results of chemical analysis of all trials of the two fish species that were salted, herring and blue whiting.

4.1 Weight changes

Fillets in all the groups increased in weight at the brine salting step, but the weight decreased during dry salting and storage period (Table 3).

Table 3: Average yield (%), standard deviations and number of samples in parenthesis of herring fillets, and headed and gutted blue whiting after each processing step as percentage of fresh weight.

	20% 1:1	20%1:1.6	15% 1:1.6	10 1:1.6
Herring 1				
After brining	116,2±2,3(15)	114,1±2,9(15)	121.0±3,4(16)	122,6±2,3(16)
After dry salting	97,1±1,9(13)	97,9±2,3(13)	97,3±2,1(14)	95,8±1,6(14)
After storage	94,7+2,6(11)	95,6+2,3(11)	94,9+2,0(12)	93,7+2,0(12)
Herring 2				
After brining	116,0±1,5(16)	113,±2,2(16)	120,4±2,3(16)	121,8±2,6(16)
After dry salting	98,3±1,4(14)	97,4±1,2(14)	99,2±1,7(14)	97,2±1,8(14)
After storage	96,6±1,5(12)	95,7±1,5(12)	97,1±1,6(12)	95,8±1,4(12)
Blue whiting 1				
After brining	109,7±2,3(23)	110,2±2,7(23)	113,6±2,1(23)	117,7±3,1(26)
After dry salting	91,9±2,2(21)	92,1±2,5(21)	91,7±1,9(21)	92,2±1,9(24)
After storage	88,4±2,5(19)	89,5±2,2(19)	88,7±2,1(19)	88,7±2,0(22)
Blue whiting 2				
After brining	111,9±2,7(21)	110,1±2,1(21)	113,7±3,1(21)	117,2±2,6(21)
After dry salting	90,6±2,0(19)	91,1±1,9(19)	91,3±2,5(19)	91,6±3.0(19)
After storage	89,2±1,9(17)	89,2±1,7(17)	88,8±2.0(17)	88,5±2,0(17)

Two fillets or fish from each group were collected for chemical analysis in each step of salting, so the number of fillets weighed decrease in the process.

4.1.1 Yield changes after brining

All treatment groups showed a considerable increase in weight after brining, varying from 9-22%. A difference was also found between different groups in the same trial (t-test, $p<0.05$).
The yield gain was significantly higher in fish brine salted with higher fish to brine ratio in all trials except in blue whiting 1 (Figure 4).

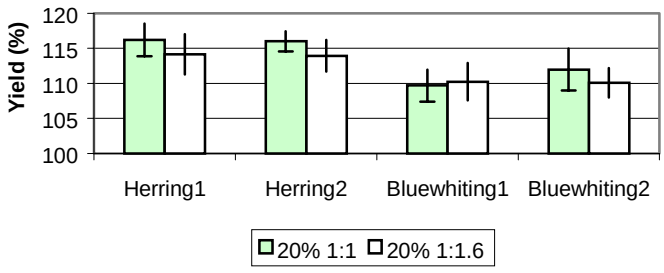


Figure 4: Yield of herring fillets and whole blue whiting after brine salting in two different ratios.

The yield among three different concentrations of the brine with the same fish: brine ratio shows that both trials gained weight in the same pattern (Figure 5). Lower salt concentration of brine was resulted in higher yields of the fish. For both trials of herring there was no significant difference between the yield of fish in 15% brine solutions and in 10% brine solutions ($p>0.05$). There was a significant difference among other groups in the same trial ($p<0.05$).

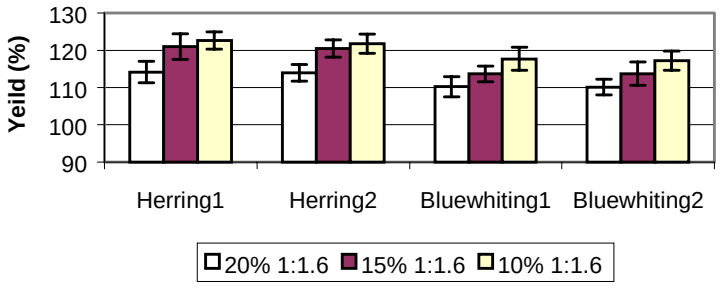


Figure 5: Yield of blue whiting and herring after brine salting in three different concentrations.

4.1.2 Yield changes after dry salting

After 10 days of dry salting all groups within the trial weighed less than the fresh fish had originally (Table 2, Figure6). There was no significant difference among groups within trials except for herring 2 where the group brine salted in 15% concentration weighed more than the others (Anova, $p<0.05$).

After the dry salting, there was no difference between groups, which were salted with different fish:brine ratios in 20% brine solution. The herring fillets originally brine salted in the lowest concentration were significantly lighter after dry salting then the other two treatments in trial 1 (t-test, $p<0.05$). In trial 2 herring originally brine salted in 15% was also significantly heavier than fillets in the other two treatments. Neither trial of blue whiting showed a significant difference in yield after dry salting (Figure 6).

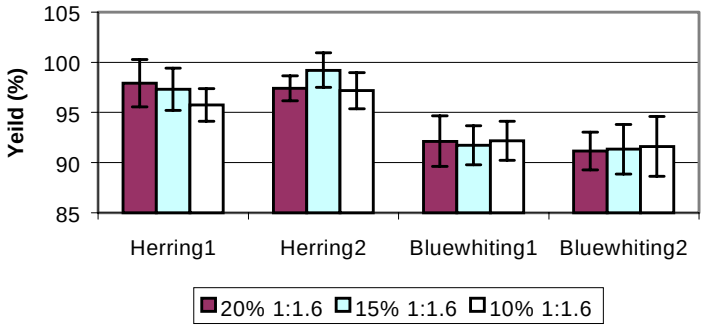


Figure 6: Yield of the groups previously brined in different concentrations in all trials after dry salting.

4.1.3 Yield after storage

After 20 days of storage the yield of all groups in each trial was almost equal. There was no significant difference between groups within trials (Figure 7). No significant difference was seen between groups among blue whiting trials (t-test, $p>0.05$). However, some groups in herring trial 1 showed yield difference compared with same treatment groups in herring trial 2 (t-test, $p<0.05$). There was significant difference between species in yield (t-test $p<0.05$), when comparing same treatment groups. Only trial 1 herring 20%1:1.6 group with trial 1 blue whiting 20% 1:1.6 showed insignificant difference in yield (t-test, $p>0.05$).

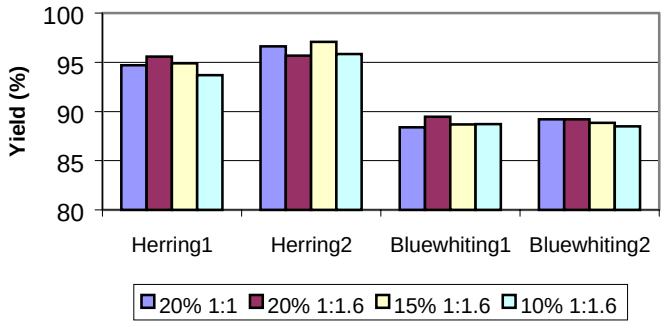


Figure 7: Yield of all trials after 20 days of storage.

4.1.4 Yield after rehydration

After 10-12 days of storage the fish was rehydrated and desalted by soaking in water. The change in the yield was determined. Two groups of each species from trial 1 (herring 1 and blue whiting 1) were taken for rehydration.
In the first 24 hours of the rehydration period herring and blue whiting absorbed water and gained weight. Blue whiting absorbed water faster than herring fillets. In the second 24 hrs of rehydration, herring fillets lost weight faster than the blue whiting ($p<0.01$,

Figure8). Herring gave less yield than blue whiting after 48 hrs of rehydration (Figure 9). There was no significant difference in yield between the groups brine salted in 20% solution of the two groups treated with 10% brine. Herring yielded insignificantly less after 48 hours rehydration than blue whiting (t-test, p>0.05).

