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Effect of salt content in slurry ice on quality of fresh and thawed Atlantic mackerel (*Scomber scombrus*)

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Report summary

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Titill / Title	**Effect of salt content in slurry ice on quality of fresh and thawed Atlantic mackerel (*Scomber scombrus*)**		
Höfundar / Authors	Paulina E. Romotowska, Björn Margeirsson, Gísli Kristjánsson, Sigurjón Arason, Magnea G. Karlsdóttir, Sæmundur Elíasson, Arnljótur B. Bergsson		
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Ágrip á íslensku:	Markmið tilraunarinnar var að bæta aðferðir við kælingu og geymslu á ferskum afurðum í því skyni að bæta gæði frystra makrílafurða. Samanburður var gerður á kælingu í hefðbundnum ískrapa og saltbættum ískrapa. Með því að bæta salti í ískrapann var vonast til að lækka mætti hitastig fersks makríls og viðhalda þannig gæðum hans lengur. Ferski makríllinn var geymdur í allt að sjö daga frá veiðum. Annað markmið rannsóknarinnar var að kanna hvort þessu mismunandi kæling á ferskum makríl hefur áhrif á gæðarýrnun frystra makrílafurða. Niðurstöðurnar sýndu að hitastigdreifing í kerunum var í samhengi við saltstyrk þar sem lægra hitastig fékkst í keri með hærra saltinnihaldi (3,3%). Aftur á móti hafði frostgeymslan mun meiri á áhrif á gæðaþætti eins of ferskleika og los makrílafurðanna samanborið við áhrif forkælingar, þar sem áhrif mismunandi saltstyrks í ískrapanum var hverfandi m.t.t. þessara gæðaþátta.		
Lykilorð á íslensku:	*Ískrapi, saltstyrkur, kæling, frysting, makríll, gæði, geymsluþol*		
Summary in English:	The present experiment is part of the research project - Increased value of mackerel through systematic chilling. The aim of this study was to improve methods of chilling and storing of fresh products in order to obtain better quality of frozen mackerel products. This project was carried out to develop slurry ice mixture with addition of extra salt, with the intention of temperature decrease during chill storage up to seven days after catch. Secondary objective of this research was to investigate if different chilling condition of fresh fish has an effect on the quality assignment of long-term frozen mackerel products. The results showed that temperature distribution in the tubs was correlated to the salt concentration where lower temperature was obtained in the tub with higher salt content (3.3%). Furthermore, freshness, gaping and peritoneum deterioration have been affected by the storage process but not by different salt concentration in slurry ice during chilled storage. Due to high quality variation within the same group of the mackerel is needed to conduct more methods for quality evaluation such as oxidation analysis and sensory analysis.		
English keywords:	*Slurry ice, salt content, chill storage, frozen storage, Atlantic mackerel, quality, shelf life*		

Table of Content

Introduction

The spoilage rate of fresh fish products is affected by many parameters and starts immediately during post catch handling. Fish nutritional lost and changes of its physical properties are mainly caused by activity of muscle enzymes and microbial enzymes, as well as due to lipid oxidation and hydrolysis. Furthermore, fish species, fat content, fatty acid composition, age and condition of fresh fish have great impact on shelf life and quality of marine products. Deterioration process during chill storage can be controlled by temperature optimization (Huss 1995, Garton 1992, Ackman 1992, Olafsdóttir *et al.* 1997). Good and rapid cooling of mackerel after catch in considered as a very important in order to maintain the best quality and shelf life of fresh products, especially on board, before fish is gutted while self-digestion processes my occur. Slurry ice application is recently one of the most popular preservative techniques used during chilling storage of the cold water fish. Slurry ice, also called as liquid, fluid or slush ice, can decrease temperature of the product below initial freezing point (below 0 ˚C) what have a great impact on shelf life of the fish on board, during transportation and storage time (Chapman 1990, Harada 1991). Furthermore, in order to improve temperature optimization during chilled storage, sodium chloride can be applied into the slurry ice. This process could results in changes of thermodynamic properties of ice and benefitting in better cooling capacity (Melinder 2010).

The aim of this study was to improve methods of chilling and storing of fresh products in order to obtain better quality of frozen mackerel products. This project was carried out to develop slurry ice mixture with addition of extra salt, with the intention of temperature decrease during chill storage up to seven days after catch. Furthermore, another objective of this research was to investigate if different chilling condition of fresh fish has an effect on the quality changes of long-term frozen mackerel products. The present experiment is part of the research project “Increased value of mackerel through systematic chilling” and “Quality optimization of frozen mackerel products”, funded by the AVS research fund (Ref. No.: R 029-12 and R 040-12, respectively).

Material & Methods

Fish material, processing and sampling

Mackerel samples in this experiment were collected by Hraðfrystihúsið Gunnvör hf. The fish was caught from August 7th to August 9th 2012 on by Páll Pálsson (ÍS-102). The samples were taken from the third haul around 9 pm on August 8th and put into four separated tubs (440 L), as shown in Figures 1 to 4.

Two of the tubs (II, IV) were prepared with slurry ice containing 80 kg of seawater, 60 kg of ice and 1.7 kg salt. The other two tubs (I, III) were prepared only with 80 kg of seawater and 60 kg of ice (Table 1).

The tubs were brought to land around 9 pm on August 9th where two shovels of ice were spread over each tub at 22:50 on August 9th. On August 10th, tub I without salt addition and tub II with extra salt, were sent with a cooling truck to Matís for further analysis (Figure 6).

Table 1 Slurry ice mixtures.

	Seawater (kg)	Ice (kg)	Salt (kg)	Salt content (%)
Tub I	80	60		2.1
Tub II	80	60	1.7	3.3
Tub III	80	60		2.1
Tub IV	80	60	1.7	3.3

Tubs III and IV were stored at Hraðfrystihúsið Gunnvör hf., where samples were taken daily from August 10th to August 12th, as well as on August 13th and August. Furthermore, three shovels of ice were added over each tub on August 12th. Quality evaluation results from these samples are not included in this report.

Figure 1 Tub I without salt.

Figure 2 Tub III without salt.

Figure 3 Tub II with salt.

Figure 4 Tub IV with salt.

Figure 5 The four tubs after icing.

Figure 6 Tubs in a cold store.

Experiment design

In the following experiment, samples were collected after 4, 5, 6 and 7 days of chill storage (August 12th, 13th, 14th and 15th 2012) from both of the tubs: without extra salt (I) and with salt addition (II). Furthermore, mackerel was taken from different place in the tub: samples from top layer and bottom layer. Overall, there was 4 groups, with 20 individuals in each group (n=20 per group) taken for quality evaluation.

- **Group 1:** tub without salt, top layer
- **Group 2:** tub without salt, bottom layer
- **Group 3:** tub with salt, top layer
- **Group 4:** tub with salt, bottom layer

Moreover, samples from each sampling point (4, 5, 6, 7 days) and each group (group 1, 2, 3, 4) were frozen with the use of spiral freezer and were stored for 18 months at -25 ˚C. Finally, after thawing the fish quality was evaluated with the same parameters as chilled samples.

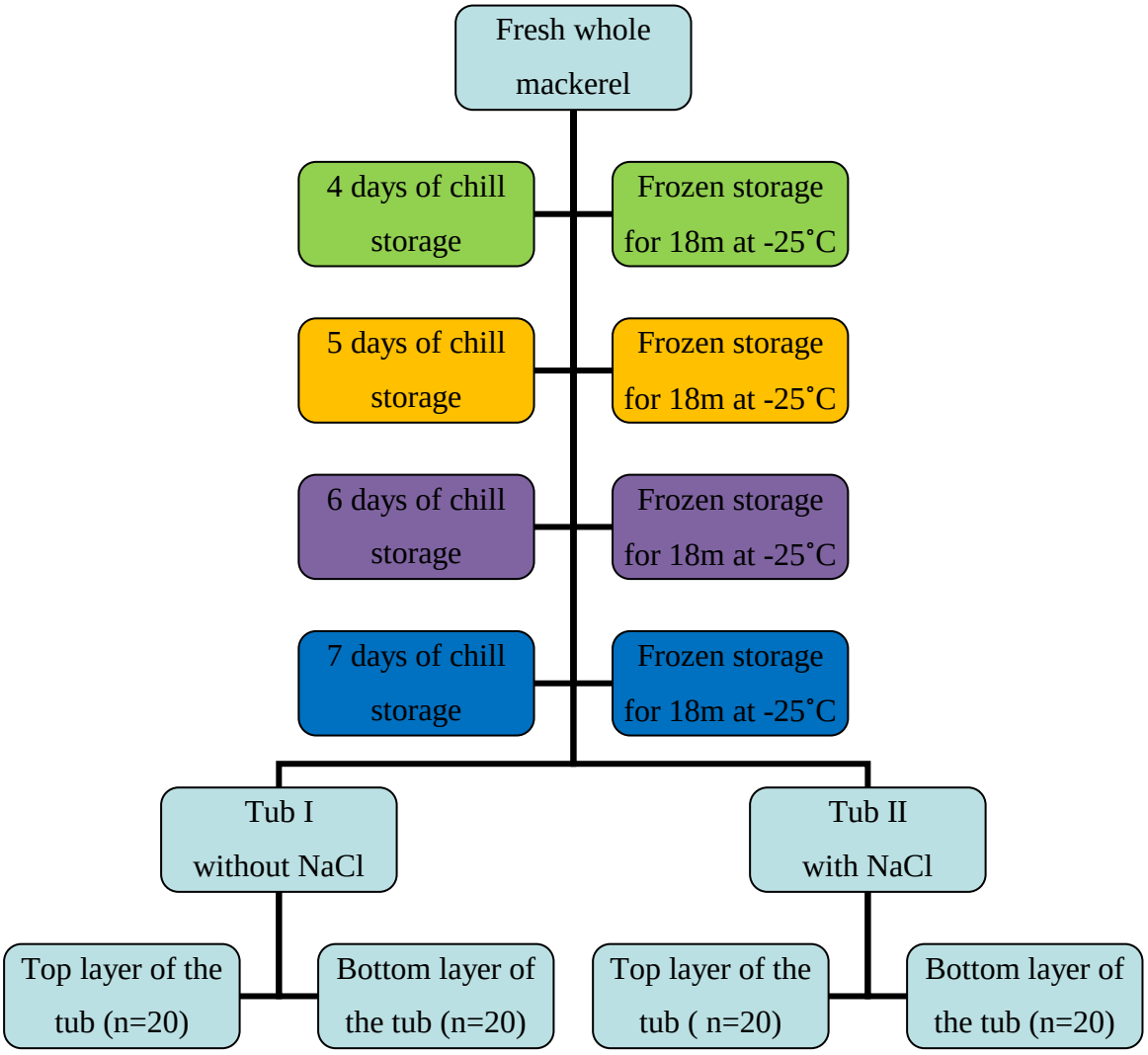

Figure 7 Experiment design.

Temperature measurements

Temperature distribution during the chilled storage in slurry ice was determinated. The aim of the experiment was to evaluate whether different salt concentration affects temperature fluctuation and how that may affect the fish quality. Therefore, temperature loggers were placed in different location in the tubs, as well as inside the mackerel flesh:

- inside the fish in top layer of the tub
- inside the slurry ice on top of the top
- inside the fish in bottom layer of the tub
- inside the slurry ice on bottom of the tub
- outside the tub (ambient)

Quality evaluation

The SINTEF Fisheries and Aquaculture, has set up electronic guide for pelagic fish quality evaluation. The handbook in intended as an aid for the entire pelagic industry in Norway to ensure uniform quality assessment of raw material at all stages (capture, receipt, transportation, and marketing). The electronic guide was designed in the projects funded by the Fisheries and Aquaculture Industry Association (FHL) “Individual-based quality grading and quality certification of pelagic fish", " Pelagic quality - from the ocean to the barrel " and was carried out by SINTEF Fisheries and Aquaculture (SINTEF 2012). Table 2 gives information on how the mackerel was grated in present study.

