The effects of different packaging solutions on the shelf life of fresh cod loins – drainage holes, cooling media and plastic bags

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Report summary

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Titill / Title	**The effects of different packaging solutions on the shelf life of fresh cod loins – drainage holes, cooling media and plastic bags /** Áhrif mismunandi pökkunarlausna á geymsluþol ferskra þorskhnakka – drengöt, kælimiðlar og plastpokar		
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Styrktaraðilar /Funding:	Tempra ehf., Útgerðarfélag Akureyringa ehf.		
Ágrip á íslensku:	Markmið rannsóknarinnar var að kanna áhrif mismunandi frauðplastkassa (með og án drengata), magn kælimiðils og plastpoka samanborið við plastfilmu í kassa á gæði ferskra þorskhnakka. Aldur hráefnis við vinnslu var um tveir sólarhringar. Fimm mismunandi tilraunahópar voru undirbúnir og geymdir við -1,7 °C í fimm daga og í beinu framhaldi geymdir við 2 °C í 9 daga, eða það sem eftir lifði geymslutímans. Skynmat (Torry ferskleikamat) og drip/vatnstap við geymslu var metið 1, 7, 9, 12 og 14 dögum eftir pökkun. Niðurstöðurnar gáfu til kynna að hnakkastykki sem pakkað var undir plastfilmu í frauðplastkassa án drengata og með minnsta magnið (250 g) af kælimiðli í kassanum skemmdust marktækt hraðar samanborið við aðra tilraunahópa. Lengsta geymsluþolið frá pökkun (12 dagar) mældist hjá afurðum sem var pakkað í frauðplastkassa án drengata, en voru í plastpoka inni í kassanum og með meira magn (750 g) af kælimiðli (ís) utan plastpokans. Niðurstöðurnar undirstrikuðu mikilvægi þess að viðhalda lágu og stöðugu hitastigi allan geymslutímann.		
Lykilorð á íslensku:	*Geymsluþol; ferskur fiskur; þorskur; frauðplastkassar; drengöt; plastpokar*		
Summary in English:	The aim of the study was to explore the effects of different expanded polystyrene (EPS) boxes (with and without drainage holes), cooling media and plastic bags compared to plastic films inside the boxes on the shelf life of fresh cod loins. The fish was caught two days before processing. Five experimental groups were prepared and stored at around -1.7 °C for five days followed by subsequent storage at around 2 °C for nine days. Sensory (Torry score) and drip loss evaluations were performed 1, 7, 9, 12 and 14 days post packaging. The results indicated that loins packed under a plastic film in EPS boxes (without drainage holes) and with the lowest amount (250 g) of cooling medium spoiled faster compared with the other experimental groups. The longest shelf life from packaging (12 days) was obtained for loins packed in EPS boxes inside a plastic bag and covered with a larger amount (750 g) of ice. Furthermore, the sensory results were in accordance to the temperature profiles of the experimental groups, stating the advantages of a low and stable storage temperature.		
English keywords:	*Shelf life; fresh fish; cod; EPS boxes; drainage holes; plastic bags*		

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1 INTRODUCTION

Fresh fish has a short shelf life even at refrigeration temperatures. The limited shelf life is a large hurdle for the export of fresh fish products from Iceland to mainland Europe or USA. Traditionally, rather well insulated expanded polystyrene (EPS) boxes have been utilised for export of Icelandic fresh fish products up to this date. EPS boxes are usually white, manufactured from moulded polystyrene beads and up to 98% of the boxes consist of air pores. The air decreases the density and increases the insulation performance but decreases strength and increases the required storage volume for the boxes. Studies have indicated that the insulation of EPS boxes is better than other fresh fish packaging such as corrugated plastic boxes (Anyadiegwu & Archer, 2002; Margeirsson *et al.*, 2009; Margeirsson *et al.*, 2011; Margeirsson *et al.*, 2012). The EPS boxes are either with or without drainage holes. The role of the drainage holes is to allow excess water, originating from melted ice and drip loss from the fish, to drain away during transportation and storage. Therefore, an absorbent pad is usually placed in the bottom of EPS box without these drainage holes.

The aim of the study was to explore the effects of different EPS boxes (with and without drainage holes), cooling media and plastic bags vs. plastic films inside the boxes on the shelf life of fresh cod loins. Sensory analysis (Torry score) and evaluation of drip loss were performed throughout the storage period to identify the fish quality and shelf life.

2 MATERIALS & METHODS

2.1 Raw material and experimental design

Atlantic cod (*Gadus morhua*) was caught on December 5th 2016 by wet fish trawlers (Snæfell EA-310 and Björgúlfur EA-312) in the water West of Iceland. The fish was bled, gutted, rinsed, iced in tubs and stored chilled until processed at ÚA (Akureyri, Iceland) and Samherji (Dalvík, Iceland) 2 days later. After beheading, filleting, cooling, skinning, trimming, the cod loins were divided into five experimental groups, as described in **Table 1** (groups A-D from Snæfell EA-310 were processed at ÚA while group E from Björgúlfur EA-312 was processed at Samherji), and shipped via airfreight to Matís in Reykjavík the same day. The experimental groups were stored at around -1.7 °C for five days followed by subsequent storage at around 2 °C throughout the remaining storage period. Each box contained approximately 5 kg of cod loins and on each sampling day one box per experimental group was evaluated. All experimental groups were evaluated 1, 7, 9, 12 and 14 days post packaging.