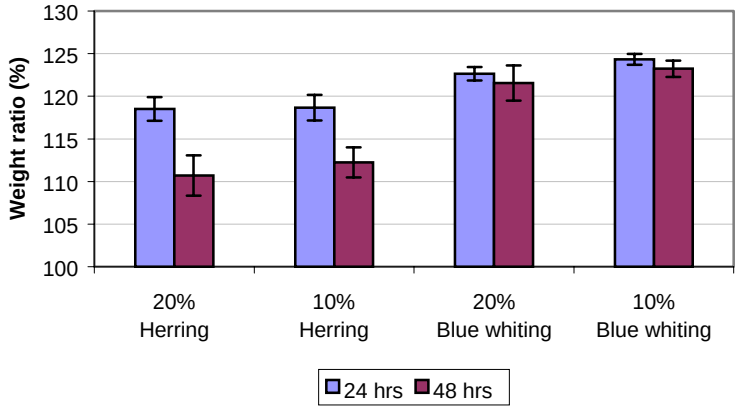


Figure 8: Weight changes during rehydration in 1:4 fish to water ratio at 0°C for 24 hours and 48 hours, as an initial weight, weight before rehydration was applied.

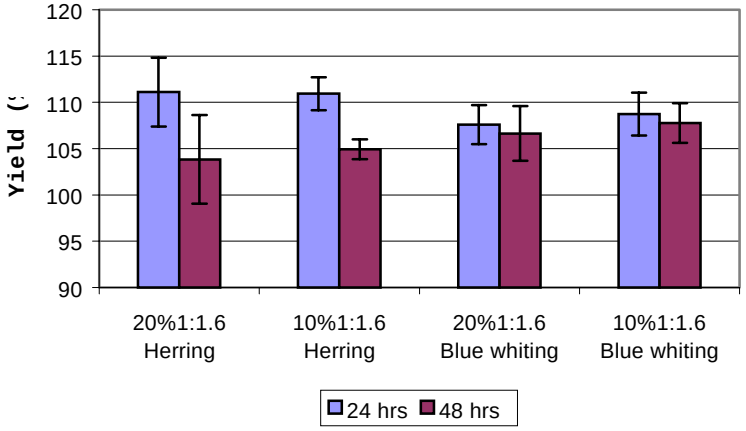


Figure 9: The yield after rehydration in 1:4 fish to water ratio at 0°C for 24 hrs and 48 hours for herring 1 and blue whiting 1

4.2 Changes in chemical composition

The quantity of water, fat, salt, protein and pH changed in the fish muscle at all stages of the salting process. The chemical content of the raw material in each species should have been similar in both trials, because fish from the same area was used for the experiment. Initial moisture content of blue whiting 1 and blue whiting 2 (raw material) was 79.48% and 78.48% respectively. At the end of the storage this value reduced to nearly 58%, while the salt content increased from 0.54% (raw material) to 20.77% after storage

(Appendix 1 Table 2). The raw material in herring 1 had lower fat content than is typical for herring caught in June. So for calculations, the fat content of herring 2 was used (Appendix 1, table 1). The reduction of salt content from the initial brine solution was identical in trial 1 and trial 2 for each species (Appendix 2).

4.2.1 Salt and water content changes

The salt content in fish muscle increased rapidly during the first 36 hours of brine salting for all groups in all trials (Figures 10 and 11).

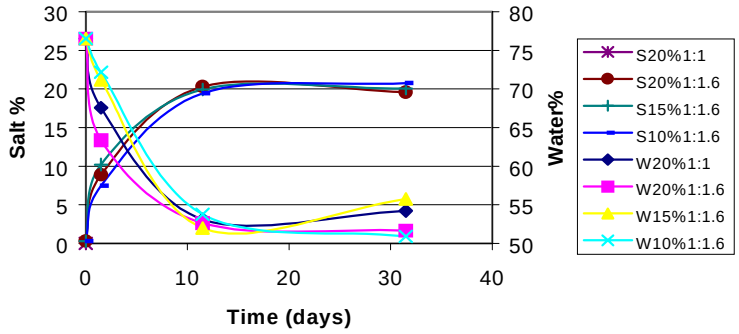


Figure 10: Change in salt and water content of the trial 1 herring during the whole salting process (S-Salt, W-Water).

The surrounding brine has a much higher salt content than the fish muscle. So the salt from the brine penetrates into the fish muscle until the fish muscle and the surrounding brine has reached an equilibrium (Voskresensky 1965).
The changes in salt content in the 2nd trial herring followed the same pattern as herring 1 (Appendix 4, Figure 1). Those changes are identical to the salt changes in blue whiting (Figure 11 and Appendix 4, Figure 2). The final salt contents after storage of herring fillets and blue whiting were almost the same, 18.75 %-20.77% for herring and 20.17%-20.89% for blue whiting.

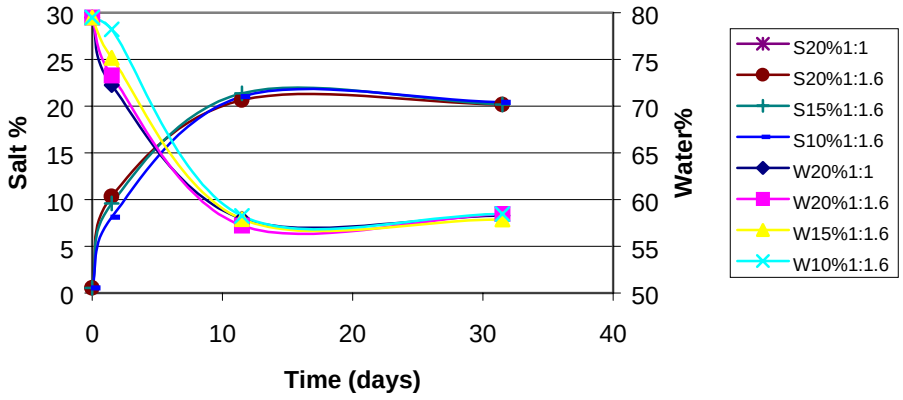


Figure 11: Change in salt and water content of blue whiting 1 during the whole salting process (S-Salt, W-Water).

The pattern observed in salt content after brining was similar for all groups (Figure 12 and Appendix 1, Tables 1 and 2). Groups brine-salted in lower concentrations had lower salt contents of muscle, while the group brine salted in 20% salt solution had the highest salt concentration. The fish to brine ratio 1:1.6 (20%) had higher salt content than the group with ratio 1:1 (20%) except for blue whiting 1 (Appendix 5, Figure 2).

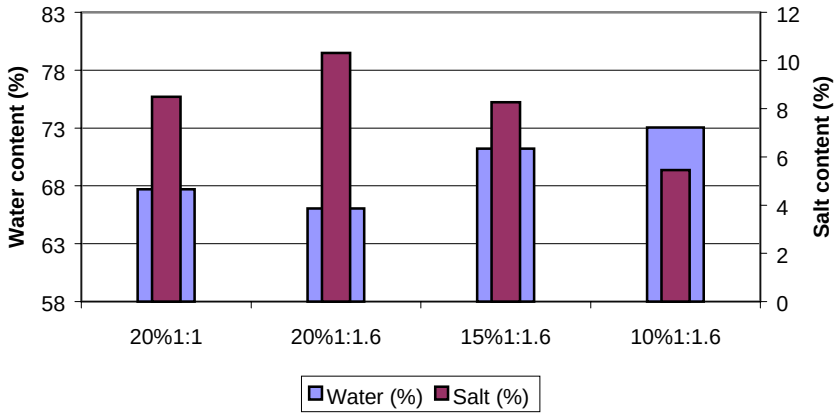


Figure 12: Salt and water content of the muscle of herring 2 after brining.

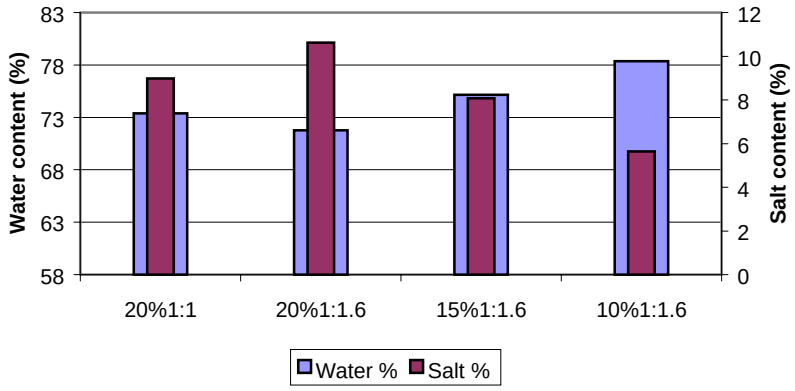


Figure 13: Salt and water content of the muscle of blue whiting 2 after brining.

