Effects of CBC cooling on Norwegian cod

Experiments in Dalvík, Iceland, January 2009

Lárus Þorvaldsson
Kolbrún Sveinsdóttir
Kristín Anna Þórarinsdóttir
Hannes Magnússon
Sigurjón Arason

Table of Contents

Introduction 3

Methods and materials 3

- Experimental setup 3
- Raw material 3
- Weight of groups 5
- Temperature logging 6
- Cooking yield 6
- Sensory evaluation 6
- Microbial measurements 9
- Chemical measurements 10

Results and discussion 11

- Temperature during storage 11
- Sensory evaluation 15
  - Summary 20
- Microbial measurements 20
- Chemical measurements 21
- Cooking yield 23

References 23

Introduction

The goal of the project was to see how a new cooling method "Combined Blast and Contact freezing (CBC)" developed by Skaginn hf. influenced the quality and shelf life of cod caught in the Baltic sea. The effects of CBC cooling with and without cooling mats were analyzed with respect to temperature, chemical and microbiological measurements and sensory analysis. This gave an indication on how the different cooling methods influenced the shelf life of the product.

The owner of the project is Fiskeri- og havbruksnæringens landsforening (FHL) (contact person: Kristian Prytz) and Aker Seafoods, ASA (contact person: Jóhannes Pálsson).

Methods and materials

Experimental setup

In the original experiment setup the eight experiment groups seen in table 1 were planed.

Table 1: original experiment setup.

#	species	part	CBC	mats
1	cod	loins	yes	yes
2	cod	loins	yes	no
3	cod	loins	no	yes
4	cod	tails	yes	yes
5	cod	tails	yes	no
6	cod	tails	no	yes
7	haddock	fillets	yes	no
8	haddock	fillets	no	yes

In the experiment process the amount of cod tails and haddock fillets proved not to be sufficient for a full trial. The experiment groups were therefore the following

1. **CBC**: Cod fillets were cooled in CBC cooler, cut in loins and tails and then pruned. The loins were then packed in Styrofoam boxes without a cooling mat.
2. **CBC-MAT**: Cod fillets were cooled in CBC cooler, cut in loins and tails and then pruned. The loins were then packed in Styrofoam boxes with a cooling mat.
3. **MAT**: The cod fillets did not go through CBC cooling. They were cut in loins and tails and then packed in Styrofoam boxes with a cooling mat.

Raw material

400 kg of cod and 200 kg of haddock were caught and headed in the Baltic sea on the 9th of January and landed in Norway. On the 11th of January the fish was transported to Dalvík by air-cargo. There it was put in a cold storage room at Samherji's fish processing plant, where it was kept until it was processed in the afternoon on the 13th of January.

Weight of groups

Table 2: average and the total weight of the loins in each group.

	CBC-d06	CBC-d08	CBC-d12	CBC-d15	CBC-MAT-d06	CBC-MAT-d08	CBC-MAT-d12	CBC-MAT-d15	MAT-d08
avr. weight of loin [g]	335,4	366,9	434,4	368,6	336,5	233,8	333,8	370,2	308,1
deviation from mean	-2,2%	6,9%	26,6%	7,5%	-1,9%	-31,9%	-2,7%	7,9%	-10,2%
total weight [g]	2347,6	4402,3	3040,7	2949,0	3028,4	2805,3	3004,1	2961,3	4929,5
deviation from mean	-28,3%	34,5%	-7,1%	-9,9%	-7,5%	-14,3%	-8,3%	-9,6%	50,6%

As can be seen from table Table 2 there were large deviations in the average weight of each loin and in the total weight of each group. The reason for this is that the packing could not be performed under controlled conditions. This resulted in loins weighting from 233,8 g to 434,4 g and the total weight of groups from 2347,6 g to 4929,5 g. The weight of the groups has to be taken into account, for example when considering response to thermal load during storage.

Temperature logging

Four to five temperature loggers were put in each Styrofoam box and one on the outside of each box.