Table 2 Quality evaluation scheme for Atlantic mackerel SINTEF 2012.

Parameters	Characteristic	Grade	Example
Freshness – assessed by finger pressure on the loin part	Firm, springy	0	
	Firmness gained after 2-4 sec. after pressure	1	
	Soft texture, firmness after 5 sec or no springiness at all	2	
Skin appearance	No mechanical damage	0	
	Visible cuts, but only on the surface	1	
	Large and dip cuts	2	

Parameters	Characteristic	Grade	Example
Gaping	No visible gaps	0	
	Not more than 5 gaps	1	
	Not more than 10 gaps	2	
	More than 10 small gaps	3	
	Many large gaps	4	
	Deterioration of the flesh	5	

Parameters	Characteristic	Grade	Example
Blood spots	No blood spots	0	
	Few small blood spots < 5	1	
	Many and/or large blood spots > 5	2	
Peritoneum	Strong, firm membrane	0	
	Soft membrane, easily detaching	1	
	Destroyed membrane, visible bones	2	

Determination of salt content

Salt content was determined using standard method, Volhard titration (AOAC no. 196.18 2000).

Measurements of biogenic amines (histamine)

Biogenic amines (histamine) are extracted from a homogenized sample with 10% TCA. A specific amount of internal standard is added on dilution of the extract. Separation and detection of histamine was conducted by a HPLC system with the use of gradient elution and derivatization with o-phtaldiealdehyde (OPA). Fluorescents detection with excitation wave length at: Exitation: 336 nm and Emission: 440 nm. Method was modified by Matís ohf from different sources (Cichy *et al.* 1993, Corbin J.L. 1989, Gouygou J.P. 1987, Gouygou J.P. 1989, Kirschbaum J. 1994, Malle P. 1996, Marcé M. 1995, Taibi G. 1993).

Microbiological examination

Bacterial count was determinate by method described by Downes *et al.* 2001.

Statistical analysis

Samples were analyzed statistically using the General Linear Model (GLM) and One-Way Analysis of Variance. Duncan's and ANOVA comparison test was used to obtain the significance ($p = 0.05$) of differences between means (NCSS 2000, NCSS, Utah, USA). The significance level was set at $p \leq 0.05$. Furthermore, calculation of Pearson´s correlation coefficients between different variables was performed using Microsoft Office Excel 2010 (Microsoft Inc., Redmond, USA).

Results & Discussions

Temperature distribution

Temperature loggers were placed inside the slurry ice on top and bottom of each tub (I, II) as well as inside the fish. Additionally, the ambient temperature was recorded. In term of temperature distribution inside the tub and inside the fish flesh results were approximately the same, however temperature inside the fish was slightly higher than slurry ice in the tub I (without salt).

Referring to Figure 8 and 9, temperature in the tub without salt addition (tub I) was higher until 73 hours of chilled storage compared to the temperature in the tub with salt addition. Temperature in tub I after 26 hours from catch reached 2 ˚C and went down to -1 ˚C after 74 hours, subsequently temperature increased and after 120 hours from catch oscillated around 0-1˚C until 330 hours from catch. Moreover, temperature in the tub II, after 26 hours from catch reached lowest temperature point at -1 ˚C and this temperature stayed steady until 96 hours after catch. Consequently, temperature slowly increased up to 1 ˚C after 168 hours from catch and was rather stable until 240 hours. After that time temperature constantly increased up to 2.5 ˚C after 330 hours.

This is positively regarded since it can advantageous in quality control and better temperature optimization during chilled storage. Due to use of sodium chloride in the slurry ice below freezing point the temperature fluctuation can be reduced. This process might have been a result of enthalpy changes caused by ice melting without temperature rising (Melinder 2010).

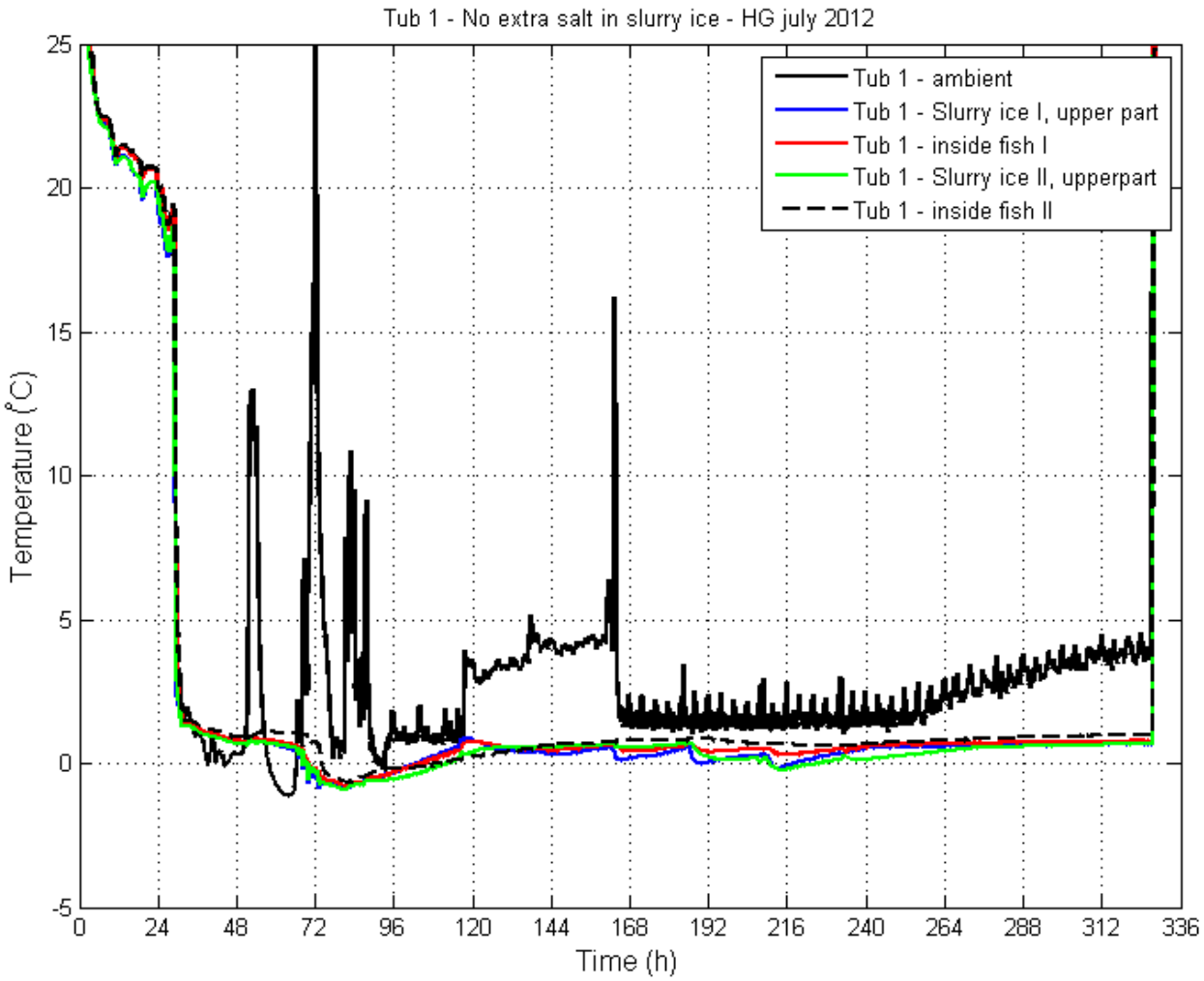

Figure 8 Temperatures distribution in the tub I without salt addition during chilled storage of mackerel.

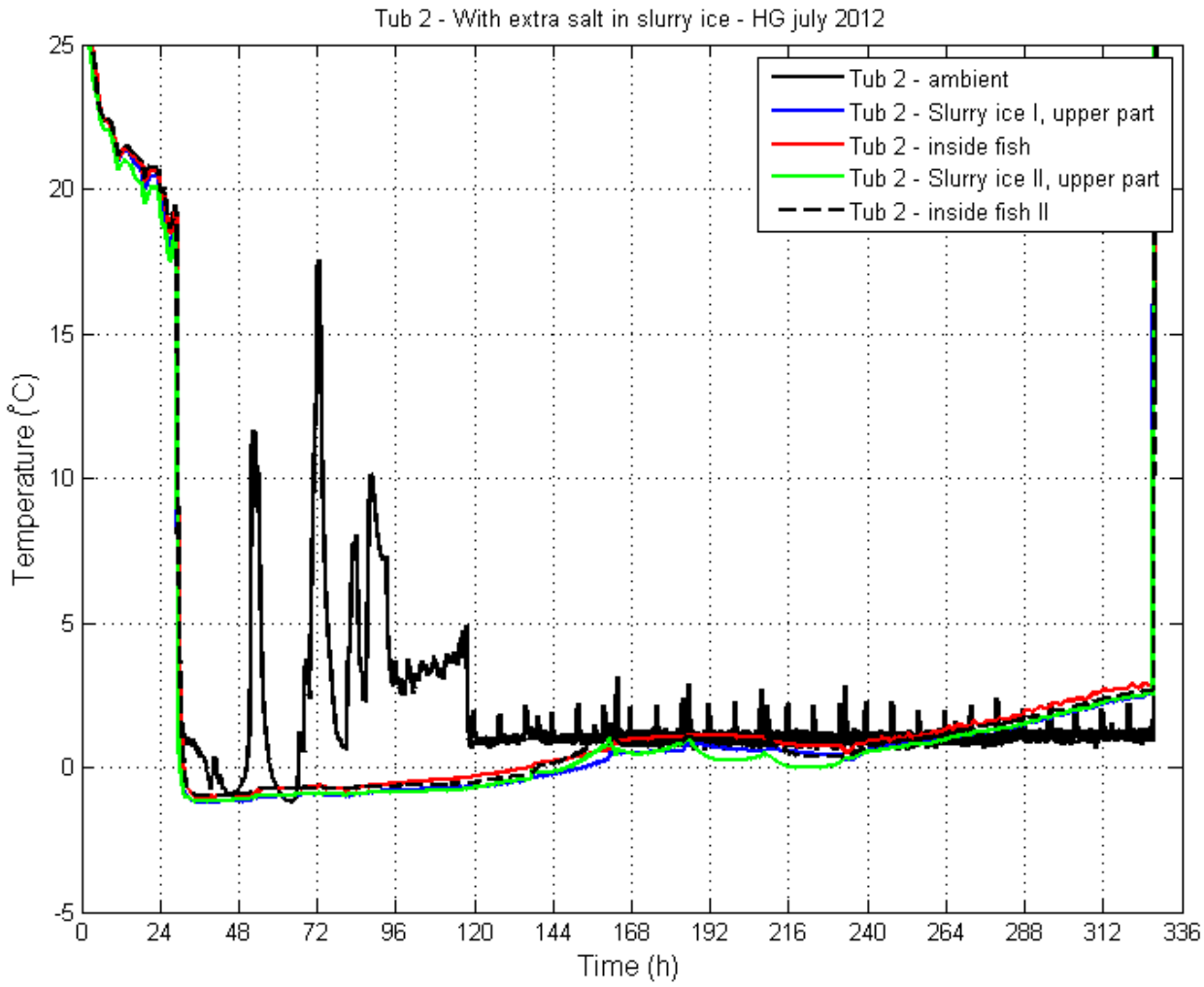

Figure 9 Temperatures distribution in the tub II with salt addition during chilled storage of mackerel.