All the groups decrease in water content during the first days after brine salting. The water content of herring and blue whiting decreased rapidly during the first two steps (brine salting and dry salting) of the salting process (Figure 10 and 11), but after that the decrease is slow. Comparison of the total value of water-fat contents and salt content for the same treatment (20% concentration) of both species (Figure 14), show that total water and fat content of blue whiting was less than in herring fillets. But changes in salt content

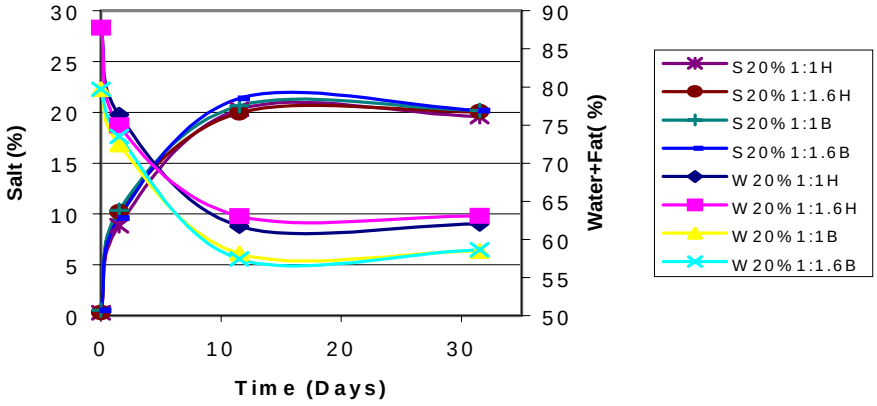


Figure 14: Changes in salt and total water- fat content with time for different ratios for both species (W = Water + Fat, S = Salt, H = Herring, B = Blue whiting).

were identical for all ratios and both species. The same pattern was observed for other salt concentrations (Figure 15).

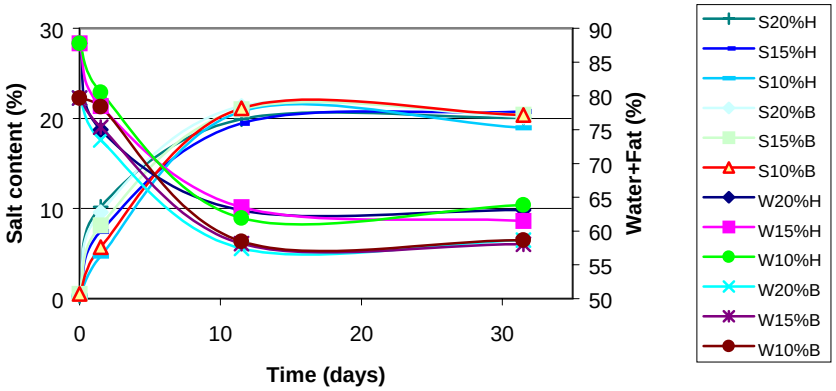


Figure 15: Changes in salt and the total water and fat contents for deferent concentrations for both species (W = Water + Fat, S = Salt, H = Herring, B = Blue whiting).

4.3 Changes in protein content

Protein was determined as total nitrogen using the Kjeldal method. In the fish muscle there are also non-protein nitrogen molecules. Non protein nitrogen accounts for 9.2-18.3% of the total nitrogen in teleost fishes. In the case of gadoids non protein nitogen is in the range of 16-18% (Simidu 1961).
Protein content of herring and blue whiting was stable during salting process. A small reduction in protein content of blue whiting was observed at the end of the brine salting process (Figure 16). Chemical analysis of brine solutions before and after brining shows that protein existed in the brine after brining, but not before (Appendix 2). Protein concentration in brine varied 1.38%-1.97% for herring and 0.96%-1.45% for blue whiting.

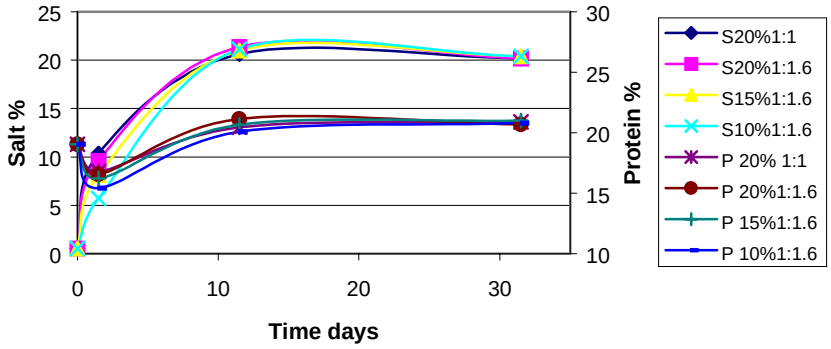


Figure 16: Changes in salt and protein of blue whiting 1.

4.3.1 Changes in fat content

The relative fat content of herring in trial 1 was less than half that in trial 2 (4.5% vs. 11.26%). The fat content of blue whiting was low and similar in both trials (0.12% vs. 0.17%). Fat content was only determined for herring throughout the curing process, and was found to increase after an initial reduction (Figure 17). The change was not related to the concentration of brine.

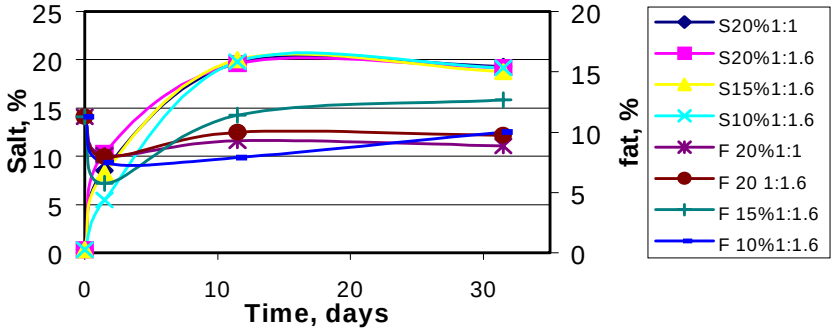


Figure 17: Changes in salt and fat of herring 2.

4.3.2 Changes in chemical composition after rehydration

After storage the moisture and salt content of herring 1 (20% 1:1.6) was 51.46% and 20.05% respectively. After 48 hours of rehydration the salt content was reduced to 0.96% and moisture content increased to 76.91% (Table 3). Similar results were observed for the 10% 1:1.6 group.

Table 4: Chemical composition of fish flesh after 48 hours of rehydration.

	%Protein	%Moisture	% Fat	% Salt	pH
Herring 1					
20%1:1.6	13.58	76.91	7.60	0.96	6.01
10%1:1.6	13.20	75.90	8.90	0.89	6.03
Blue whiting 1					
20%1:1.6	15.53	82.20	-	1.64	6.37
10%1:1.6	15.32	82.40	-	1.56	6.40

At the end of storage both groups of the trial blue whiting 1 had a moisture and salt content of around 53% and 19.19% respectively. During rehydration the salt content was reduced to 1.6% and moisture content increased to 82.3% (Table 3).

4.4 Recovery yield

Because of the large weight changes during salting, recovery yield may give a better idea of changes in chemical composition, than relative changes.
Recovery yield of water in herring trial 1 was positive for all groups except in the group brined in 20% 1:1.6 ratio (Figure18). This pattern was repeated in other trials with small variations (Appendix 9, Figures 1, 2, 3).