Table 1. Description of the experimental groups. *Traditional included cooling via liquid cooling in brine for 10-20 sec., while superchilled included cooling via Superchiller (Marel, Iceland).

Group	Pre-cooling*	Cooling aid inside EPS box	EPS box
A	Traditional	750 g ice on top of plastic film	Box with drainage holes, no absorbent pad
B	Traditional	750 g ice on top of plastic film	Whole box + absorbent pad at the bottom
C	Traditional	750 g ice on top of closed plastic bag	Whole box + absorbent pad at bottom of the plastic bag.
D	Traditional	250 g ice pack	Whole box + absorbent pad at the bottom
E	Superchilled	750 g ice on top of plastic film	Whole box + absorbent pad at the bottom

2.2 *Temperature monitoring*

The temperature profiles of the different experimental groups were recorded throughout the storage period with iButton (DS1922L) temperature loggers from Maxim Integrated Products (San Jose, CA 95134, USA) and TidbiT (UTBI-001) loggers from Onset (Bourne, MA 02532, USA).

2.3 *Drip loss*

The loin water loss was recorded throughout the storage period by comparing the weight of the loins before packaging and post storage as stated in following equation:

$$Drip\ loss\ (\%) = \frac{weight\ of\ fillets\ before\ storage\ (g) - weight\ of\ fillets\ after\ storage\ (g)}{weight\ of\ fillets\ before\ storage\ (g)} x\ 100$$

2.4 *Sensory evaluation*

Torry freshness score sheet (Shewan *et al*., 1953; **Table 2**) was used to assess cooked samples of cod. The texture of the samples was also evaluated using GDA (Generic Descriptive Analysis) as described by Lawless & Heymann (2010). Eight panellists participated in the sensory evaluation. They had all been trained according to international standards (ISO 8586, 2008). The members of the panel were experienced in using the sensory methods used in this evaluation. Portions weighing about 50 g were cut from the cod loins and placed in aluminium boxes coded with three-digit random numbers. The samples were cooked for 6 minutes in a pre-warmed oven (Convotherm Elektrogeräte GmbH, Eglfing, Germany) at 95-100 °C with air circulation and steam, and then served warm to the panel. Each panellist evaluated duplicates of each test group in a random order (five samples per session).

Table 2. Torry score sheet for freshness evaluation of cooked lean fish such as cod, haddock and Pollock (Shewan *et al.*, 1953).

Odour	Flavour	Score
Initially weak odour of sweet, boiled milk, starchy followed by strengthening of these odours	Watery, metallic, starchy. Initially no sweetness but meaty flavours with slight sweetness may develop	10
Shellfish, seaweed, boiled meat	Sweet, meaty, characteristic	9
Loss of odour, neutral odour	Sweet and characteristic flavours but reduced in intensity	8
Woodshavings, woodsap, vanillin	Neutral	7
Condensed milk, boiled potato	Insipid	6
Milk jug odours, boiled clothes-like	Slight sourness, trace of off-flavours	5
Lactic acid, sour milk, TMA	Slight bitterness, sour, off-flavours, TMA	4
Lower fatty acids (e.g. acetic or butric acids) composed grass, soapy, tallowy	Strong bitter, rubber, slight sulphide	3

2.5 Data handling

A computerised system (FIZZ, Version 2.0, 1994-2000, Biosystèmes) was used for sensory data recording. The sensory evaluation program Panelcheck V1.3.2 (Nofima, Tromsø, Norway) was used to assess panel performance. The programs NCSS 2000 (NCSS, Utah, USA), and Microsoft Excel 2007 were used for statistical analysis of the results. Analysis of variance (ANOVA, General linear model method) and Duncan´s test were used to analyse difference in Torry scores between sample groups. Correction was made for difference between the panellists use of the score sheet. The significance level was set at 5%.

3 RESULTS

3.1 Temperature monitoring

The environmental temperature of the experimental groups is summarized in **Figure 1**, showing that the temperature was rather stable throughout the whole storage period. The temperature during the first five days was around -1.7 °C which was rather lower compared to the original plan. During the following storage, the temperature was around 2.1 °C.

The temperature profiles of the experimental groups are summarized in **Figure 2** to **Figure 6**. Each profile shows the temperature distribution in the bottom corner, the middle and the top-middle of the box, as well as at the long side bottom-middle of the box. The top-middle of the box maintained generally the lowest temperature during the storage period followed by the middle part. The bottom corner and the bottom-middle at the long side of the box were more vulnerable towards temperature changes in the environment.