Biochemical methods

Histamine is one of the biogenic amines which rise in the fish muscle through the bacterial spoilage. Histamine level was analyzed in this study, because it is believed that histamine indicate scombroid toxicity of the pelagic fish such as mackerel (Huss 1995). Analysis of fresh mackerel from each sampling point showed histamine values lower than 10 ppm in all of the groups, where the limit for fishery products is 100 ppm (BIM). According to Huss (1995), histamine production may have not been related spoilage of the mackerel during chilled storage. Thus, more of the measurements such as level of putrescine, cadaverine, spermidine and spermine is needed to estimate quality index (Mietz 1977).

Bacterial count was performed in 5% salt agar and incubation at 22 °C for 72 hours. The results showed less than 10 microorganisms per 1g in all of the measured samples. It is clear that chilled storage at temperature near 0 ˚C inhibits bacterial growth (Huss 1995).

Salt content of the samples from the tub without extra salt (tub I) seems to be similar for the fish kept on top and bottom of the tub, at each step of chilled storage (Figure 10). However, salt uptake was grater in the samples placed at the bottom of the tub with salt addition (tub II) ($p > 0.05$). Furthermore, salt content in this group of samples showed steady increase until 7^{th} day after catch ($p > 0.05$). Due to the statistical similarity between each group more samples need to be gathered to be certain that the salt concentration have an effect on shelf life of the mackerel.

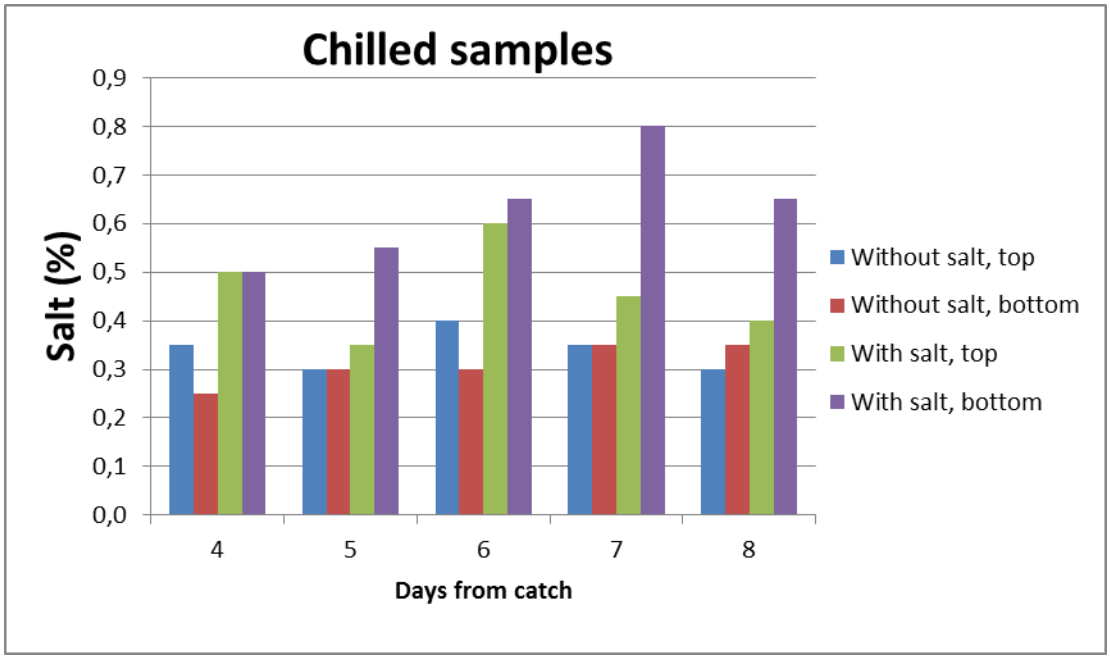

Figure 10 Salt content of chilled samples (n=2).

Assessment of fish quality**Error! Not a valid link.**

Freshness deterioration

Freshness deterioration was significantly ($p < 0.05$) higher in the thawed samples which were stored for 18 months at -25˚C, compared to the chill stored samples (Figure 12). Rancidity of the fish is caused mostly by lipid oxidation which in the chilled samples develop slowly comparing to frozen samples where oxidation process occurs during whole long term storage (FAO 1989).

Freshness deterioration score of the thawed samples increased slightly after 6 days from catch ($p > 0.05$), while chilled samples had the highest freshness loss ($p < 0.05$) after 6 days of storage and similar freshness after 4, 5, and 7 days after catch (Figure 13). These changes may have been due to rather high standard deviation within the group caused by variation of the raw material, for example, variation in fat content, water content or age of the fish.

Moreover, there was no significant difference in freshness between the samples stored in the tub without salt addition (tub I) and samples from the tub with extra salt (tub II), neither after chill storage or frozen storage (Figure 14). Although, results showed better freshness in the samples stored with salt addition after 4 days from catch ($p > 0.05$) (Figure 16), what could have been correlated to the lower storage temperature in the tub II (with NaCl) until 72 hour from catch (Figures 8, 9).

Furthermore, results showed no significant difference in freshness rate of the samples placed on top and bottom of tubs in any of groups (Figures 15, 16, 17).

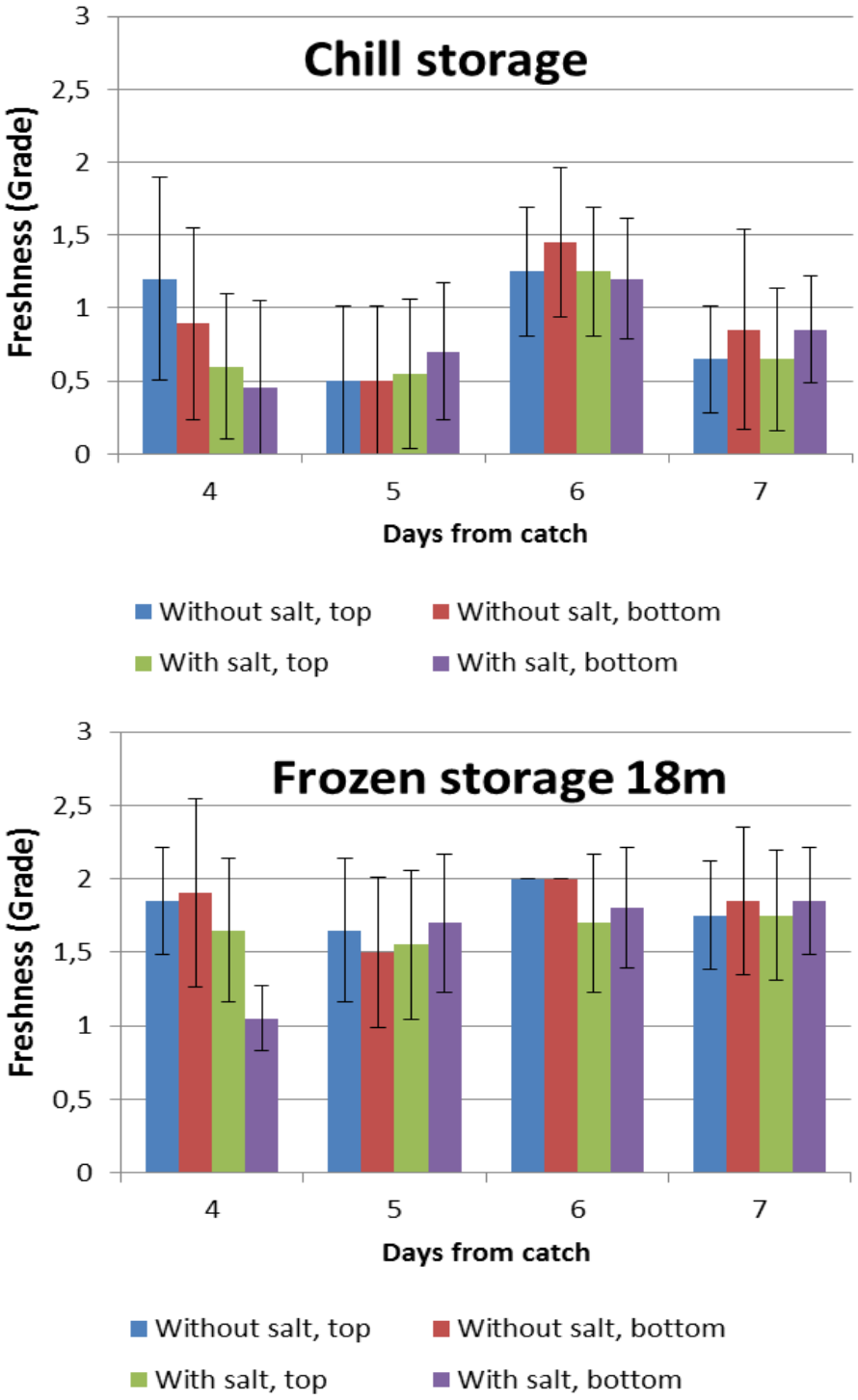

Figure 11 Freshness (grades) affected by time after catch (days), position of the fish in slurry ice as well as salt concentration in slurry ice, during chilled and frozen storage, respectively (average ± stdv. of n=20 samples).

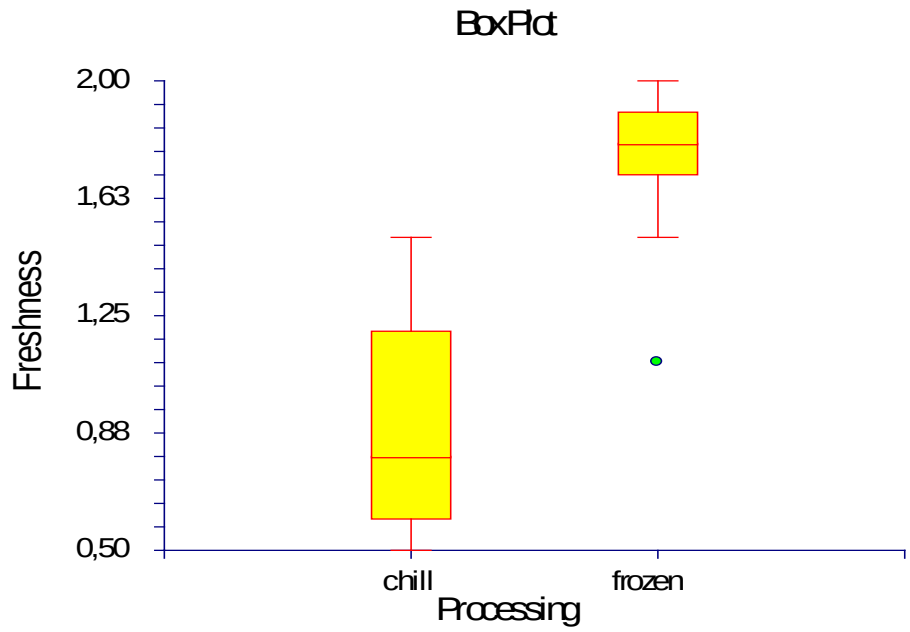

Figure 12 Freshness (grades) of mackerel after chilled and frozen storage. Box plots presents grades average and stdv of all of the groups (with and without NaCl, bottom, top, day 4, 5, 6, 7) (n=16) for each processing condition separately.