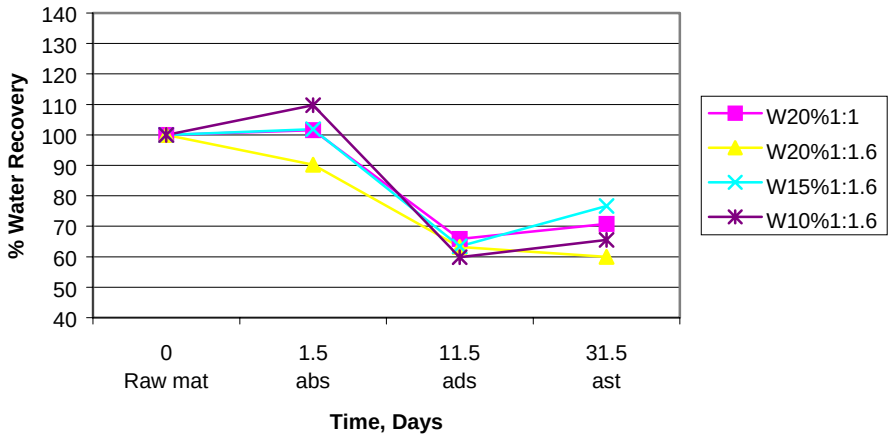


Figure 18: Recovery yield of water in herring 1 (W= Water, abs= After brine salting, ads= After dry salting, ast= After storage).

Recovery yield of salt during the brine salting stage reflects the concentration of the brine and the fish to brine ratio. At the end of the dry salting stage, recovery yield of salt was

similar for all groups. The initial treatment bears no relationship to the final recovery yield of salt at the end of storage (Figure19). The similar pattern was observed for all treatments (Appendix 10).

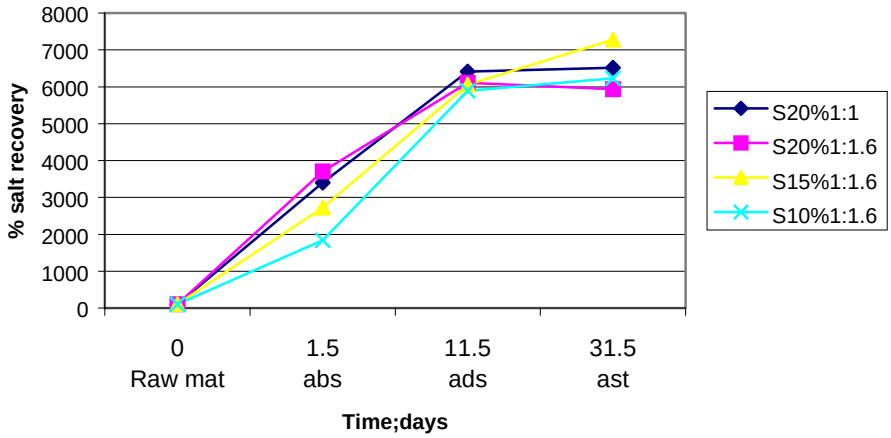


Figure 19: Recovery yield of salt in herring 1 (S= Salt, abs= After brine salting, ads= After dry salting, ast= After storage).

Protein was the most stable component during the salting process. The recovery yield of protein declined during brine salting in all trials (Figure 20).

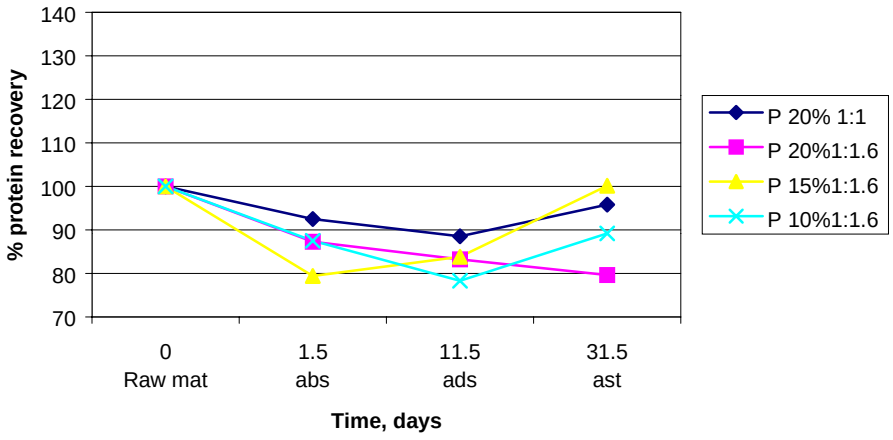


Figure 20: Recovery yield of protein in herring 1 (P= Protein, abs= After brine salting, ads= After dry salting, ast= After storage).

5. DISCUSSION

After the fish was kept in a brine solution, the mean weight of the fish increased. The weight increased in direct relation to the initial brine concentration in all cases except for blue whiting 2. As the brine concentration increases, the water loss from the muscle increases. The higher the salt concentration the less weight gained. The difference observed in blue whiting trial 2 could be due to the variation of raw material. These results do not agree with the results of Fougére (1952). In his study on cod muscle, the net extraction of water occurred when the brine concentration exceeded 12% and the fish to brine ratio 1:1. On the other hand Deng (1977) showed a concentration of 20% was needed for mullet (Mugil cephalus) fillets to observe a net weight loss. He explained the difference with higher lipid content in mullet fillets than cod fillets. Results on salt uptake during the brine salting period support the results of other researchers that salt uptake and weight gain or loss are directly proportional to the brine concentration (Aitken & Baines 1969, Ravesi and Krzynowek 1991). As the water is extracted from the fish muscle into the surrounding brine the salt starts to penetrate into the muscle (Voskresensky 1965). After brining the water and salt concentration were inversely proportional, with the highest water concentration observed in the groups subjected to the lower brine concentrations. The salt uptake after dry salting was not proportional to the previous brine concentrations.

It is noticeable that herring trial 1 had lower fat content than what is typical for herring in June (Einarsson 1988). At the same time recovery yield of fat was highly variable (Appendix 8, Figures 1 and 2). This could be because of the variation in fat content in the raw materials.

The protein content was reduced after brining. This would be due to leaching of water soluble proteins such as myogen (an albumin type protein) and salt soluble fractions, myosin (a globulin). Myosin constitutes about 75% to 80% of the total protein (Dyer et al. 1950). The protein content in brine solution after brining supports this interpretation.

To obtain an acceptable salted fish product at the end of the desalting and rehydration, the salt content should be about 0.8%-1.2%. At the end of rehydration herring fillets contained less salt than blue whiting. This can be partly explained by the fact that herring fillets were more exposed to the water than the headed, gutted blue whiting still protected by its skin.

It is important to point out that the water content of raw material of herring and blue whiting reduced from 68.7% and 79% to 52.9% and 58.2% at the end of storage, respectively (as a mean value for all groups). At the same time the salt content of herring and blue whiting increased from 0.30% and 0.53% to 19.45% and 20.41%. At the end of storage both species gained salt to similar level, irrespective of the moisture content of the raw material or the end product. Akse et al. (1993) in their study on pickle salting (for 7 days) followed by dry salting (for 17 days) of cod fillets found the salt content at the end of dry salting to be 20.7%. At the same time water content was 55.1%. From the present study it appears that there is no relationship between fat content and salt uptake. This contradicts the explanation of other researches (Zaitzev et al. 1965, Burgess and Bannerman 1963). The discrepancy might be due to the different preparation of the herring and blue whiting samples. This would be a subject for further study.

6. CONCLUSION

Fat content of fish appears to have little effect on salt uptake. It is of interest to note that at the end of the storage period the salt content of herring and blue whiting were identical. Neither keeping the fish in different brine concentrations nor keeping in the different ratios affected the salt concentration of fish muscle on further dry salting and storage. Therefore it is more economical to apply a 1:1 fish to brine ratio for the fish salting industry than a 1:1.6 ratio.
Further studies on salting fatty fish and lean fish with different concentrations and ratios to verify these results and more accurately determine the most economical fish to brine ratios would be useful.

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APPENDIX 1: DATA ON THE CHEMICAL COMPOSITION AND PH IN HERRING AND BLUE WHITING FOR ALL GROUPS AND ALL STAGES OF SALTING.

Table 1: Herring.