Table 3: Location of temperature loggers in the experiment groups with the same numbering scheme as in figure

#	horiz. loc.	vert. loc.	CBC-d08	CBC-d15	CBC-d18	CBC-MAT-d08	CBC-MAT-d15	CBC-MAT-d18	MAT-d08
1	middle	bottom							
2	middle	middle							
3	middle	top							
4	corner	bottom							
5	corner	top							
6	side	bottom							

Table 3 shows on which locations the temperature loggers were put in each box. Figure 1 shows the location of each temperature logger graphically, with a consistent numbering scheme to table 3. In addition to those loggers, a logger for ambient temperature was attached on the side of each box. The initial temperature of the fillets w

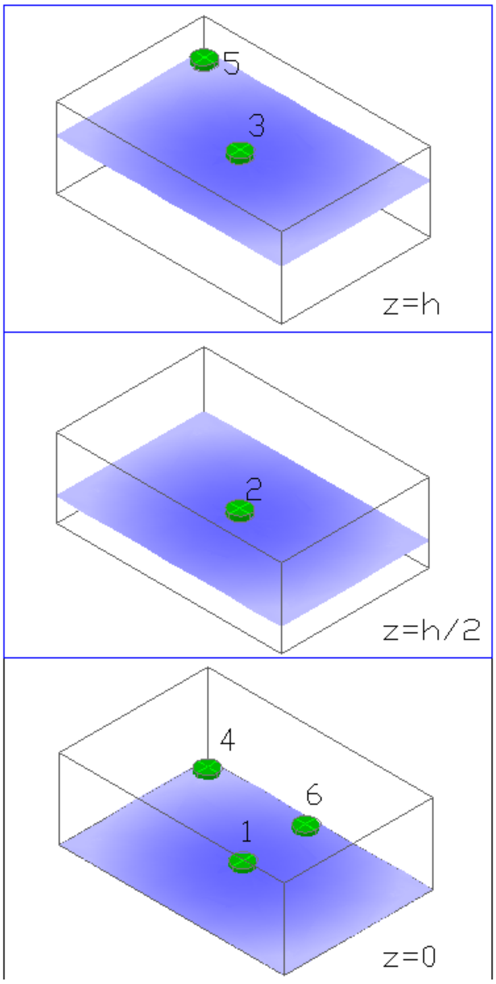

Figure 1: Location and numbering scheme of temperature loggers

Cooking yield

In finding cooking yield a single loin from each group was selected. When possible approximately 300 g loins were selected and cut in three parts: front, middle and end. Each part was weighted and pruned such that they would weight approximately the same. The cod was then cooked for eight minutes. Having cooked the loins they were allowed to cool down and drain for another 10 minutes and then finally weighted again.

Sensory evaluation

Quantitative Descriptive Analysis (QDA), introduced by Stone and Sidel (1985), was used to assess cooked samples (MA09sky001-003, 005, 009) of three sample groups of cod (Table 4). Eight panellists all trained according to international standards (ISO 8586-1, 1993); including detection and recognition of tastes and odours, trained in the use of scales and in the development and use of descriptors participated in the sensory evaluation. The members of the panel were trained in QDA method for cod. The panel was trained in recognition of sensory characteristics of the samples and describing the intensity of each attribute for a given sample using an unstructured scale (from 0 to 100%). Most of the attributes were defined and described by the sensory panel during other projects (Sveinsdottir et al 2009). The sensory attributes were 30 and are described in Table 5. In addition, the samples were evaluated with the Torry freshness score sheet for lean fish such as cod (Table 6). Scores between 10 (very fresh) to 3 (unfit) are given according to descriptions for freshness characteristics for odour and flavour characteristic for lean fish. When the average score is below 5,5, the fish is no longer fit for consumption as by then, the spoilage characteristics have become evident.

Samples weighing ca. 40 g were taken from the loin part of the fillets 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 to the panel. Each panellist evaluated duplicates of each sample in a random order in five sessions (maximum four samples per session).