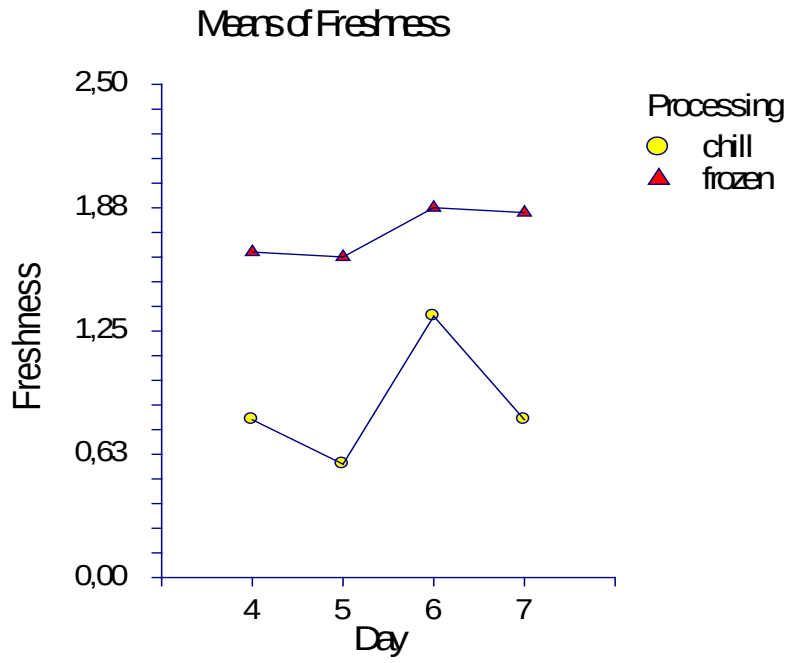

Figure 13 Freshness (grades) of chill and frozen stored mackerel affected by time after catch (days). Graph presents average of samples of all of the groups (with and without NaCl, bottom, top) at each sampling point (n=4) for different processing separately.

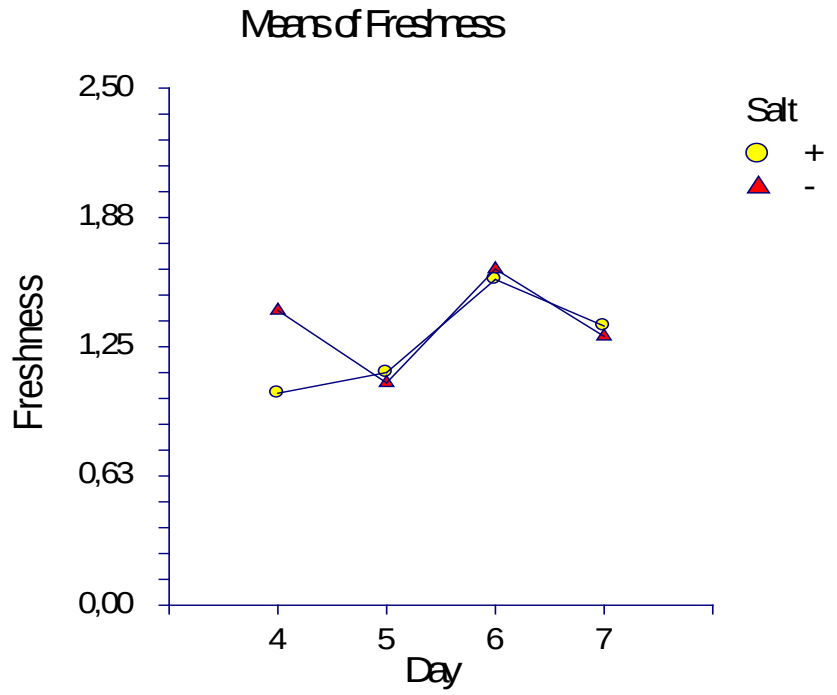

Figure 14 Freshness (grades) of the mackerel affected by time after catch (days) and concentration of the salt in slurry ice. Graph presents average of chill and frozen stored samples (bottom and top) at each sampling point (n=4) for different salt treatment separately.

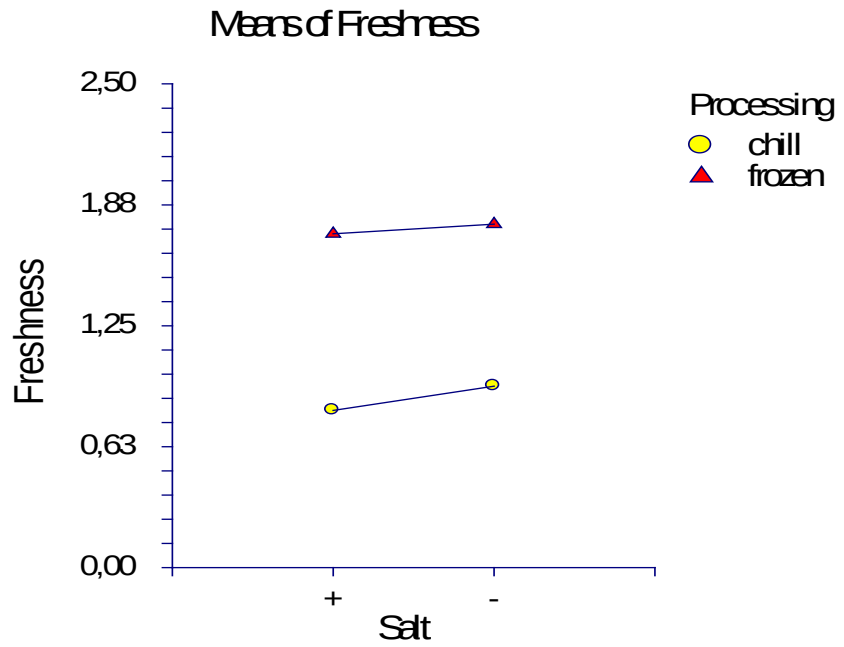

Figure 15 Freshness (grades) of the mackerel affected by salt concentration in ice slurry during chill and frozen storage. Graph presents average of all groups (bottom and top, day 4, 5, 6, 7; n=8) for different processing separately.

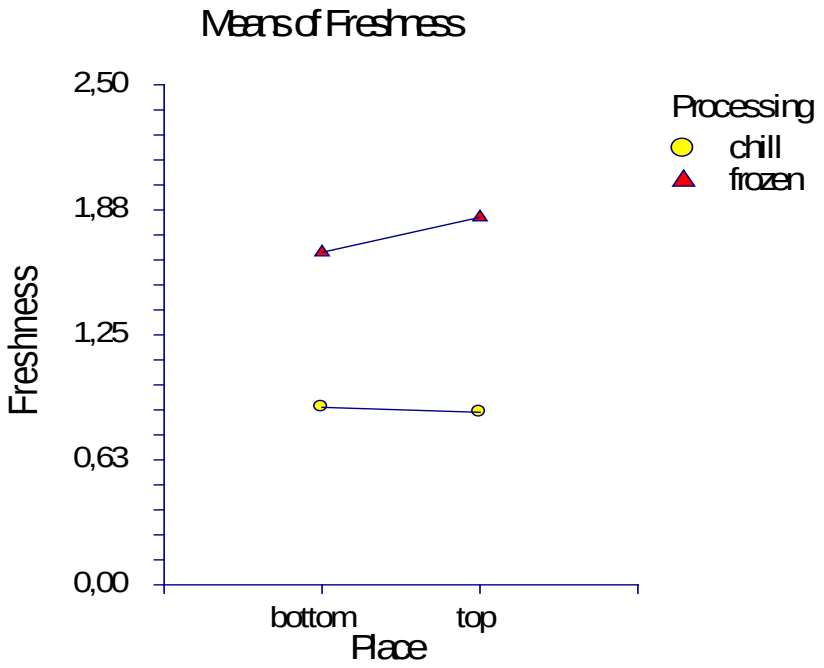

Figure 16 Freshness (grades) of the mackerel affected by position of the fish in ice slurry during chill and frozen storage. Graph presents average of all groups (with and without NaCl, day 4, 5, 6, 7, n=8) for different processing separately.

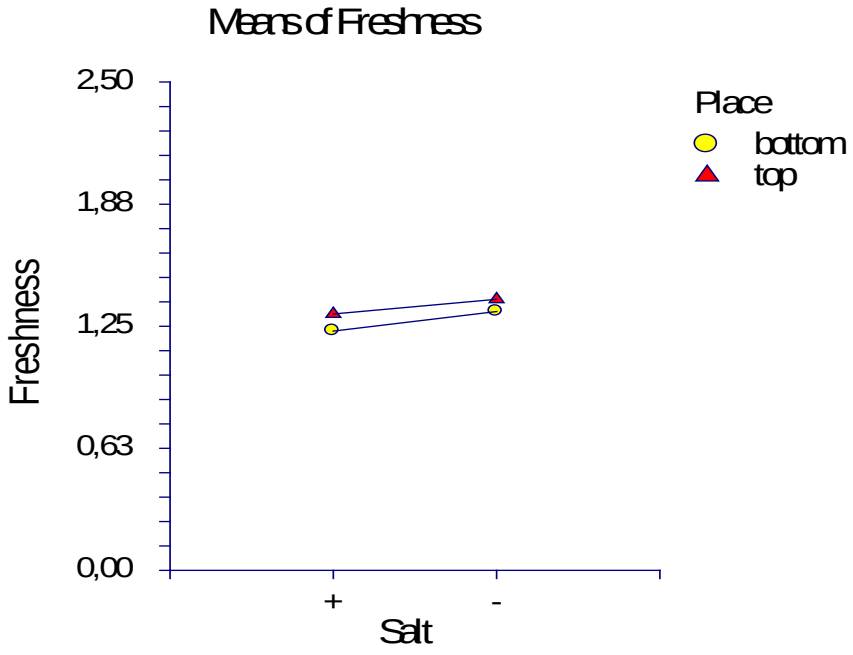

Figure 17 Freshness (grades) of the mackerel as affected by position of the fish in ice slurry with different salt concentration. Graph presents average of results obtained during chilled and frozen storage after 4, 5, 6, 7 days from catch (n=8).

Fillets gaping

According to the Figure 20 there was linear positive correlation of gaping level between chilled and frozen samples at each sampling point (after 4, 5, 6, 7 days from catch), where frozen stored mackerel reached significantly ($p < 0.05$) higher grade of flesh gaping comparing to chilled stored samples (Figure 19). Distribution of gaping rate during the time after catch is significantly correlated to the freshness loss of the frozen stored samples ($r = 0.6$, $p = 0.02$). These results indicate that mackerel after 5 days of chilled storage reached the best quality. This may be attributed to the temperature distribution after catch where lowest temperature (-1˚C up to 0˚C) were reach until 120 hours from catch (5 days) in both tubs I and II (Figure 8, 9).

Furthermore, there was no significant difference in gaping between the samples stored in the tub without salt addition (tub I) and samples from the tub with extra salt (tub II), neither after chill storage or frozen storage (Figure 21). Although, results showed slightly lower grade of gaping in the samples stored with extra salt ($p > 0.05$). Moreover, gaping rate of the samples placed on top and bottom of tubs seems to be similar, but fish placed on the bottom had slightly lower grade of gaping, especially after 6 days from catch (Figure 22, 23).