		% Protein	% Moisture	% Fat	% Salt	pH
Herring1	Raw material	17.34	76.50	4.5	0.30	6.28
After Brining	20% 1:1	13.95	67.58	8.76	8.88	5.90
	20% 1:1.6	13.88	63.35	11.64	10.20	5.87
	15% 1:1.6	12.58	71.16	7.34	7.47	5.93
	10% 1:1.6	13.04	72.16	8.39	4.74	6.02
After dry Salting	20% 1:1	16.19	53.10	8.65	20.29	5.73
	20% 1:1.6	15.69	52.62	10.45	19.93	5.72
	15% 1:1.6	15.57	51.98	11.56	19.45	5.73
	10% 1:1.6	15.95	53.77	8.14	20.77	5.75
After Storage	20% 1:1	16.63	54.19	7.85	19.57	5.69
	20% 1:1.6	15.55	51.64	11.45	20.05	5.72
	15% 1:1.6	16.52	55.77	5.71	20.77	5.73
	10% 1:1.6	15.69	50.89	12.97	18.97	5.77
Herring 2	Raw material	18.13	68.73	11.26	0.30	6.20
After Brining	20% 1:1	14.64	67.70	8.08	8.49	5.92
	20% 1:1.6	14.14	66.06	7.96	10.32	5.85
	15% 1:1.6	13.45	71.22	5.75	8.27	5.93
	10% 1:1.6	12.96	73.03	7.48	5.46	5.98
After dry Salting	20% 1:1	16.70	52.70	9.30	19.70	5.67
	20% 1:1.6	16.80	52.10	10.00	19.60	5.62
	15% 1:1.6	15.90	51.50	11.40	20.00	5.69
	10% 1:1.6	17.20	53.30	7.90	19.80	5.71
After Storage	20% 1:1	16.90	53.25	8.88	19.33	5.70
	20% 1:1.6	16.80	52.89	9.72	19.21	5.69
	15% 1:1.6	16.00	51.38	12.70	18.75	5.72
	10% 1:1.6	16.20	53.16	10.00	19.16	5.74

Table 2: Blue whiting.

		% Protein	% Moisture	% Fat	% Salt	pH
Blue whiting1	Raw material	19.05	79.48	0.12	0.54	6.67
After brining	20% 1:1	16.79	72.27	0.22	10.35	6.30
	20% 1:1.6	16.55	73.30	0.27	9.6	6.33
	15% 1:1.6	16.22	75.16	0.56	8.13	6.43
	10% 1:1.6	15.42	78.20	0.09	5.73	6.43
After dry salting	20% 1:1	20.46	57.96	-	20.65	6.19
	20% 1:1.6	21.15	57.21	-	21.37	6.19
	15% 1:1.6	20.67	57.92	-	21.01	6.20
	10% 1:1.6	20.09	58.27	-	21.13	6.25
After storage	20% 1:1	20.90	58.3	-	20.17	6.22
	20% 1:1.6	20.70	58.4	0,20	20.17	6.23
	15% 1:1.6	21.00	57.9	-	20.41	6.18
	10% 1:1.6	20.80	58.5	-	20.39	6.26
Blue whiting 2	Raw material	20.24	78.48	0.17	0.51	6.61
After brining	20% 1:1	17.12	73.37	-	8.97	6.38
	20% 1:1.6	17.18	71.78	-	10.63	6.32
	15% 1:1.6	16.36	75.15	0.30	8.07	6.36
	10% 1:1.6	15.65	78.35	-	5.64	6.49
After dry salting	20% 1:1	19.67	58.5	-	21.13	6.21
	20% 1:1.6	21.03	57.6	-	20.53	6.27
	15% 1:1.6	21.48	57.2	-	20.53	6.20
	10% 1:1.6	20.22	58.2	-	21.01	6.26
After storage	20% 1:1	21.60	57.8	-	20.41	6.23
	20% 1:1.6	21.10	58.19	-	20.70	6.28
	15% 1:1.6	20.30	58.64	-	20.89	6.33
	10% 1:1.6	21.70	57.80	-	20.17	6.19

APPENDIX 2: PROTEIN CONTENT, SALT CONTENT AND PH OF BRINE SOLUTION BEFORE AND AFTER BRINING.

	Protein	Salt		pH	
	After brining	Before brining	After brining	Before brining	After brining
Herring 1					
20% 1:1	1.93	19.63	11.93	8.25	5.80
20% 1:1.6	1.42	19.63	14.14	8.25	5.78
15% 1:1.6	1.56	14.60	10.38	8.36	5.83
10% 1:1.6	1.55	9.73	7.09	8.42	6.00
Herring 2					
20% 1:1	1.97	19.15	11.68	8.18	5.84
20% 1:1.6	1.38	19.15	13.97	8.18	5.81
15% 1:1.6	1.47	14.48	10.57	8.32	5.90
10% 1:1.6	1.56	9.70	7.21	8.37	5.99
Blue whiting 1					
20% 1:1	1.02	19.35	11.42	8.20	6.45
20% 1:1.6	1.40	19.35	13.82	8.20	6.48
15% 1:1.6	1.04	14.54	10.61	8.14	6.52
10% 1:1.6	1.18	9.95	6.99	8.12	6.61
Blue whiting 2					
20% 1:1	1.45	19.54	12.01	8.16	6.48
20% 1:1.6	0.96	19.54	14.03	8.16	6.49
15% 1:1.6	1.02	14.69	10.73	8.36	6.52
10% 1:1.6	1.06	9.67	7.19	8.35	6.58

APPENDIX 3: SALT CONTENT AND PH OF WATER USED FOR REHYDRATION OF FISH.

	24 hrs		48 hrs	
	salt	Ph	salt	Ph
Herring 1				
20%1:1.6	3.97	5.99	0.86	6.23
10%1:1.6	4.16	5.99	0.84	6.28
Blue whiting 1				
20%1:1.6	4.2	6.69	0.97	6.69
10%1:1.6	4.07	6.69	0.93	6.9

APPENDIX 4

Changes in salt and water content of herring 2 and blue whiting 2 during the whole process of salting (S-Salt, W-water).

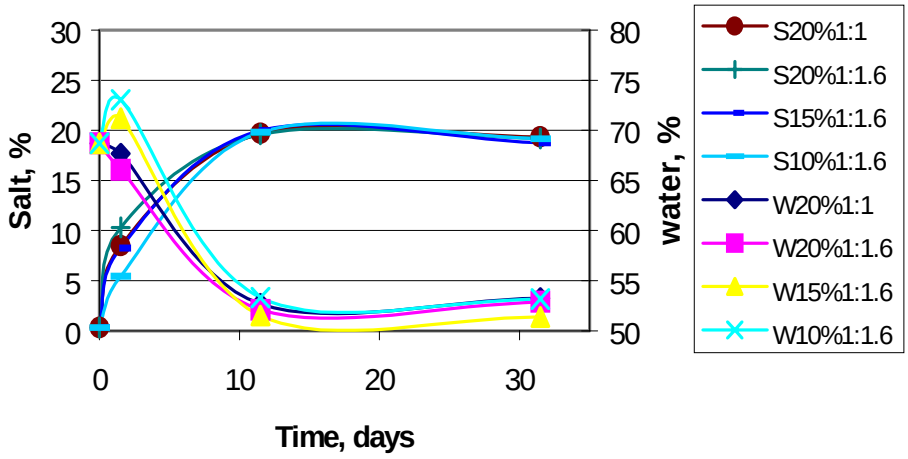


Figure 1: Herring 2.

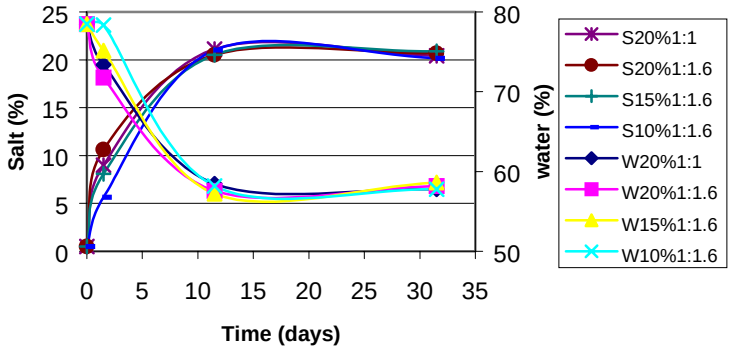


Figure 2: Blue whiting 2.

APPENDIX 5: CHANGES IN SALT AND WATER CONTENT OF HERRING 1 AND BLUE WHITING 1 AFTER BRINE SALTING.