A computerized system (FIZZ, Version 2.0, 1994-2000, Biosystémes) was used for data recording. QDA data was corrected for level effects (effects caused by level differences between assessors and replicates) by the method of Thybo and Martens (2000). Principal Component Analysis (PCA) on mean level corrected values of sensory attributes and samples was performed. Analysis of variance (ANOVA) was carried out on QDA data in the statistical program NCSS 2000 (NCSS, Utah, USA). The program calculates multiple comparisons using Duncan's multiple comparison test. The significance level was set at 5%, if not stated elsewhere.

Table 4: Definition of sample groups evaluated by sensory evaluation

Sample group	short name	sampling days
CBC cooling	CBC	6, 8, 12, 15
CBC cooling with mats	CBC-MAT	6, 8, 12, 15
Mats	MAT	8

Table 5: Sensory vocabulary for cooked samples of cod (*Gadus morhua*)

Sensory attribute	Short name	Description of attribute
Odour		
sweet	o-sweet	sweet odour
shellfish	o-shellfish	shellfish, characteristic fresh
meaty	o-meat	meaty odour, reminds of boiled meat, halibut
vanilla/boiled milk	o-milk	vanilla, sweet boiled milk
boiled potatoes	o-potatoes	odour reminds of whole warm boiled potatoes
frozen storage	o-frozen	reminds of odour found in refrigerator or freezing compartment
table cloth	o-table cloth	reminds of a unclean damp table cloth
TMA	o-TMA	TMA odour, reminds of dried salted fish, amine
sour	o-sour	sour odour, spoilage sour, acetic acid
sulphur	o-sulphur	sulphur, matchstick, boiled kale
Appearance		
light/dark colour	a-dark	Left end: light, white colour. Right end: dark, yellowish, brownish, grey
homogenous/ heterogeneous	a-heterogeneous	Left end: homogenous, even colour. Right end: discoloured, heterogeneous, stains
white precipitation	a-precipitation	white precipitation in the broth or on the fish
Flavour		
salt	f-salt	salt taste
metallic	f-metallic	metallic flavour as of fresh cod
sweet	f-sweet	characteristic sweet flavour of new/fresh boiled cod
meaty	f-meat	meaty flavour, reminds of boiled meat, meat sour
frozen storage	f-frozen	reminds of food which has soaked in refrigerator/freezing odour
pungent	f-pungent	pungent flavour, bitter
sour taste	f-sour	sour taste, spoilage sour
TMA	f-TMA	TMA flavour, reminds of dried salted fish, amine
Putrid	f-putrid	Strenght of off-flavour, putrid flavour
Texture		
flakiness	t-flakes	the fish portion slides into flakes when pressed with the fork
firm/soft	t-soft	Left end: firm. Right end: soft. Evaluate how firm or soft the fish is during the first bite
dry/juicy	t-juicy	Left end: dry. Right end: Juicy. Evaluated after chewing several times: dry - pulls juice from the mouth
tough/tender	t-tender	Left end: tough. Right end: tender. Evaluated after chewing several times
mushy	t-mushy	mushy texture
meaty	t-meaty	meaty texture, meaty mouth feel
clammy	t-clammy	clammy texture, (dry redwine, tannin)
rubbery	t-rubbery	rubbery texture, chewing gum

Table 6: Torry score sheet for freshness evaluation of cooked lean fish such as cod, haddock and pollock

Odour	Flavour	Score
Initially weak odour of sweet, boiled milk, starchy, followed by strenghtening 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, reminiscent of boiled clothes	Slight sourness, trace of "off"-flavours	**5**
Lactic acid, sour milk, TMA	Slight bitterness, sour, "off"-flavours, TMA	**4**
Lower fatty acids (eg acetic or butyric acids) decomposed grass, soapy, turnipy, tallowy	Strong bitterness, rubber, slight sulphide	**3**

Microbial measurements

Total viable psychrotrophic counts (TVC) and counts of H_2S-producing bacteria were evaluated on iron agar (IA) as described by Gram and others (1987) with the exception that 1% NaCl was used instead of 0.5%. Plates were surface-plated and incubated at 17°C for 4 d. Bacteria forming black colonies on this medium produce H_2S from sodium thiosulphate and/or cysteine. In all experiments cooled Maximum Recovery Dilutent (MRD, Oxoid) was used for dilutions.