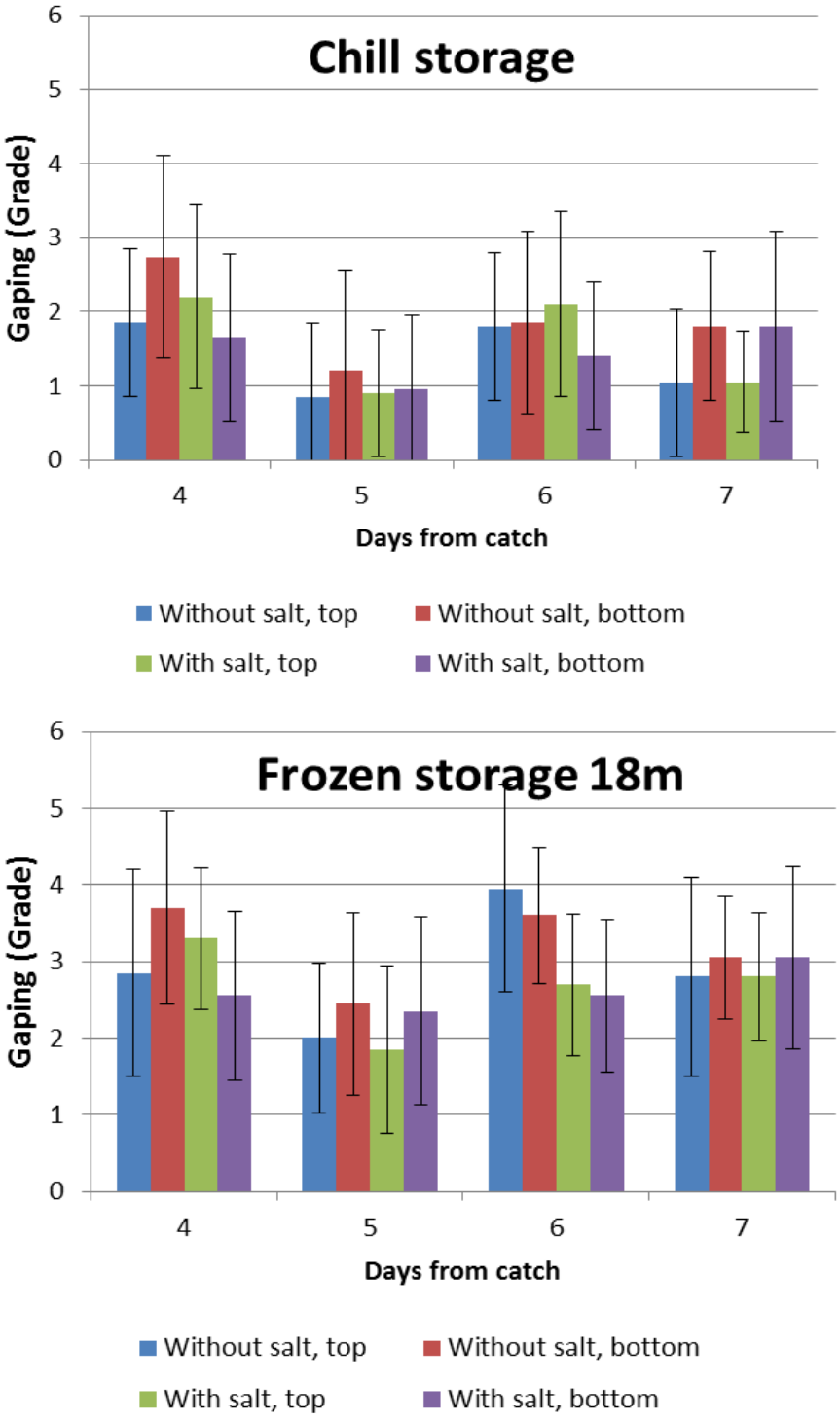

Figure 18 Flesh gaping (grades) affected by time after catch (days), position of the fish in slurry ice as well as salt concentration in slurry ice, during chilled and frozen storage, respectively (average ± stdv. of n=20 samples).

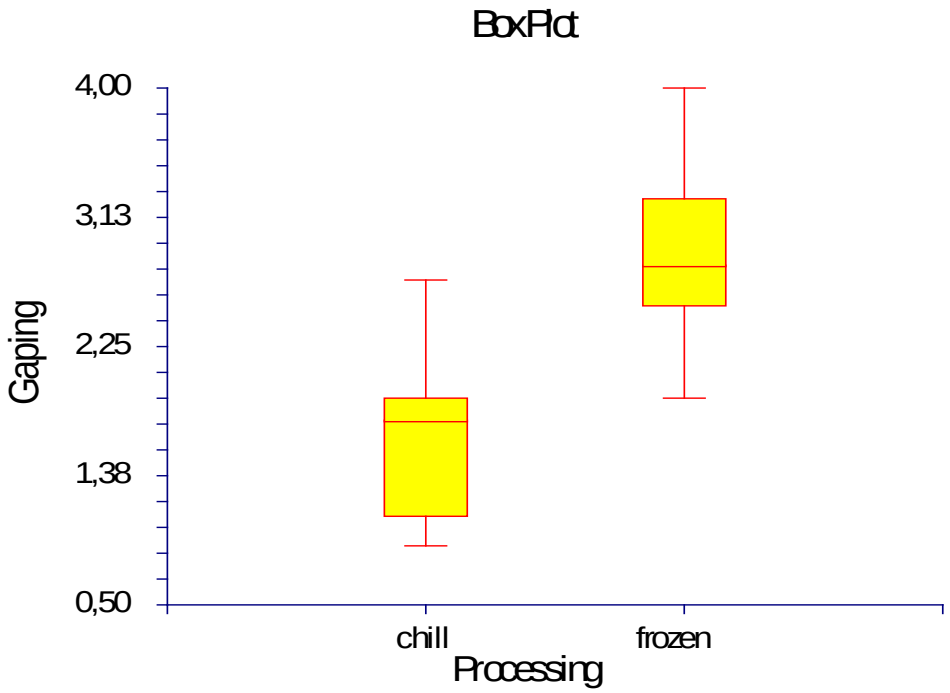

Figure 19 Flesh gaping (grades) of mackerel after chilled and frozen storage. Box plots presents grades average and stdv of all of the groups (with and without NaCl, bottom, top, day 4, 5, 6, 7) (n=16) for each processing condition separately.

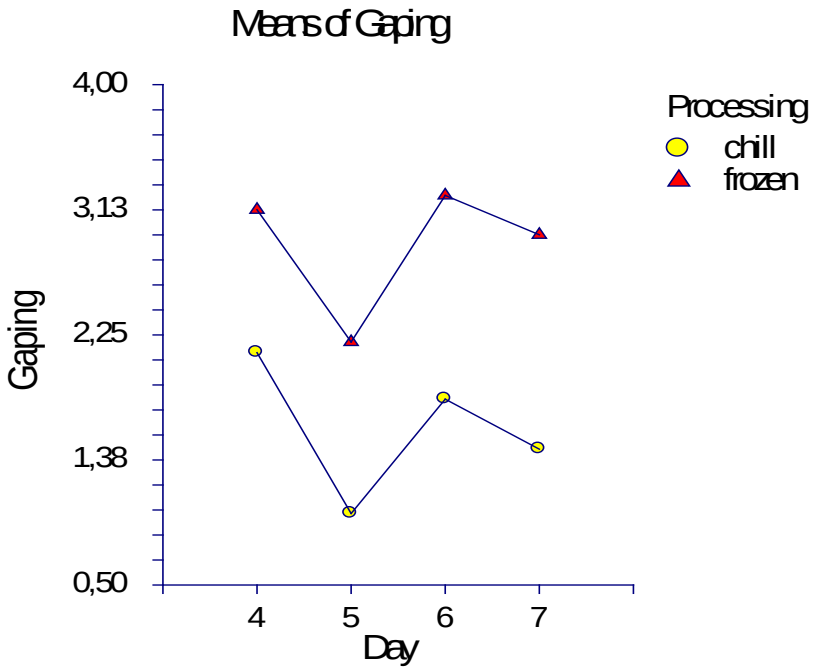

Figure 20 Flesh gaping (grades) of chill and frozen stored mackerel affected by time after catch (days). Graph presents average of samples of all of the groups (with and without NaCl, bottom, top) at each sampling point (n=4) for different processing separately.

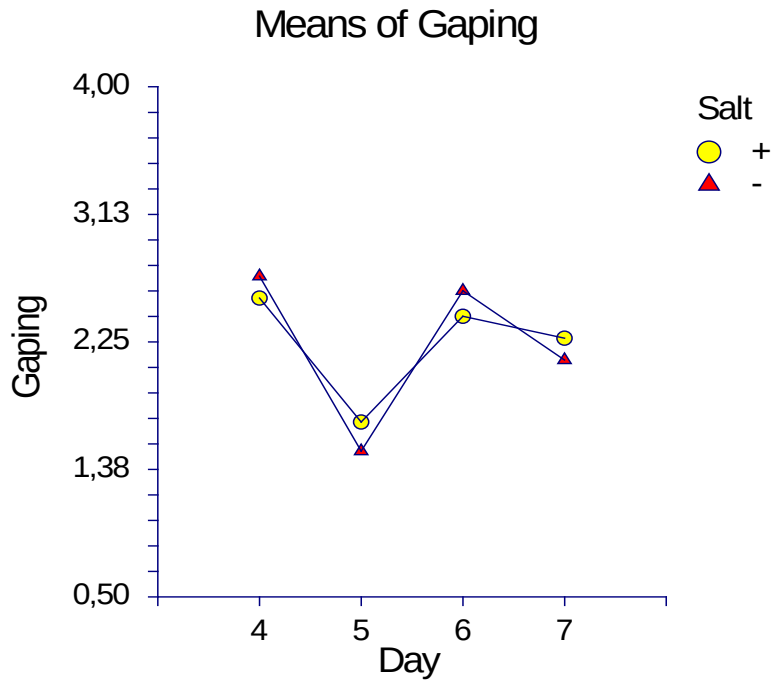

Figure 21 Flesh gaping (grades) of the mackerel affected by time after catch (days) and concentration of the salt in slurry ice. Graph presents average of chill and frozen stored samples (bottom and top) at each sampling point (n=4) for different salt treatment separately.

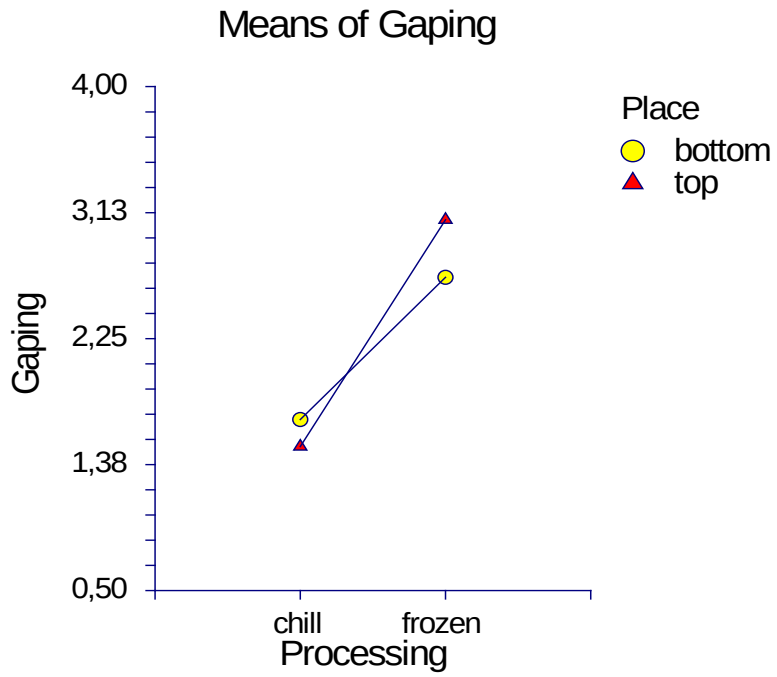

Figure 22 Flesh gaping (grades) of the mackerel affected by position of the fish in ice slurry during chill and frozen storage. Graph presents average of all groups (with and without NaCl, day 4, 5, 6, 7, n=8) for different processing separately.