When groups A and B were compared, it was evident that the box with drainage holes (group A) provided less insulation compared to the whole box (group B). Due to poorer insulation of the boxes with the drainage holes, the fish temperature decreased more in group A than in group B during the first five days of storage at around -1.7 °C, thus preparing the fish in group A better for the mild temperature abuse at around 2 °C for nine days. The effects of 750 g of ice vs. 250 g of ice pack were compared (groups B and group D, respectively), the benefits of using more ice to maintain a low temperature was evident. Furthermore, packing loins in plastic bags with ice on top and outside the plastic bags (group C) resulted in slower temperature rise compared to placing plastic film on top of the loins and ice (group B).

The superchilled E-group was obviously at a more preferred temperature during packing, i.e. at around -0.8 to -0.6 °C (**Figure 6**), as compared to around 2-4 °C for the other groups (**Figure 2** to **Figure 5**).

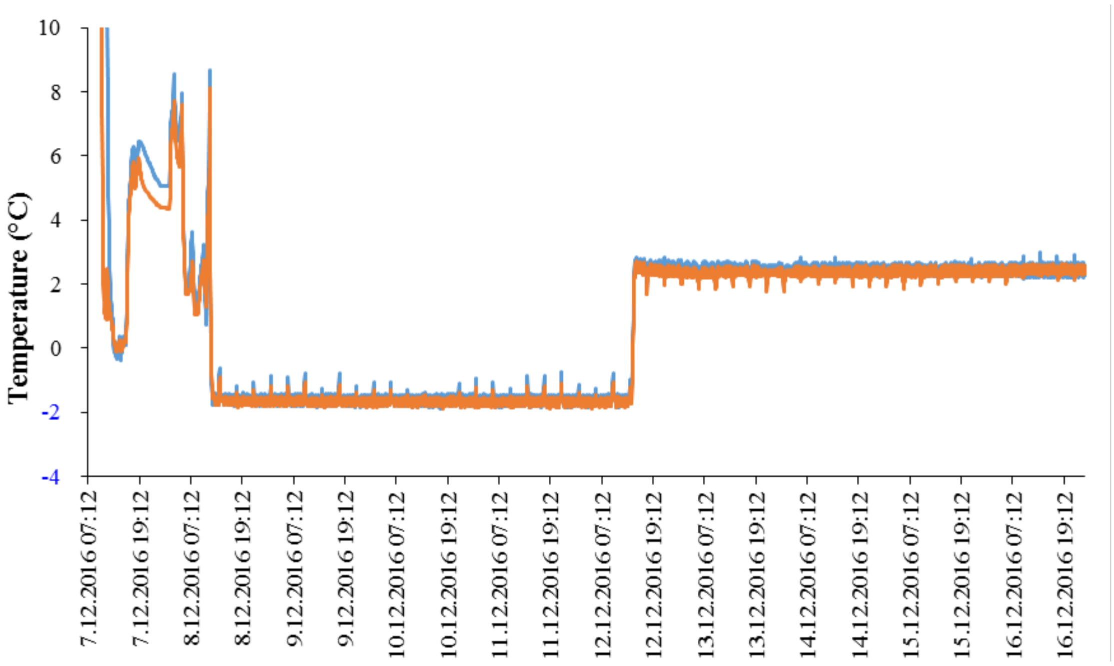

Figure 1. Temperature profile of the storing facility (environment) where the experimental groups were stored for up to 14 days post packaging. The processing were performed on December 7th 2016 in Akureyri (groups A-D) and Dalvík (group E), followed by shipment via air freight to Matís laboratory where the experimental groups were stored for five days at -1.7 °C and subsequently at 2.1 °C throughout the remaining storage period.