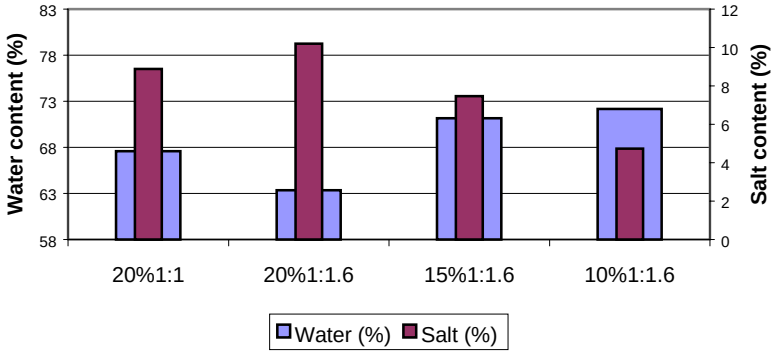


Figure 1: Herring 1

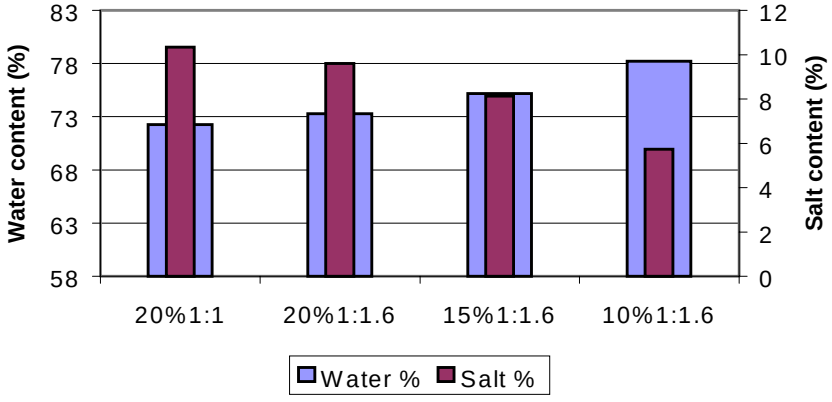


Figure 2: Blue whiting 1.

APPENDIX 6: CHANGES IN SALT AND PROTEIN OF HERRING 2, HERRING 1 AND BLUE WHITING 2 DURING WHOLE SALTING PROCESS.

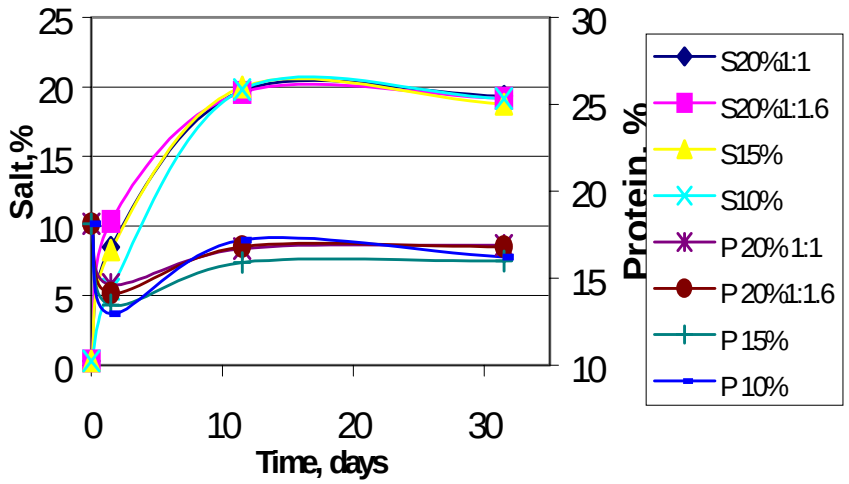


Figure 1: Herring 2.

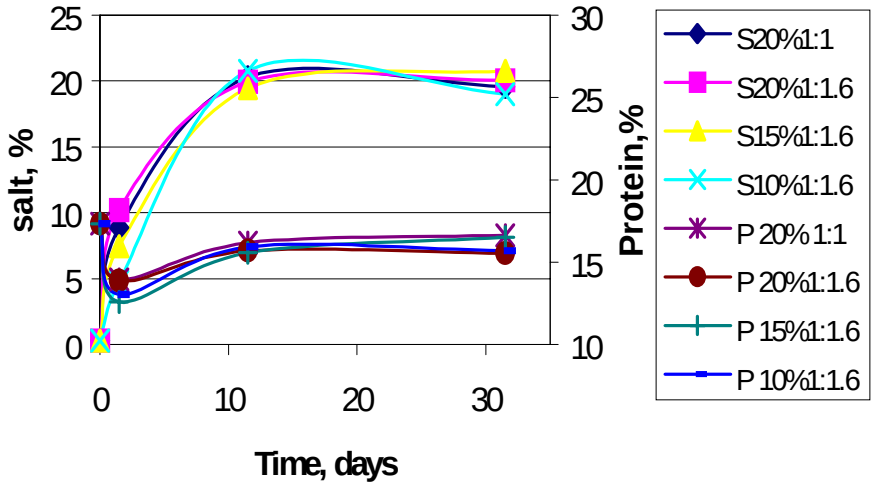


Figure 2: Herring 1.

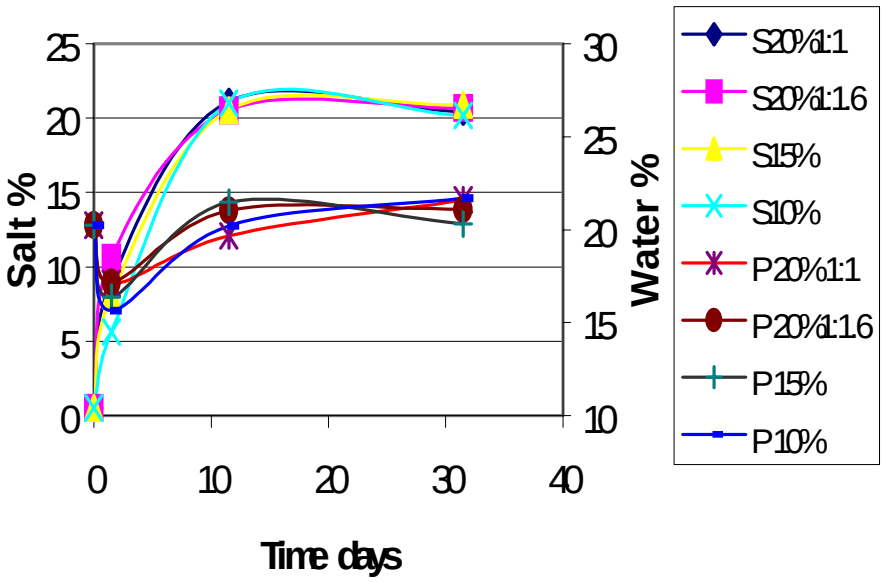
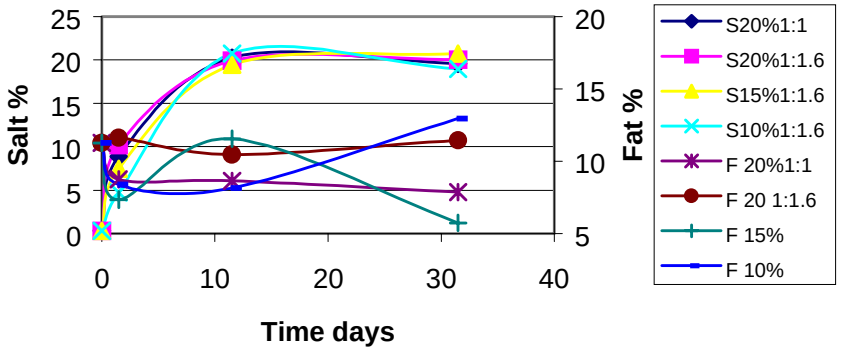


Figure 3: Blue whiting 2.

APPENDIX 7: CHANGES IN BETWEEN SALT AND FAT OF FILETS HERRING 1.



APPENDIX 8: RECOVERY YIELD OF FAT IN HERRING 2 AND HERRING 1 (F= FAT, ABS= AFTER BRINE SALTING, ADS= AFTER DRY SALTING, AST= AFTER STORAGE).