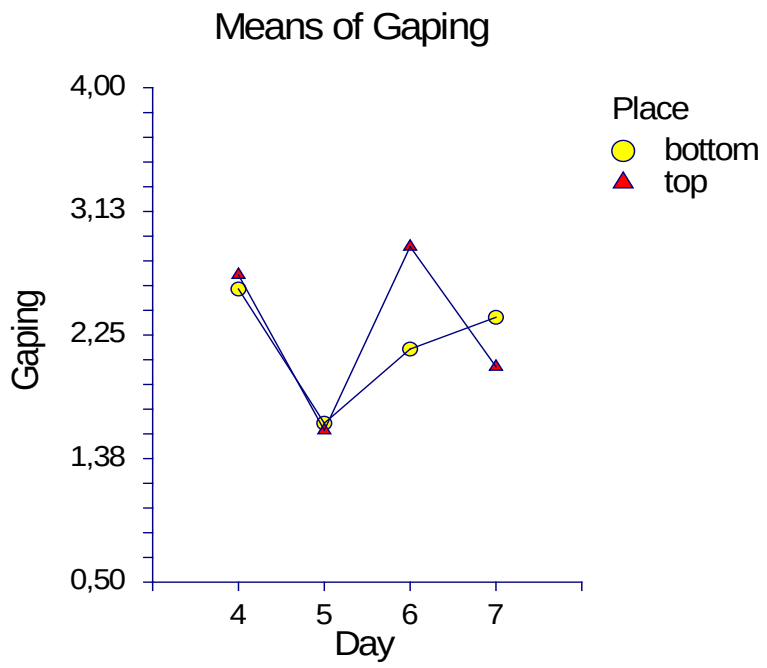

Figure 23 Flesh gaping (grades) of the mackerel affected by position of the fish in ice slurry, and time of storage after catch. Graph presents average of samples of all of the groups (with and without NaCl, chill and frozen storage: n=4) at each sampling point.

Blood spot

Inversely to freshness and gaping rate, blood spots grate was lower in the samples after frozen storage comparing to the chilled samples ($p = 0.005$) (Figure 26).

Furthermore, blood spots rate decreased significantly after 4 days from catch in the frozen stored samples ($p = 0.008$) and continually decreased with the time (Figure 27). Therefore it can be concluded that the chilling process was conducted properly (reduced flesh temperature of mackerel) what resulted in reduction of bruises rate in the thawed samples OAC 2013, Beverly 2003.

Furthermore, similar to freshness and gaping rate, results showed slightly lower grade of blood spots in the samples stored with extra salt in slurry ice ($p > 0.05$) (Figure 28), and there was no significant difference between samples stored on top or bottom of the tubs (Figure 29). A positive correlation occurred between blood spots and gaping rate of the chilled samples ($r = 0.5$, $p = 0.03$).

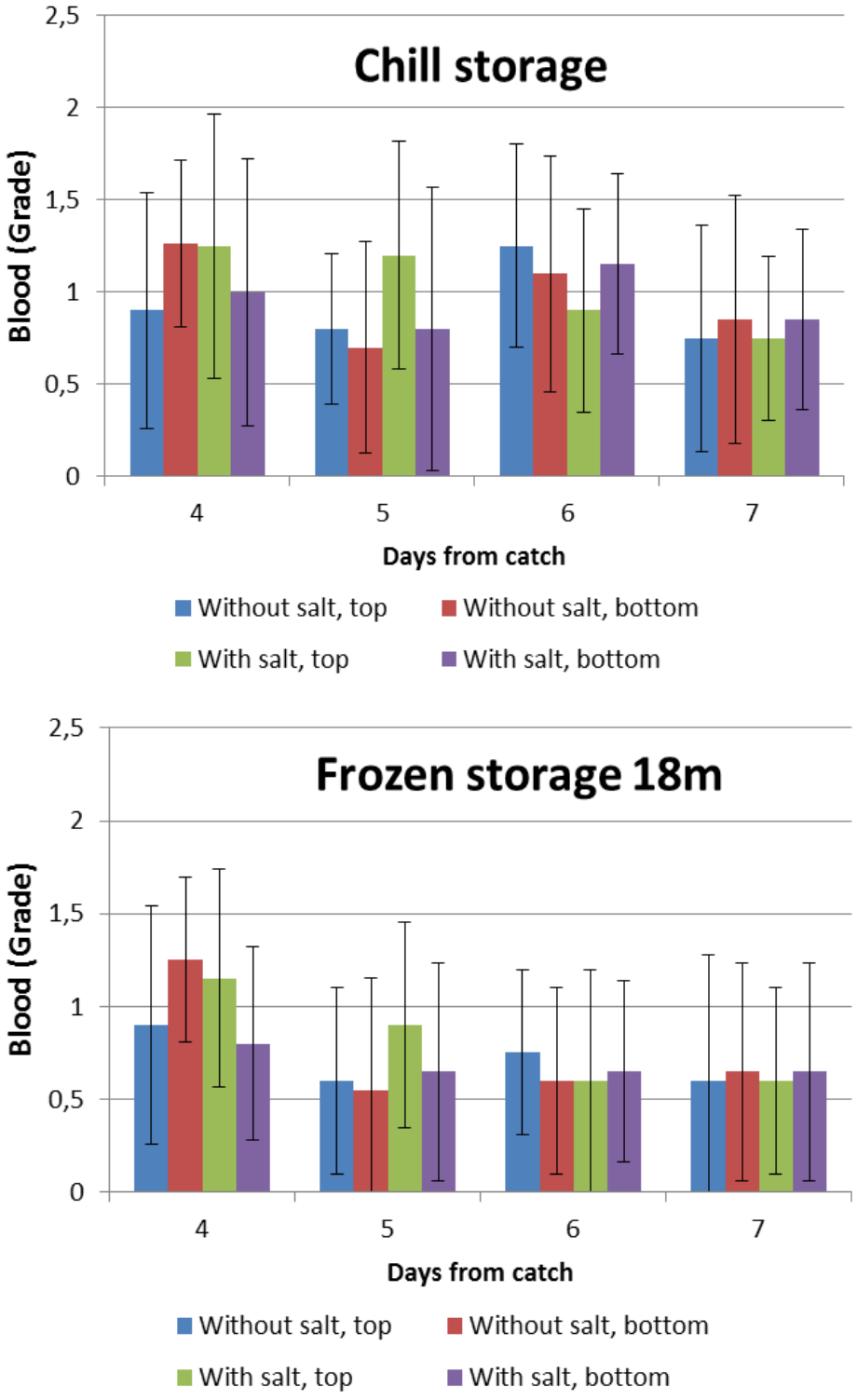

Figure 24 Blood spots (grades) affected by time after catch (days), position of the fish in slurry ice as well as salt concentration in slurry ice, during chilled and frozen storage, respectively (average ± stdv. of n=20 samples).

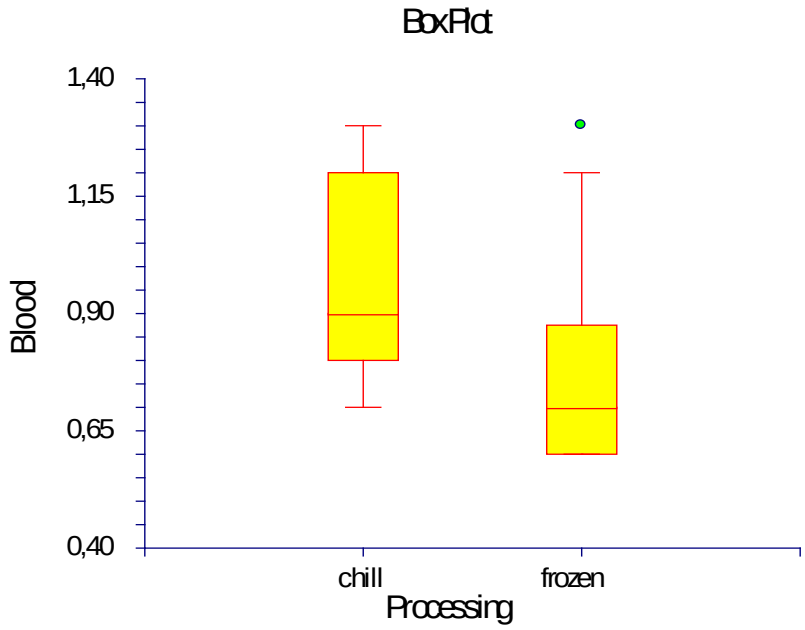

Figure 25 Blood spots (grades) of mackerel after chilled and frozen storage. Box plots presents grades average and stdv of all of the groups (with and without NaCl, bottom, top, day 4, 5, 6, 7) (n=16) for each processing condition separately.

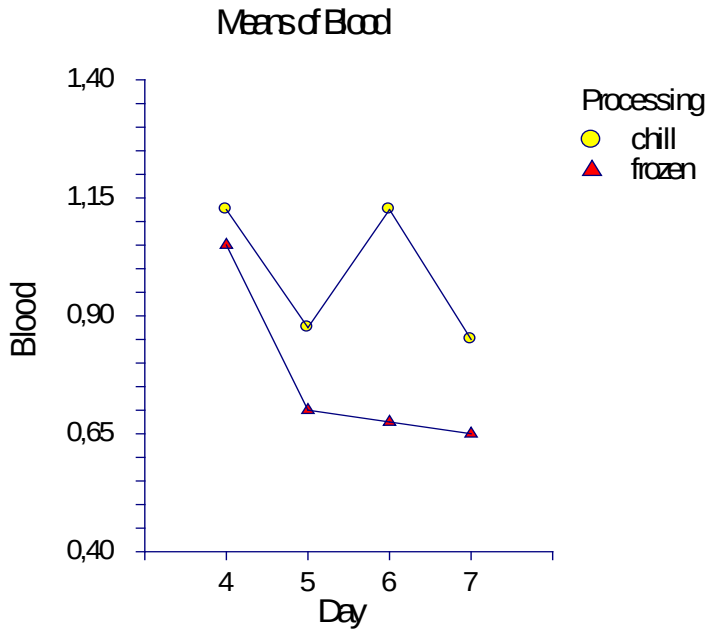

Figure 26 Blood spots (grades) of chill and frozen stored mackerel affected by time after catch (days). Graph presents average of samples of all of the groups (with and without NaCl, bottom, top) at each sampling point (n=4) for different processing separately.