Chemical measurements

The method of Malle and Tao (1987) was used for total volatile bases (TVB-N) and trimethylamine (TMA) measurements. TVB-N was measured by steam distillation (Struer TVN distillatory, STRUERS, Copenhagen) and titration, after extracting the fish muscle with 7.5% aqueous trichloracetic acid solution. The distilled TVB-N was collected in boric acid solution and then titrated with sulphuric acid solution. TMA was measured in trichloroacetic acid (TCA) extract by adding 20 ml of 35% formaldehyde, an alkaline binding mono- and diamine, TMA being the only volatile and measurable amine. All chemical analyses were done in duplicate.

The water content of each fillet was measured by accurately weighing out 5 grams of the minced sample in a ceramic bowl with sand. The sample was then mixed to the sand and dried in an oven at 103 ± 2 °C for 4 hours. The water content was based on weight differences before and after the drying of three replicates for each sample (ISO 6496, 1999). Salt content was measured with the Volhard Titrino method according to AOAC ed. 17 from 2000 (no. 976.18).

The water holding capacity (WHC) of the samples was measured with the centrifugal method described by Eide and others (1982). Approximately 2 g of minced cod was weighed into each sample glass and centrifuged for 5 minutes with a rotational speed of 3600 rpm. Four replicates were evaluated for each sample. During the centrifugation water was removed from the sample. The water drained through a polyester membrane in the bottom of the sample holder where it was collected. The water holding capacity was then calculated with the equation

$$WHC\ (\%) = \frac{Water\quad content(\%) - Weight\quad loss(\%)}{Water\quad content(\%)}$$

where the weight loss is defined as

$$Weight\quad loss(\%) = \frac{Weight\quad loss\quad in\quad centrifuge(g)}{Original\quad sample\quad weight(g)} \times 100$$

The pH was measured in a mixture of 5 g mince and 5 ml deionized water using the Radiometer PHM 80.

All analyses were done in duplicate.