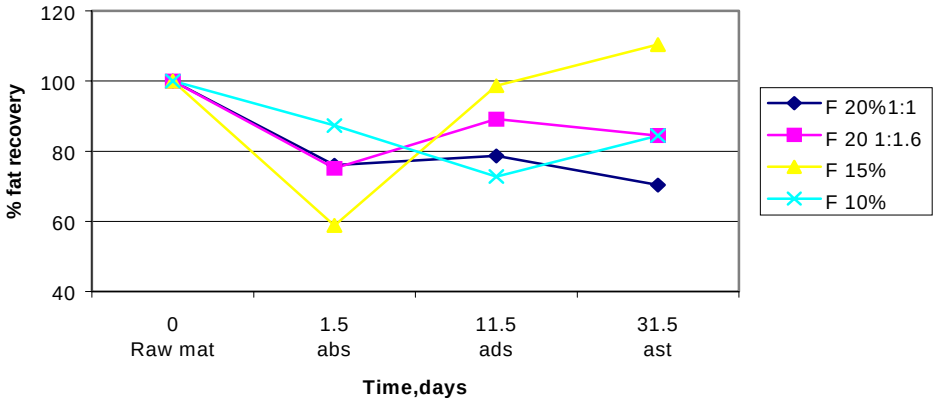


Figure1: Herring2.

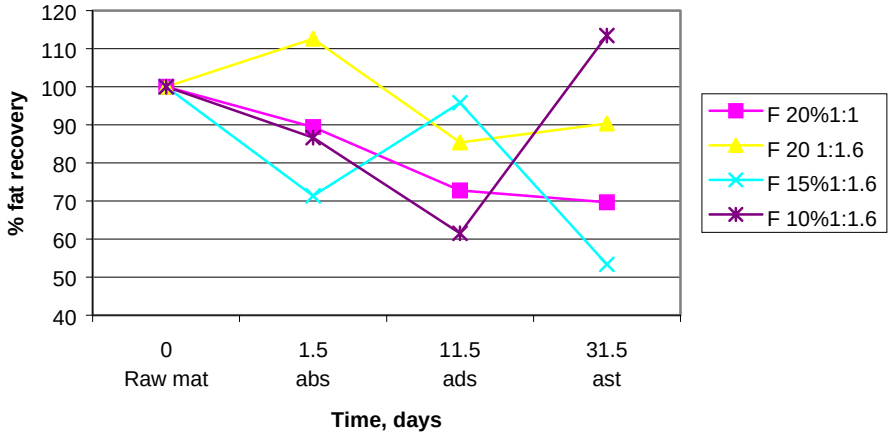


Figure 2: Herring 1.

APPENDIX 9: RECOVERY YIELD OF WATER IN HERRING 2, BLUE WHITING 1 AND BLUE WHITING 2 (W= WATER, ABS= AFTER BRINE SALTING, ADS= AFTER DRY SALTING, AST= AFTER STORAGE).

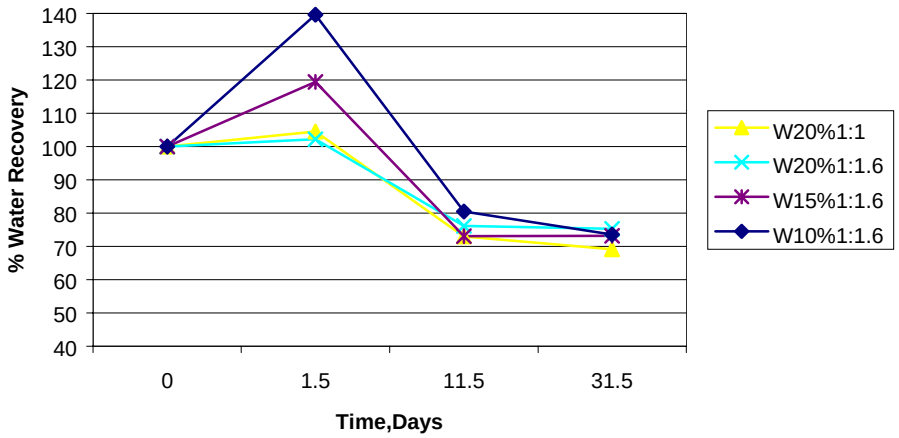


Figure 1: Herring 2.

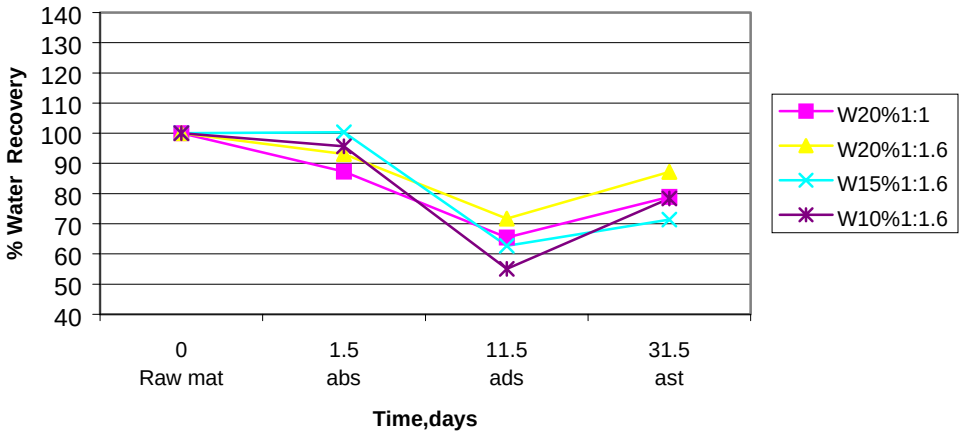


Figure 2: Blue whiting 1.

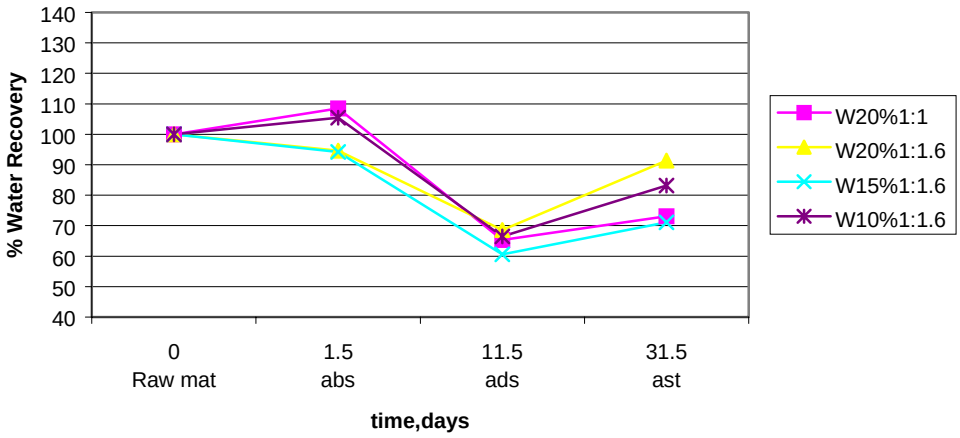


Figure 3. Blue whiting 2

APPENDIX 10: RECOVERY YIELD OF SALT IN HERRING 2, BLUE WHITING 1 AND BLUE WHITING 2 (S= SALT, ABS= AFTER BRINE SALTING, ADS= AFTER DRY SALTING, AST= AFTER STORAGE).

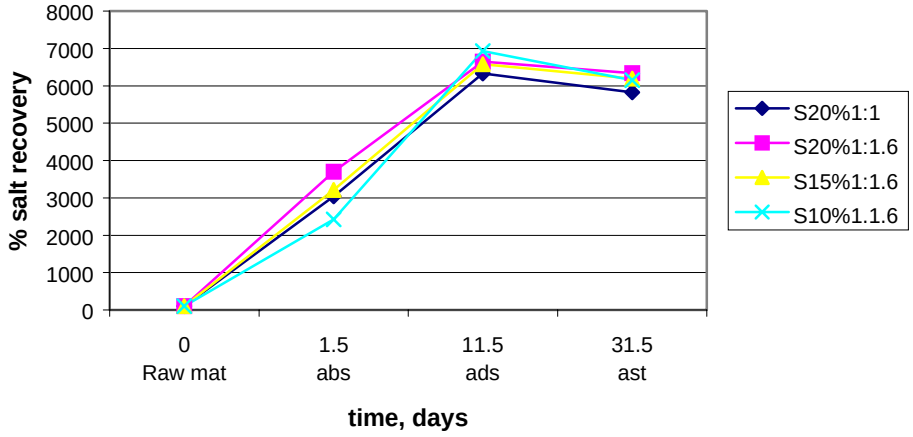


Figure 1: Herring 2.