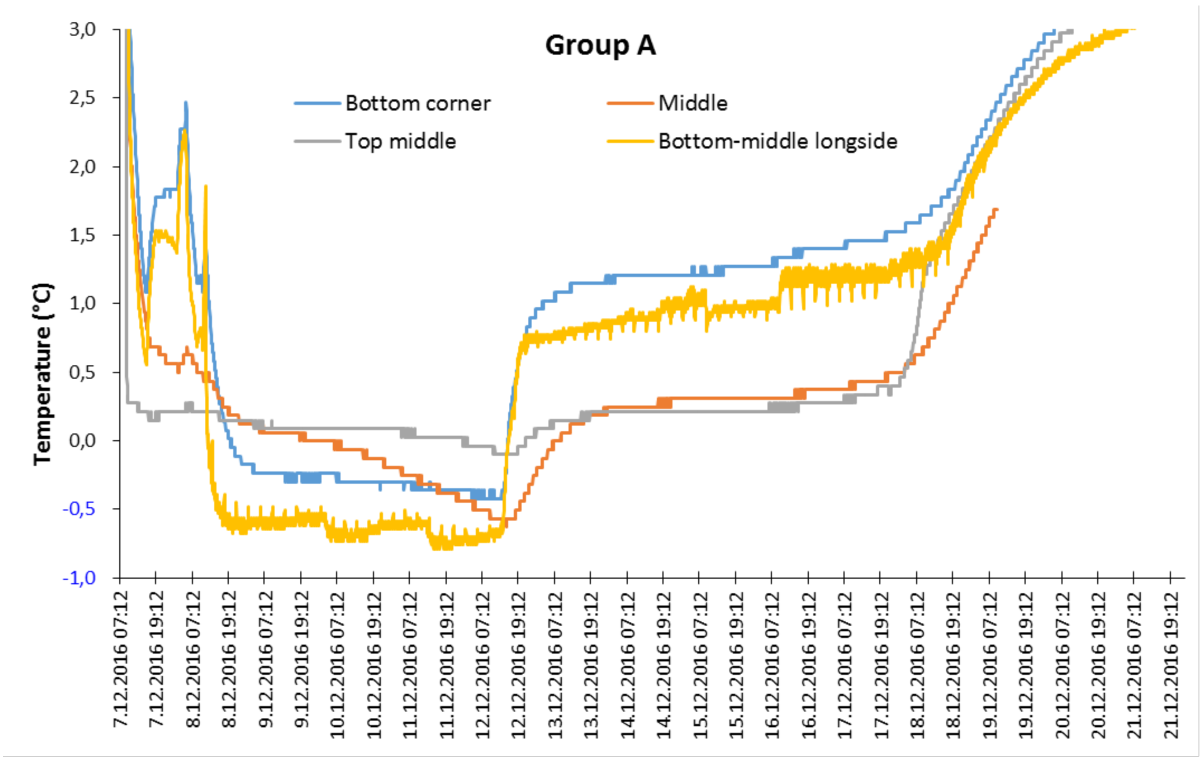

Figure 2. Temperature profile of experimental group A. The cod loins were packed in EPS box with draining holes and without absorbent pad at the bottom. Loins were covered with plastic film and 750 g of ice placed on the top.

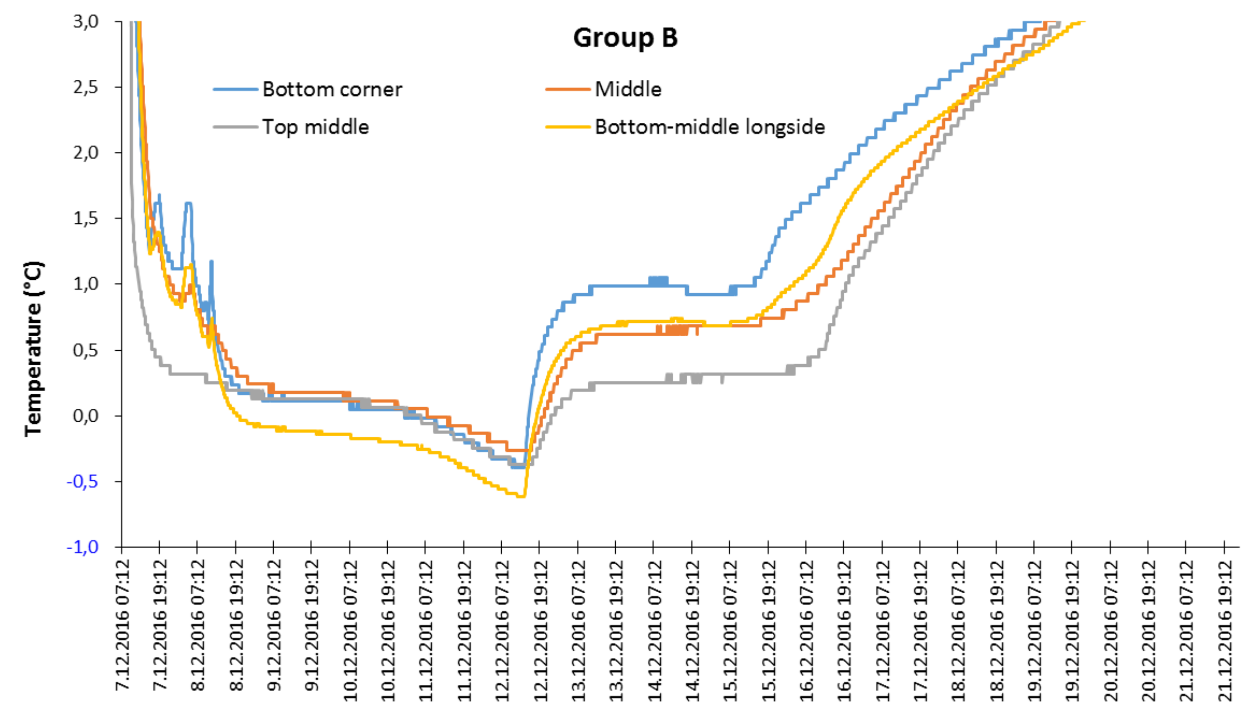

Figure 3. Temperature profile of experimental group B. The cod loins were packed in whole EPS box, loins covered with plastic film and 750 g of ice placed on the top and absorbent pad at the bottom.