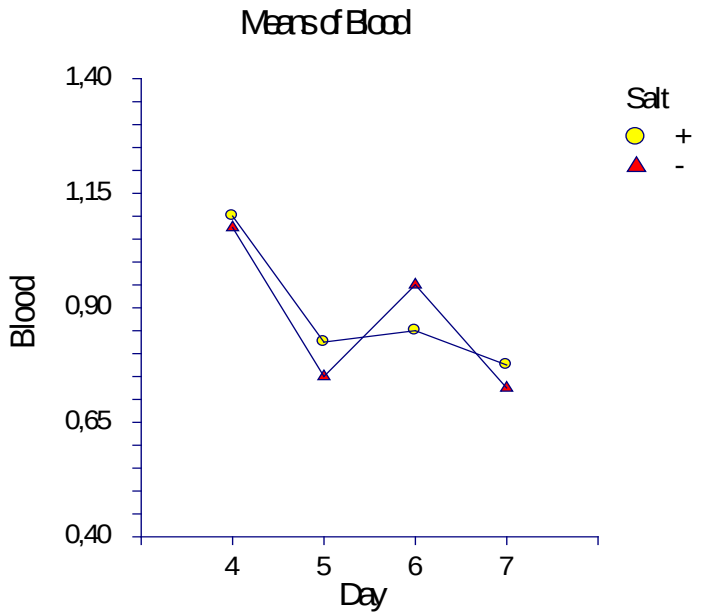

Figure 27 Blood spots (grades) of the mackerel affected by time after catch (days) and concentration of the salt in slurry ice. Graph presents average of chill and frozen stored samples (bottom and top) at each sampling point (n=4) for different salt treatment separately.

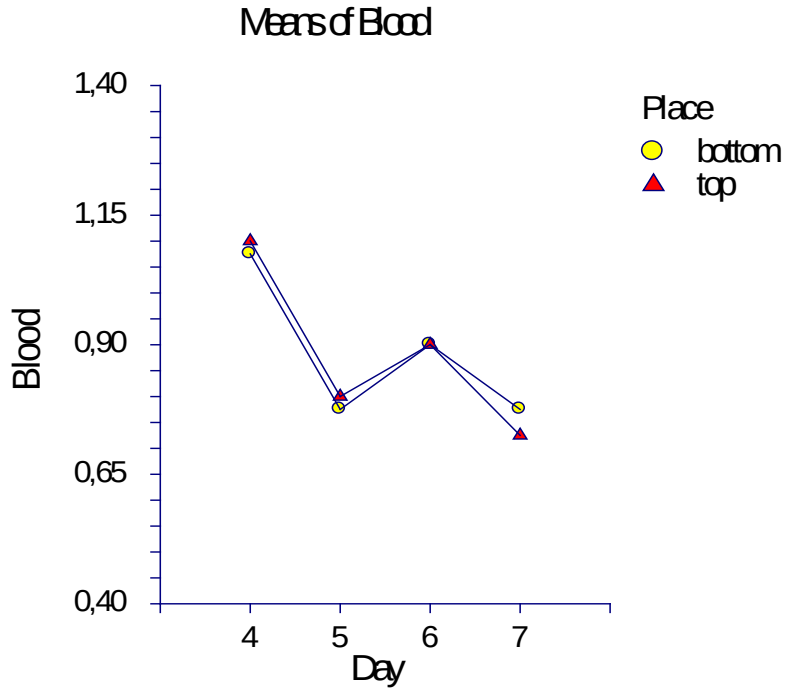

Figure 28 Blood spots (grades) of the mackerel affected by position of the fish in ice slurry, and time of storage after catch. Graph presents average of samples of all of the groups (with and without NaCl, chill and frozen storage: n=4) at each sampling point.

Peritoneum

Regarding peritoneum deterioration, results showed higher grate for frozen stored samples that for chilled (Figure 31). These changes were significant ($p < 0.05$), similarly like freshness and gaping rate which were affected by the storage time.

Furthermore, results once more suggested that mackerel after 5 days of storage had better quality compering to other days after catch (5d > 4d, 7d > 6d) – significantly lower peritoneum grade after 5 days of chill storage ($p = 0.0005$) (Figure 32).

Moreover, it seems that peritoneum deterioration is greater in the samples placed on top then on bottom of the tub ($p > 0.05$) (Figure 34).

Concerning, samples stored in slurry ice without and with salt addition, results were approximately the same, except 7th day after catch where samples from tub II (with NaCl) showed slightly lower peritoneum deterioration (Figure 33).

Additionally, freshness and gaping were positively correlated to peritoneum deterioration ($r = 0.7$, $p = 0.003$; $r = 0.594$, $p = 0.02$, respectively)

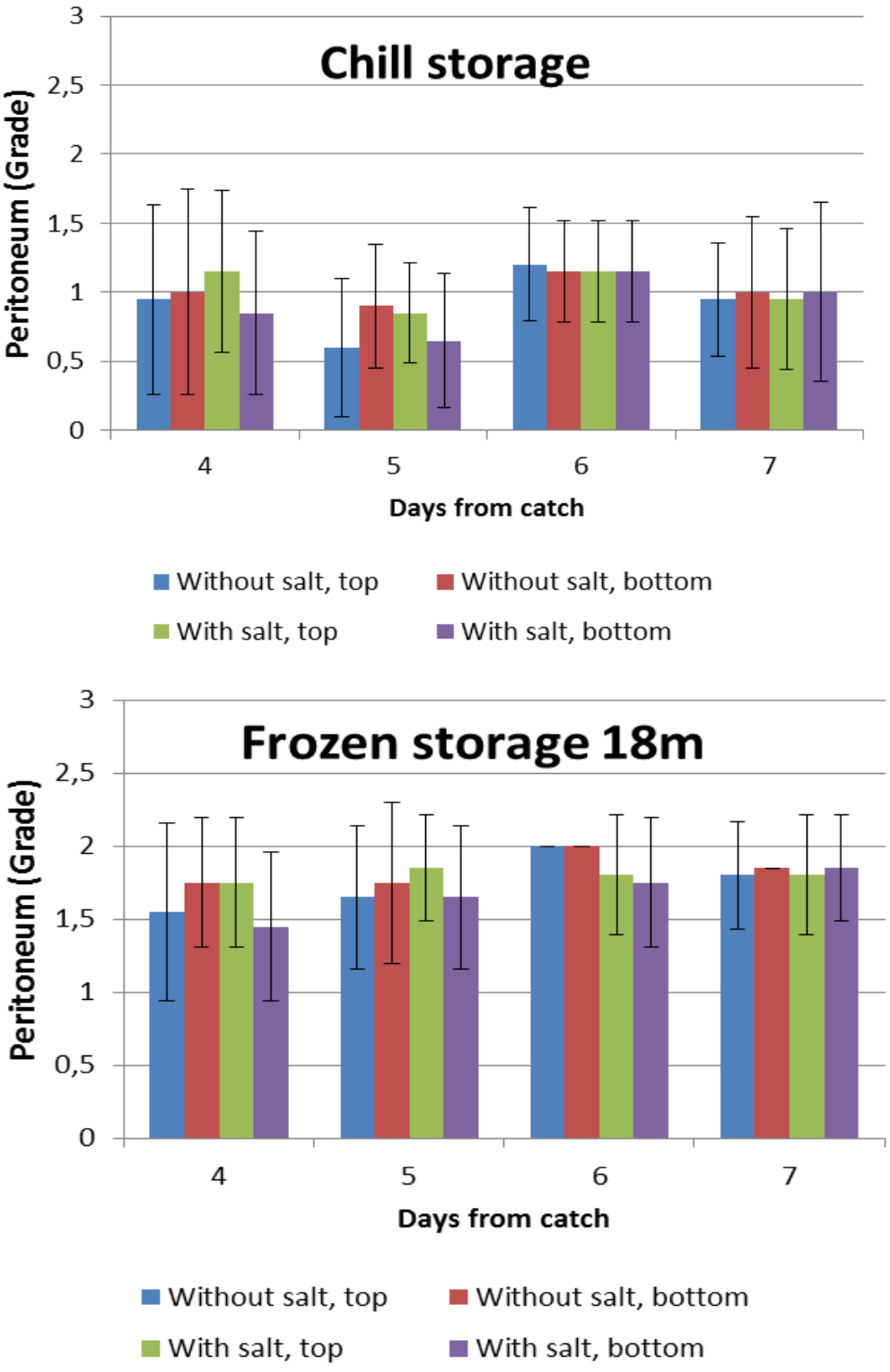

Figure 29 Peritoneum (grades) affected by time after catch (days), position of the fish in slurry ice as well as salt concentration in slurry ice, during chilled and frozen storage, respectively (average ± stdv. of n=20 samples).

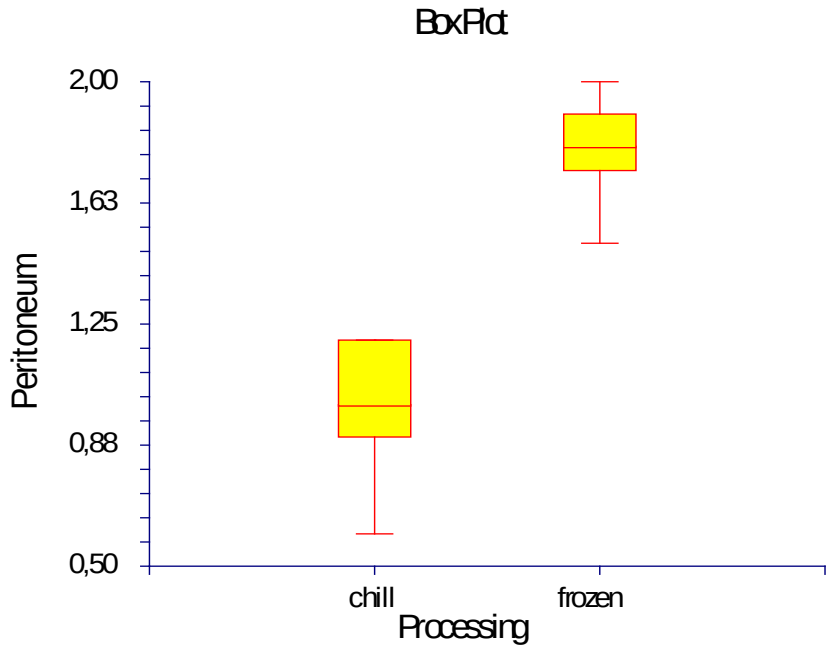

Figure 30 Peritoneum (grades) of mackerel after chilled and frozen storage. Box plots presents grades average and stdv of all of the groups (with and without NaCl, bottom, top, day 4, 5, 6, 7) (n=16) for each processing condition separately.

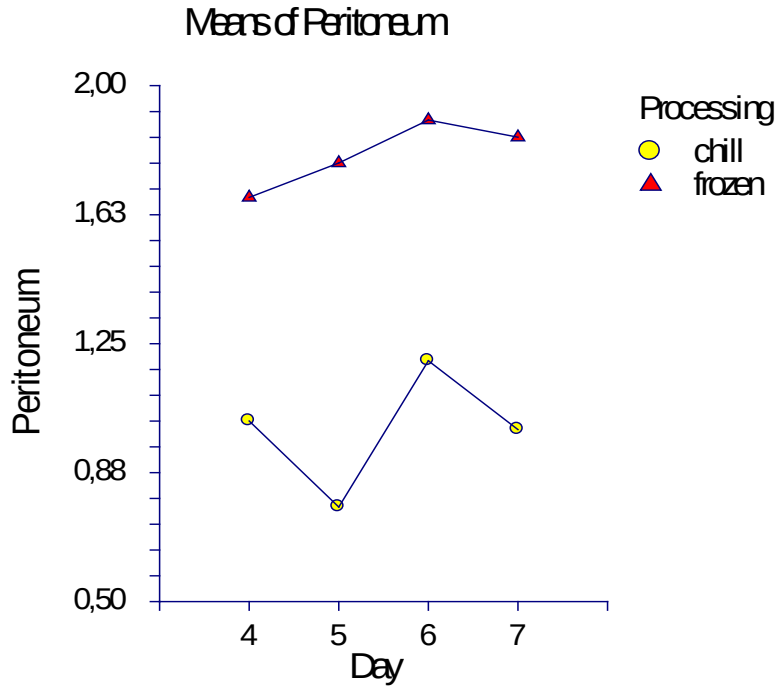

Figure 31 Peritoneum (grades) of chill and frozen stored mackerel affected by time after catch (days). Graph presents average of samples of all of the groups (with and without NaCl, bottom, top) at each sampling point (n=4) for different processing separately.