Results and discussion

Temperature during storage

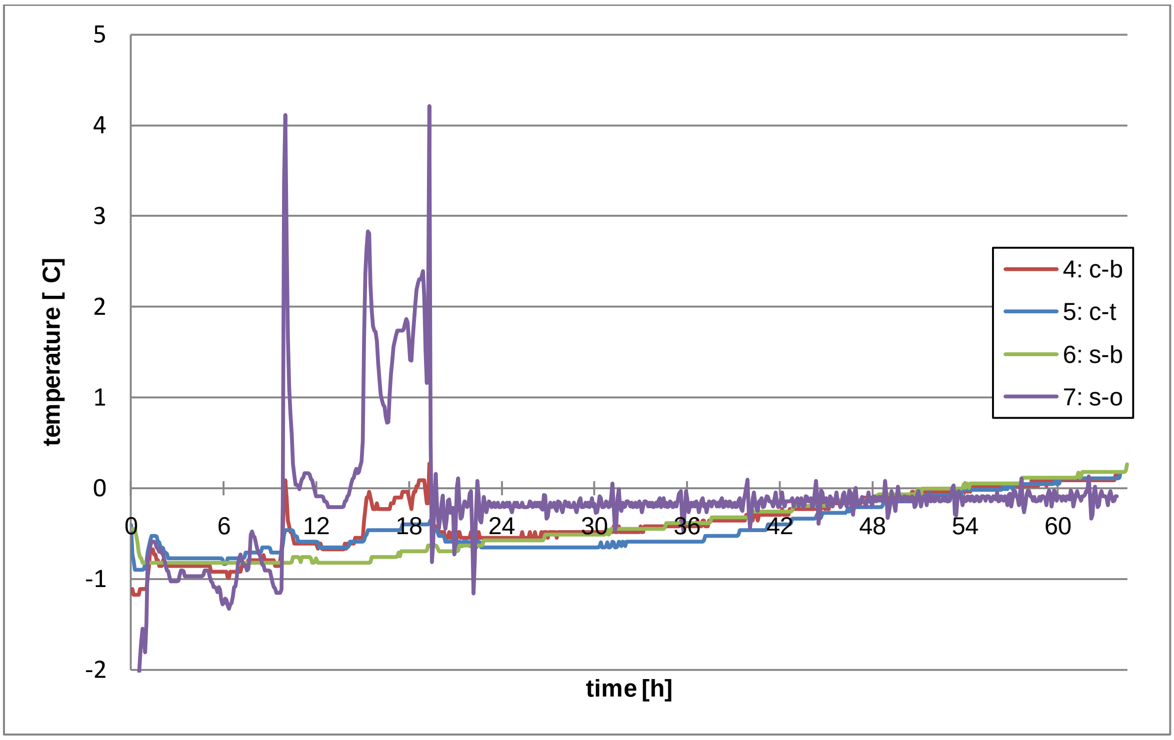

Figure 2: Temperature history of the group CBC-d08.