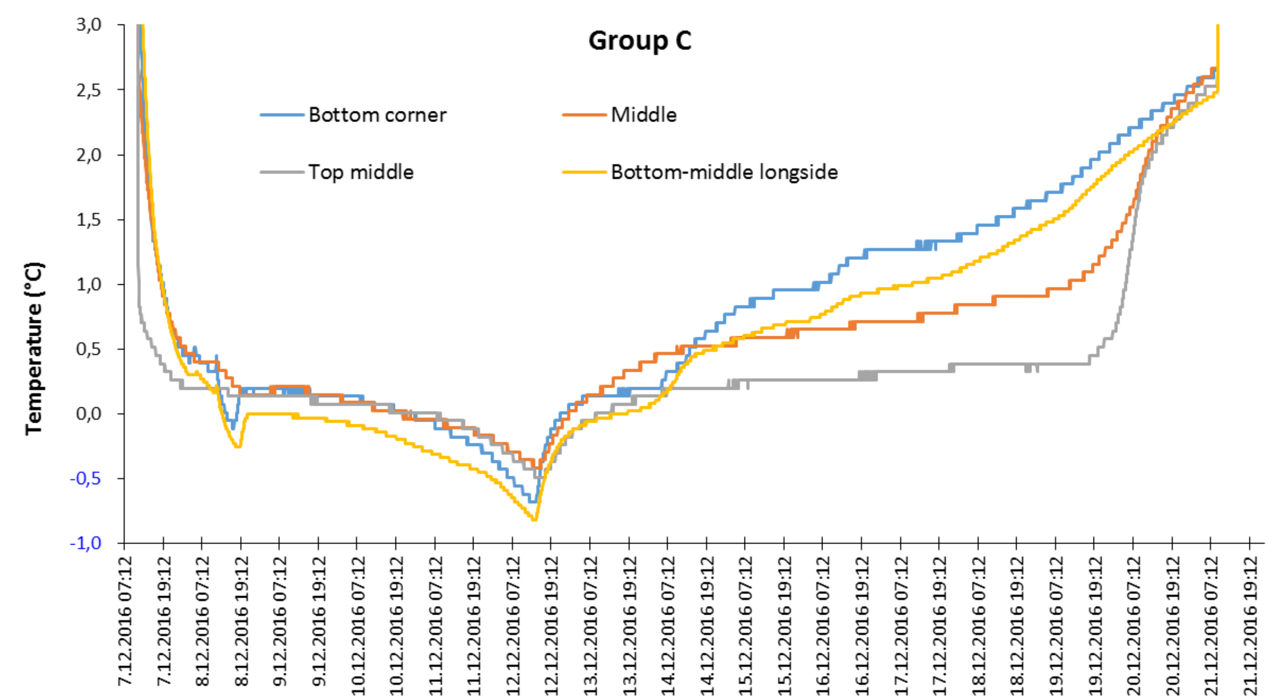

Figure 4. Temperature profile of experimental group C. The cod loins were packed in whole EPS box, loins placed in a plastic bag and covered with 750 g of ice on the top and absorbent pad at the bottom of the bag.

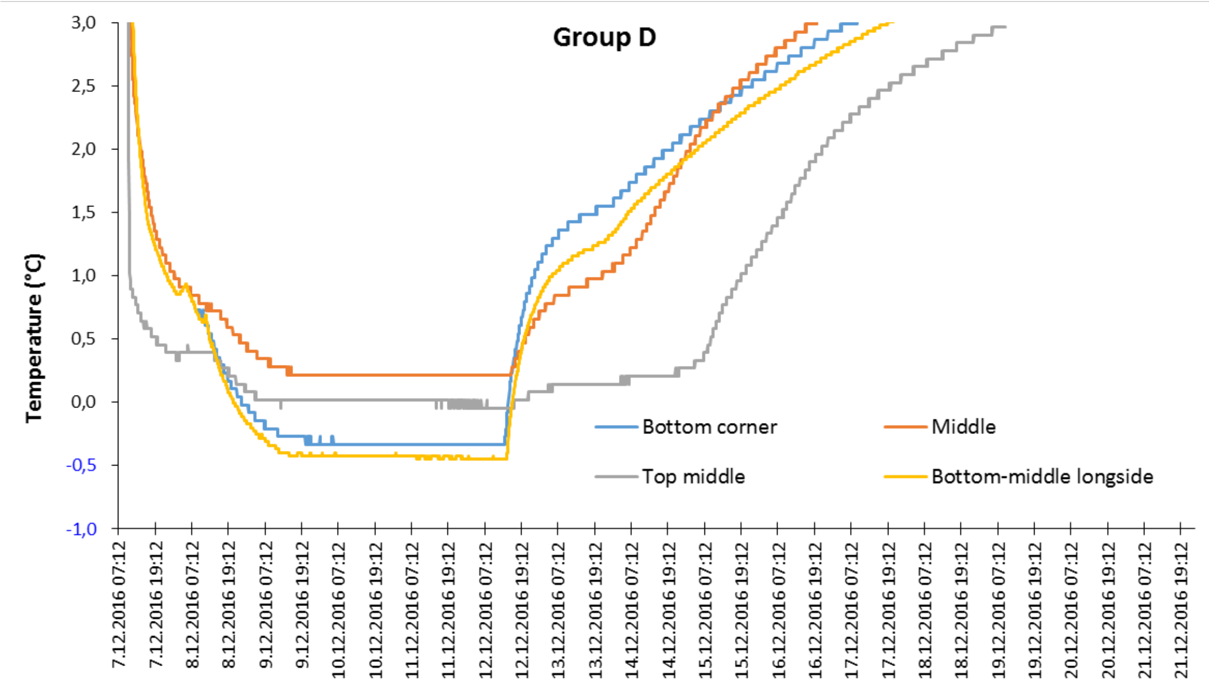

Figure 5. Temperature profile of experimental group D. The cod loins were packed in whole EPS box, covered with 250 g cooling pack on the top and absorbent pad at the bottom.