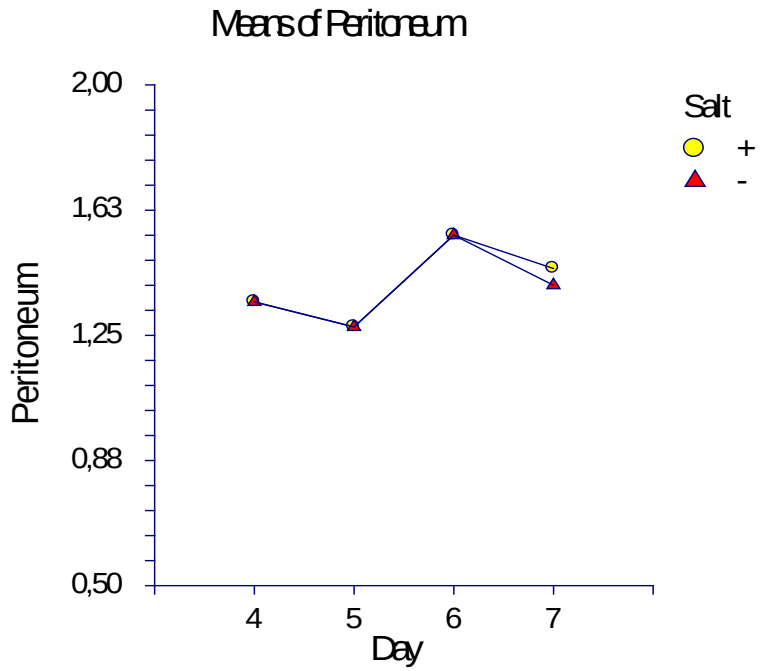

Figure 32 Peritoneum (grades) of the mackerel affected by time after catch (days) and concentration of the salt in slurry ice. Graph presents average of chill and frozen stored samples (bottom and top) at each sampling point (n=4) for different salt treatment separately.

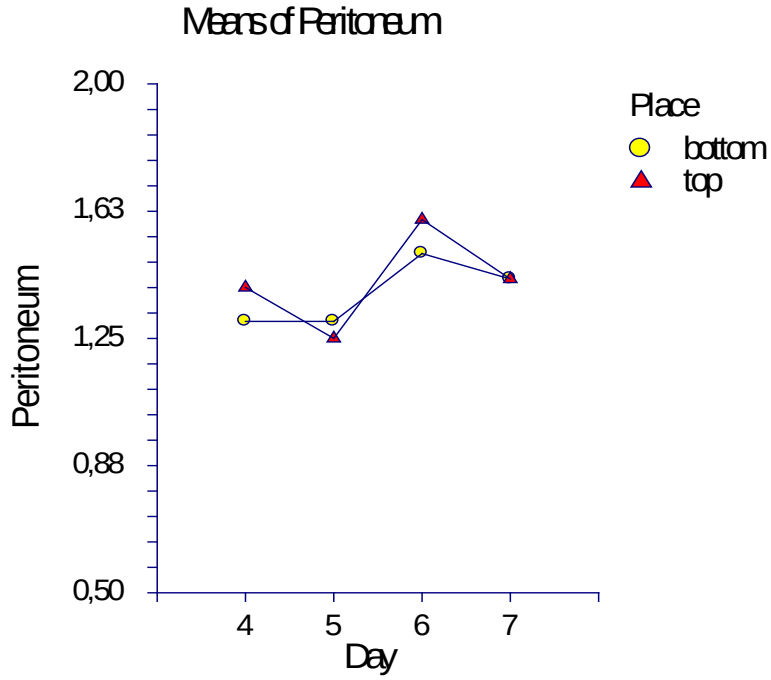

Figure 33 Peritoneum (grades) of the mackerel affected by position of the fish in ice slurry, and time of storage after catch. Graph presents average of samples of all of the groups (with and without NaCl, chill and frozen storage: n=4) at each sampling point.

Conclusions

Summarizing, the comparison of quality parameters showed that freshness, gaping and peritoneum deterioration has been affected by the storage time. Regarding temperature distribution, results confirmed speculations that higher salt concentration applied to slutty ice, decrease temperature during chill storage. According to the quality assessments, there was no evidence that different conditions of the chilled stored samples affect frozen products. Although there was a trend which suggests that mackerel stored in slurry ice with salt addition and on the bottom of the tub may have been beneficial in higher quality.

Due to the statistical similarity of the results obtained from quality evaluation it is needed to apply more suitable methods to detect changes occurred during post –mortem stage of mackerel. Quality evaluation schemes still need to be improved by choosing more understandable descriptors. Furthermore, due to high standard deviation of the raw material it is needed to conduct more assessments of fish quality, such as volatile compound methods –in order to determinate fish odors, color measurement, examination of the physical texture sensory analysis, and most important for quality evaluation of frozen stored samples – lipid oxidation analysis, in order to obtain certain confirmation of the chilled storage effect on fish quality.

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APPENDIX

Table 3 Overview of mackerel quality parameters (grades) after chill and frozen storage, respectively (average ± stdv. of n=20 samples).

Chill storage					
	Day after catch	Freshness	Gaping	Blood spots	Peritoneum	Weight (g)
Without salt, top	4	1,2 ± 0,7	1,9 ± 1,3	0,9 ± 0,6	1,0 ± 0,7	511,3 ± 108,8
	5	0,5 ± 0,5	0,9 ± 0,9	0,8 ± 0,4	0,6 ± 0,5	516,8 ± 75,8
	6	1,3 ± 0,4	1,8 ± 1,4	1,3 ± 0,6	1,2 ± 0,4	509,8 ± 109,3
	7	0,7 ± 0,4	1,1 ± 1,4	0,8 ± 0,6	1,0 ± 0,4	491,1 ± 75,7
Without salt, bottom	4	0,9 ± 0,7	2,7 ± 1,4	1,3 ± 0,5	1,0 ± 0,7	479,1 ± 96,7
	5	0,5 ± 0,5	1,2 ± 1,4	0,7 ± 0,6	0,9 ± 0,4	498,7 ± 106,2
	6	1,5 ± 0,5	1,9 ± 1,2	1,1 ± 0,6	1,2 ± 0,4	510,7 ± 75,6
	7	0,9 ± 0,7	1,8 ± 1,0	0,9 ± 0,7	1,0 ± 0,6	525,3 ± 85,2
With salt, top	4	0,6 ± 0,5	2,2 ± 1,2	1,3 ± 0,7	1,2 ± 0,6	471,8 ± 102,7
	5	0,6 ± 0,5	0,9 ± 0,9	1,2 ± 0,6	0,9 ± 0,4	483,4 ± 93,2
	6	1,3 ± 0,4	2,1 ± 1,3	0,9 ± 0,6	1,2 ± 0,4	489,6 ± 69,7
	7	0,7 ± 0,5	1,1 ± 0,7	0,8 ± 0,4	1,0 ± 0,5	510,1 ± 93,8
With salt, bottom	4	0,5 ± 0,6	1,7 ± 1,1	1,0 ± 0,7	0,9 ± 0,6	491,7 ± 91,4
	5	0,7 ± 0,5	1,0 ± 1,0	0,8 ± 0,8	0,7 ± 0,5	469,9 ± 97,0
	6	1,2 ± 0,4	1,4 ± 1,0	1,2 ± 0,5	1,2 ± 0,4	464,9 ± 76,4
	7	0,9 ± 0,4	1,8 ± 1,3	0,9 ± 0,5	1,0 ± 0,6	510,7 ± 89,4
Frozen storage						
	Day after catch	Freshness	Gaping	Blood spots	Peritoneum	Weight (g)
Without salt, top	4	1,9 ± 0,4	2,9 ± 1,3	0,9 ± 0,6	1,6 ± 0,6	523,8 ± 108,8
	5	1,7 ± 0,5	2,0 ± 1,0	0,6 ± 0,5	1,7 ± 0,5	516,8 ± 75,8
	6	2,0 ± 0,0	4,0 ± 1,4	0,8 ± 0,4	2,0 ± 0,0	509,8 ± 109,3
	7	1,8 ± 0,4	2,8 ± 1,3	0,6 ± 0,7	1,8 ± 0,4	516,8 ± 75,8
Without salt, bottom	4	1,9 ± 0,6	3,7 ± 1,3	1,3 ± 0,4	1,8 ± 0,4	473,0 ± 98,0
	5	1,5 ± 0,5	2,5 ± 1,2	0,6 ± 0,6	1,8 ± 0,6	498,7 ± 106,2
	6	2,0 ± 0,0	3,6 ± 0,9	0,6 ± 0,5	2,0 ± 0,0	510,7 ± 75,6
	7	1,9 ± 0,5	3,1 ± 0,8	0,7 ± 0,6	1,9 ± 0,0	525,3 ± 85,2
With salt, top	4	1,7 ± 0,5	3,3 ± 0,9	1,2 ± 0,6	1,8 ± 0,4	471,8 ± 102,7
	5	1,6 ± 0,5	1,9 ± 1,1	0,9 ± 0,6	1,9 ± 0,4	483,4 ± 93,2
	6	1,7 ± 0,5	2,7 ± 0,9	0,6 ± 0,6	1,8 ± 0,4	489,6 ± 69,7
	7	1,8 ± 0,4	2,8 ± 0,8	0,6 ± 0,5	1,8 ± 0,4	510,1 ± 93,8
With salt, bottom	4	1,1 ± 0,2	2,6 ± 1,1	0,8 ± 0,5	1,5 ± 0,5	491,7 ± 91,4
	5	1,7 ± 0,5	2,4 ± 1,2	0,7 ± 0,6	1,7 ± 0,5	469,9 ± 97,0
	6	1,8 ± 0,4	2,6 ± 1,0	0,7 ± 0,5	1,8 ± 0,4	464,9 ± 76,4
	7	1,9 ± 0,4	3,1 ± 1,2	0,7 ± 0,6	1,9 ± 0,4	510,7 ± 89,4

Table 4 Pearson´s correlation coefficient between quality variables of chilled samples.

	Freshness	Gaping	Blood spots	Peritoneum	Weight
Gaping	0,475				
p-value	0,063				
Blood spots	0,328	**0,534**			
p-value	0,215	**0,033**			
Peritoneum	**0,690**	**0,594**	**0,555**		
p-value	**0,003**	**0,015**	**0,026**		
Weight	0,151	-0,039	-0,388	-0,115	
p-value	0,577	0,886	0,137	0,566	
Salt content	0,115	-0,003	-0,029	0,199	-0,324
p-value	0,566	0,991	0,915	0,459	0,221

Table 5 Pearson´s correlation coefficient between quality variables of frozen stored samples.

	Freshness	Gaping	Blood spots	Peritoneum
Gaping	**0,575**			
p-value	**0,019**			
Blood spots	0,035	0,368		
p-value	0,898	0,161		
Peritoneum	**0,661**	0,463	-0,094	
p-value	**0,005**	0,071	0,729	
Weight	0,301	0,120	-0,466	0,127
p-value	0,257	0,658	0,069	0,639