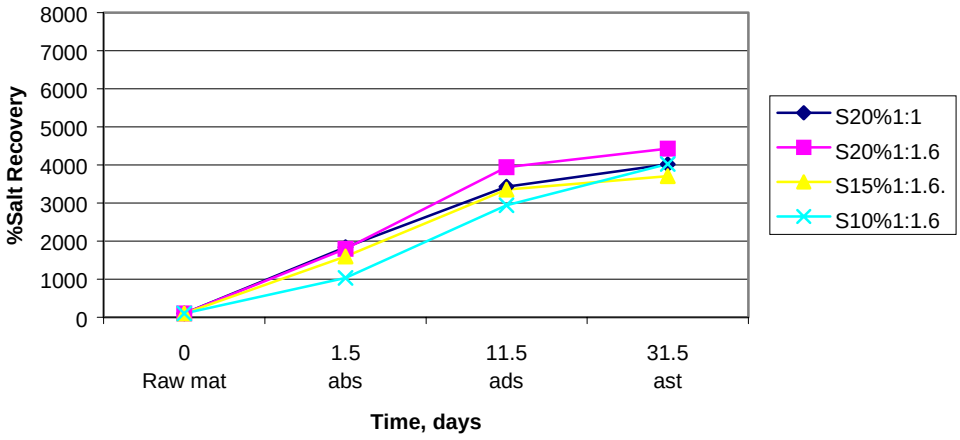


Figure 2: Blue whiting 1.

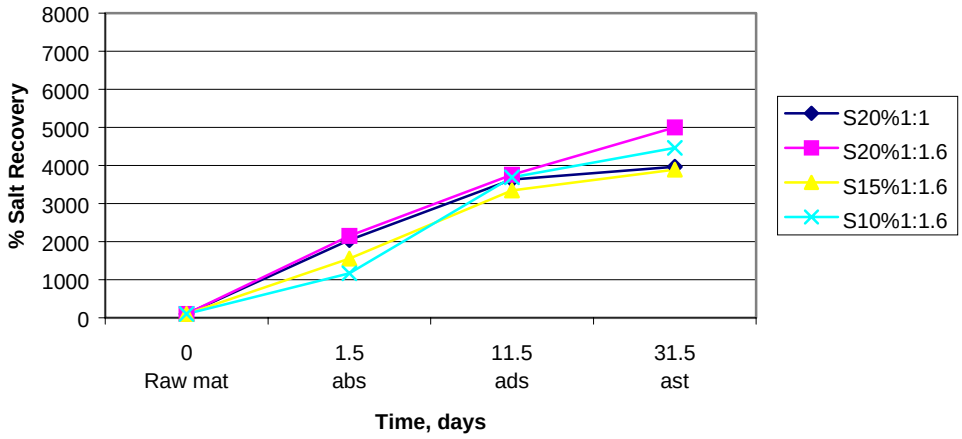


Figure 3: Blue whiting 2.

APPENDIX 11: RECOVERY YIELD OF PROTEIN IN HERRING 2, BLUE WHITING 1 AND BLUE WHITING 2 (P= PROTEIN, ABS= AFTER BRINE SALTING, ADS= AFTER DRY SALTING, AST= AFTER STORAGE).

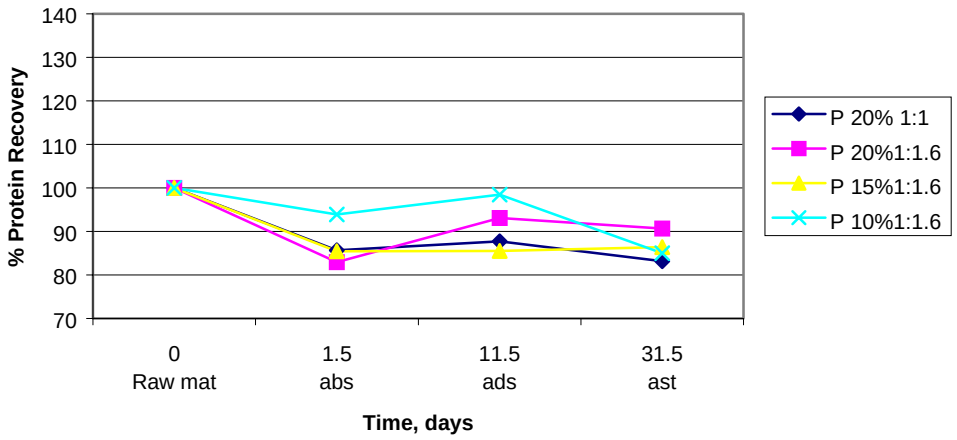


Figure 1: Herring 2.

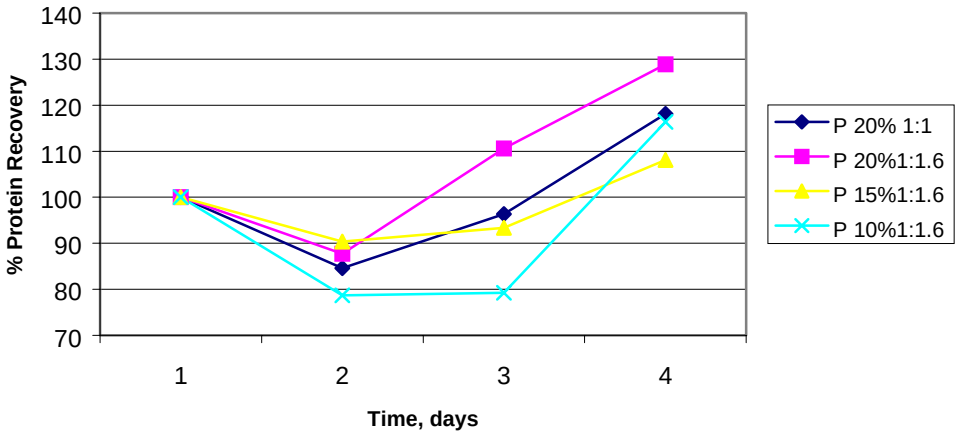


Figure 2: Blue whiting 1.

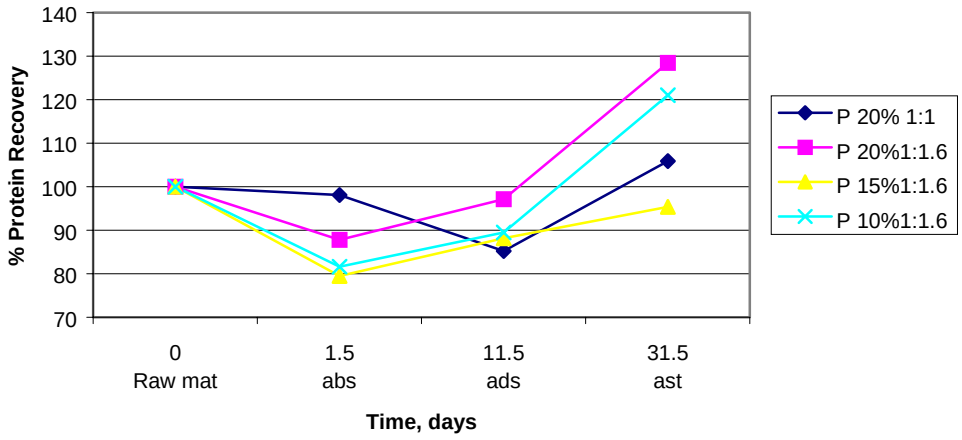


Figure 3: Blue whiting 2.

APPENDIX 12: DISTRIBUTION OF ADULT ICELANDIC NORWEGIAN HERRING AND BLUE WHITING. PLACES WHERE HERRING AND BLUE WHITING CAUGHT FOR THE EXPERIMENT.