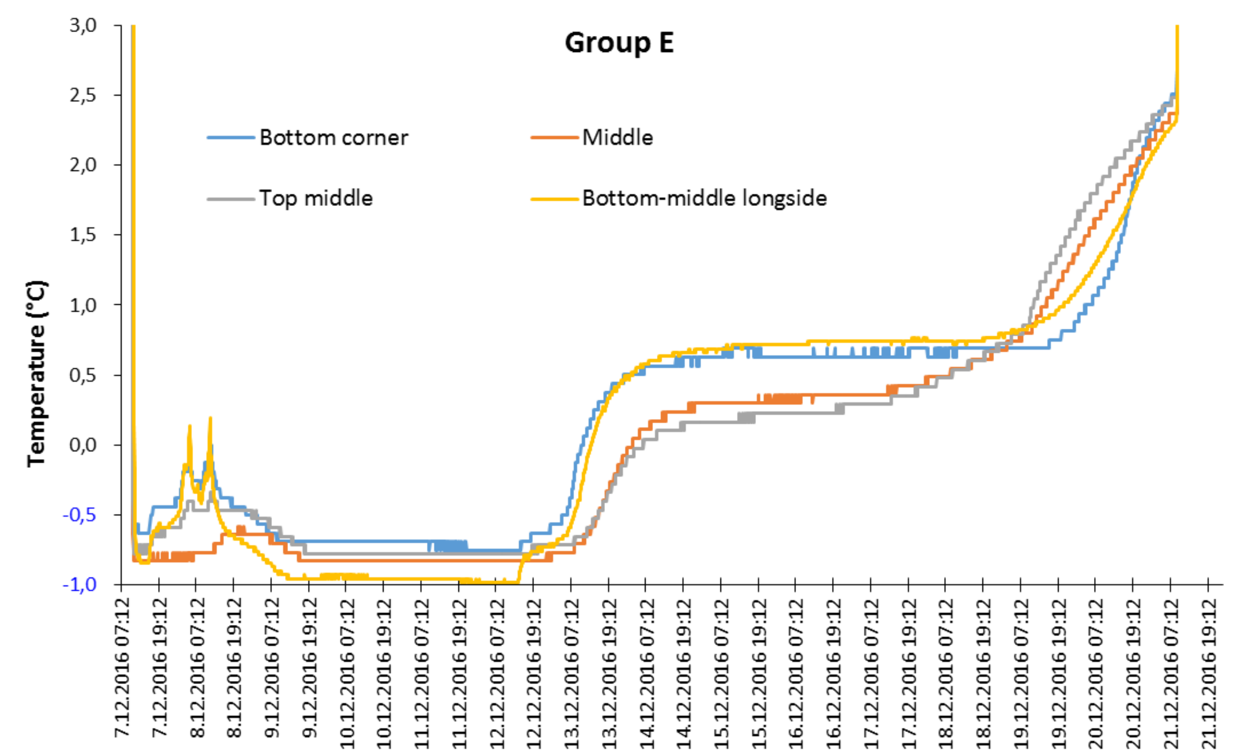

Figure 6. Temperature profile of experimental group E. The cod loins were superchilled before packaging in whole EPS box, loins covered with plastic film and 750 g of ice placed on the top and absorbent pad at the bottom.

3.2 Drip loss

The ability of the fish muscle to retain its natural water and therefore its juiciness is one of the quality criteria of fresh fish, especially from the consumer's point of view. The drip losses of the experimental groups during cold storage are summarized in **Figure 7**. The lowest drip loss was observed for group B while the highest drip loss was observed for group A and E after 9 days of storage. At the end of the storage period, the loins in group A had the highest drip loss followed by loins in group D. The drip loss of loins from other experimental groups (B, C and E) were of similar level after 14 days of storage. Present results indicate that the temperature inside the boxes affected the drip loss of the loins. The temperature profiles of group A and D (**Figure 2** and **Figure 5**, respectively) showed that the packaging solutions of these experimental groups were less efficient in maintaining a stable temperature compared to the other experimental groups and hence resulting in higher drip loss.

The drip loss of loins in group E can be derived to the superchilling of the loins prior to packaging. Fish muscle at sub-zero temperature is known to be at more risk of developing extracellular ice crystals compared to e.g. fish muscle at 0 °C, and hence increased drip loss can be experienced (Karlsdottir *et al.* 2008). Similar arguments can be made to partially explain the high drip loss of loins in group A, but due to poorer insulation of the boxes with the drainage holes the fish temperature decreased during the first five days of storage at around -1.7 °C. The drainage holes of the EPS boxes might, however, also have contributed to the high drip loss observed for group A. In contrary to other experimental groups, group A was the only group where the loins were in minimum contact to the excess water (melted ice and the loins' natural water).

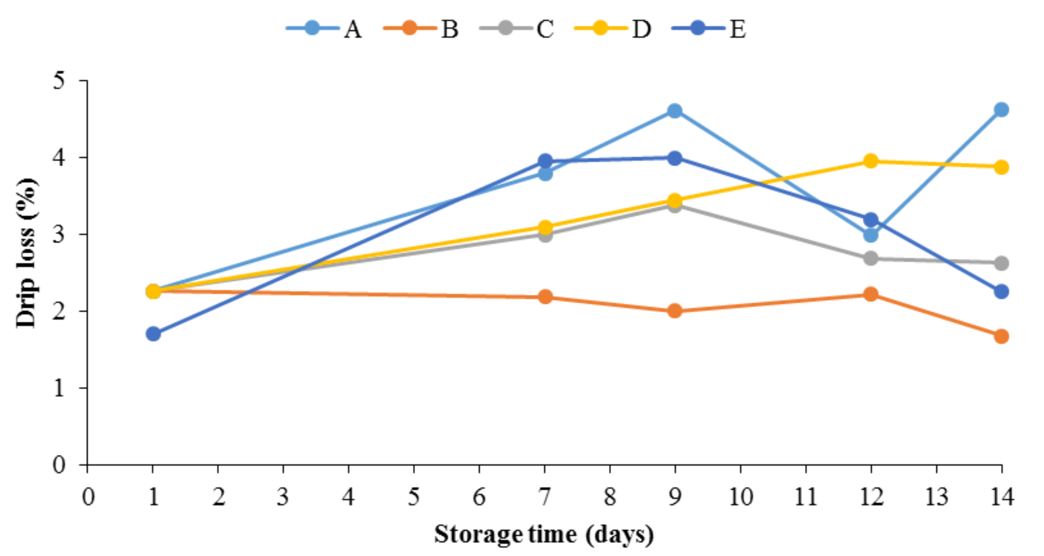

Figure 7. Drip loss (%) of the experimental groups (A-E) throughout the storage period.

It should however be noted that considerable difference in loin size was observed in group E compared to the other groups, which might affect the results. An overview of the size distribution of the loins in each experimental group on day 9, 12 and 14 are summarized in **Table 2**.

Table 3. An overview of the loin size distribution within each experimental group (A-E) after 9, 12 and 14 days of cold storage.

	Storage time (days)	MAX	MIN	AVE	SD
Group A	9	785	280	484	173
	12	652	153	327	162
	14	805	194	440	201
Group B	9	795	268	453	139
	12	834	163	448	196
	14	588	284	453	100
Group C	9	787	197	489	160
	12	767	230	411	184
	14	625	350	493	100
Group D	9	748	392	490	103
	12	967	201	488	277
	14	741	313	488	145
Group E	9	368	186	255	53
	12	517	175	269	89
	14	459	132	262	65

MAX = maximum loin weight (g); MIN = minimum loin weight (g); AVE = average loin weight (g); SD = standard deviation (g).

3.3 *Sensory evaluation – Torry score*

The difference between experimental groups was not significant with regard to the average Torry score from processing up to day 12 post packaging (**Table 3** and **Figure 8**). On day 12, group D (with only 250 g of cooling medium as compared to 750 g for the other groups) had significantly lower score compared to group C. The same trend was observed on day 14, where group C (loins packed in a plastic bag) had the highest score compared to the other experimental groups. All groups, with the exception of group D, reached the freshness limit (7.0) at day 9 post packaging. It can be assumed that group C reached the freshness limit on day 8. The shelf life of experimental groups A, B and E were estimated to be 11 days post packaging, while the shelf life of group D and C were estimated to be 10 and 12 days, respectively.

Table 4. Average Torry scores for the five experimental groups during the storage period and the p-value for difference between groups. Different letters within a row indicate significant difference between experimental groups (p<0.05).

Day	A		B	C		D		E		p-value
1			8.3					8.6		0.702
7	7.7		7.5	7.5		8.1		7.8		0.655
9	7.1		7.2	6.9		6.3		7.1		0.248
12	5.1		4.9	5.6	**a**	4.6	**b**	5.0		0.047
14	3.5	**b**	3.9	4.7	**a**	3.3	**b**	4.0	**b**	0.005

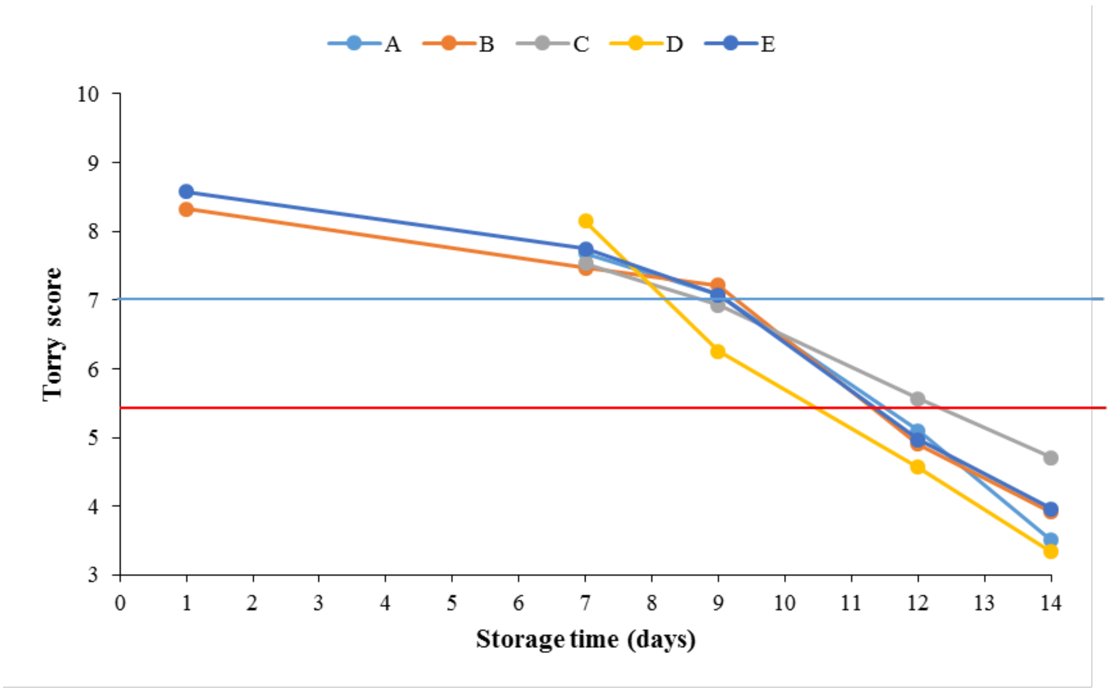

Figure 8. Average Torry score for the five experimental groups during the storage period. The blue line indicate the freshness limit (average = 7.0) and the red line indicate the limit of consumption (average = 5.5).

4 DISCUSSIONS AND CONCLUSIONS

The result of the Torry freshness score indicate that loins from experimental group D with the lowest amount of cooling medium spoiled faster compared to loins from other experimental groups, and loins packed in plastic bags inside EPS boxes with a larger amount of ice (group C) had the longest shelf life. The results suggest that packing fresh cod loins in a plastic bag might be more suitable to maintain the fish quality compared to using only a plastic film on top of the loins before applying the ice.

The Torry results were in accordance to the temperature profiles of the experimental groups, with the exception of group E, stating the advantages of a low and stable temperature. The size of the loins within group E needs to be considered when interpreting the results. The loins of group E were considerably smaller compared to loins from other experimental groups which might cause the loins to be spoiled faster. Therefore, group E was not comparable with the other experimental groups. However, the other experimental groups were highly comparable.

5 REFERENCES

Anyadiegwu M & Archer M. (2002). " Trials to compare the thermal performance of a new design of Tri-pack corrugated plastic non-reusable fish box with expanded polystyrene and single walled fibreboard boxes". The Sea Fish Industry Authority. http://truefoam.com/sites/default/files/images/products/cr192tri-pack_report.pdf

Lawless H.T., Heymann H. (2010). "Sensory evaluation of food, Principles and practices". Springer Science + Business Media. pp. 240-246.

ISO 8586. (2008). "Sensory analysis general guidance for the selection, training and monitoring of assessors. Part 1: selected assessors". Geneva, Switzerland: The International Organization for Standardization.

Karlsdottir M.G., Arason S. and Margeirsson B. (2008). "Combined blast and contact cooling – Effects on physicochemical characteristics of fresh haddock (*Melanogrammus aeglefinus*) fillets. Matís report 14-08.

Margeirsson B., Smárason B. Ö., Thordarson G., Olafsdottir A., Reynisson E., Gestsson Ó., Martinsdottir E .and Arason S. (2012). "Comparison of transport modes and packaging methods for fresh fish products - storage life study and life cycle assessment." Matís report 35-12.

Margeirsson B., Gospavic R., Pálsson H., Arason S. and Popov V. (2011). "Experimental and numerical modelling comparison of thermal performance of expanded polystyrene and corrugated plastic packaging for fresh fish." International Journal of Refrigeration 34(2): 573-585.

Margeirsson B., Arason S. and Pálsson H. (2009). "Thermal performance of corrugated plastic boxes and expanded polystyrene boxes." Matís report 01-09.

Shewan J.M., Macintosh R.G., Tucker C.G., Ehrenberg A.S.C. (1953). "The development of a numerical scoring system for the sensory assessment of the spoilage of wet white fish stored in ice". J Sci Food Agric 4:283-298.