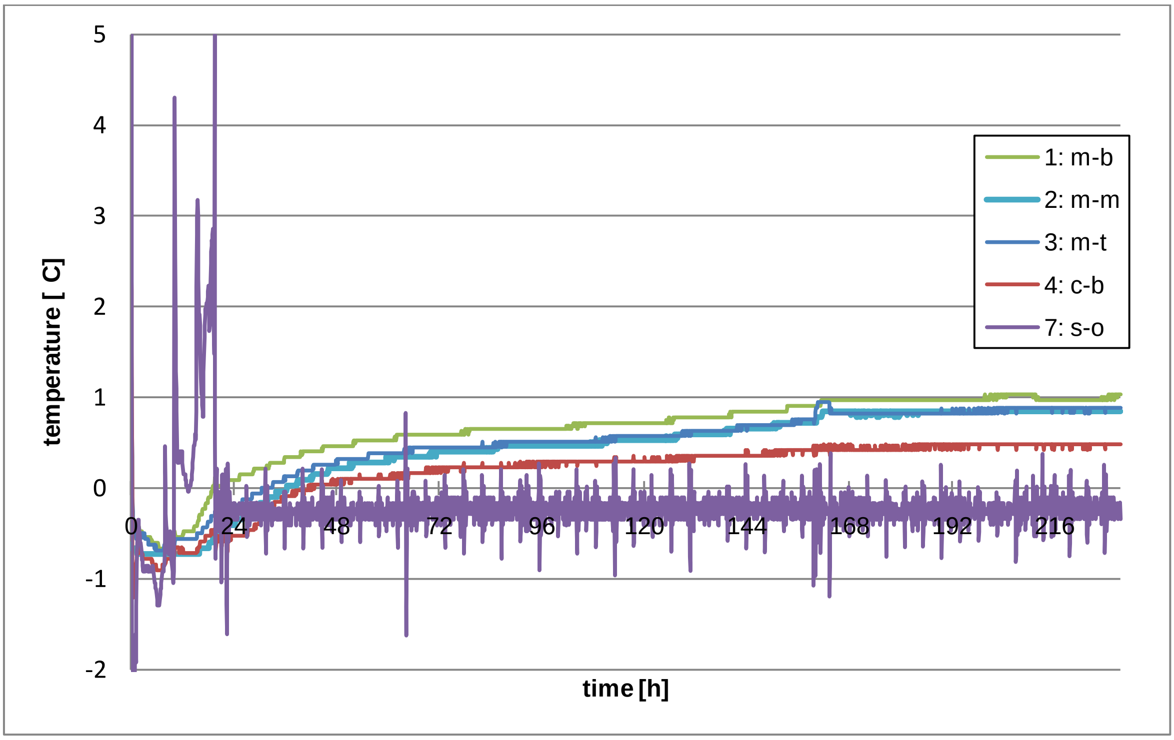

Figure 3: Temperature history of the group CBC-d15

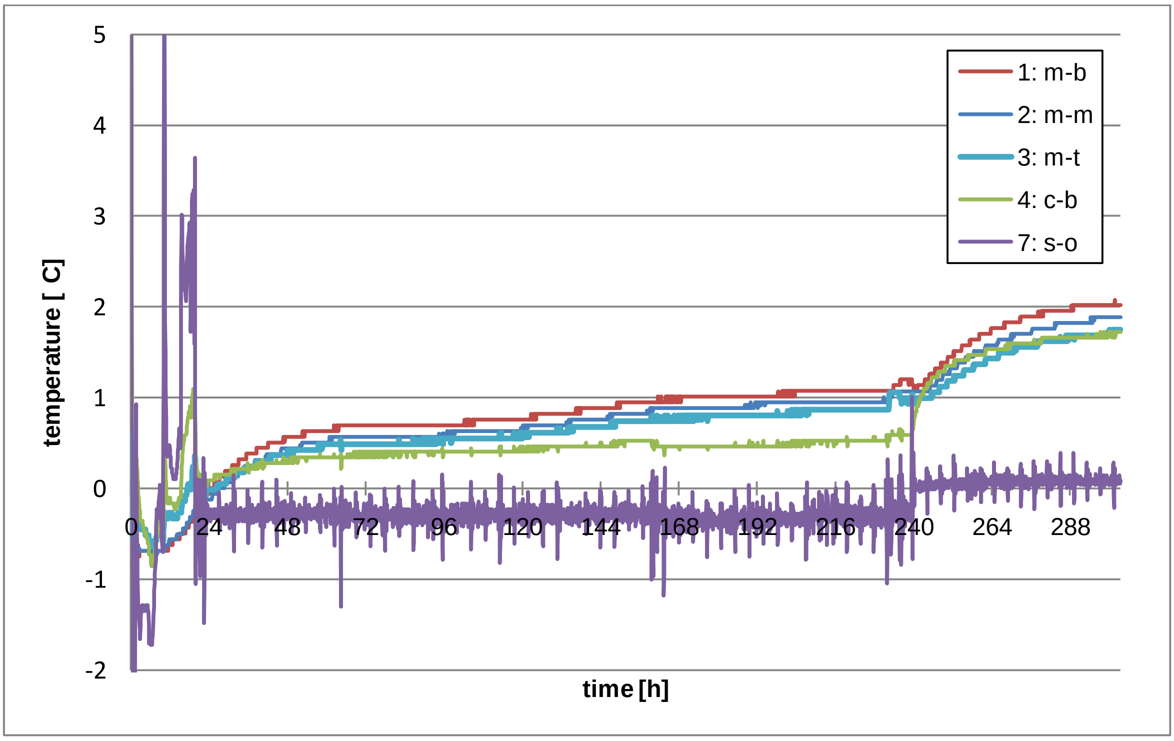

Figure 4: Temperature history of the group CBC-d18.

Figures 1-3 show the temperature from when the loins are packed at Dalvík fish processing plant and transported to Reykjavík where they are kept at a steady 0°C in Matís facilities until they are unpacked for measurement and sensory evaluation.

The surrounding temperature around -1°C during the first 8 hours is while the product was being transported from Dalvík to Reykjavík. During that time period the outside temperature was approximately -10°C. The heat load from 10-20 hours is due to the storage in Flytjandi's cold storage room. After 20 hours the material came to Matís facilities where it was kept at -1°C.

The heat load during storage at Flytjandi's cool storage room seems to result in approximately 1°C rise in temperature. An interesting feature of the temperature development is that the temperature inside the box rises even though ambient temperature is approximately 1°C lower. This is probably due to microbiological activity. This activity seems to be very sensitive to changes in ambient temperature, as can be seen after 240 hours, where a rise of 0.25°C in ambient temperature results in a significant rise in the temperature of the material inside the Styrofoam box.

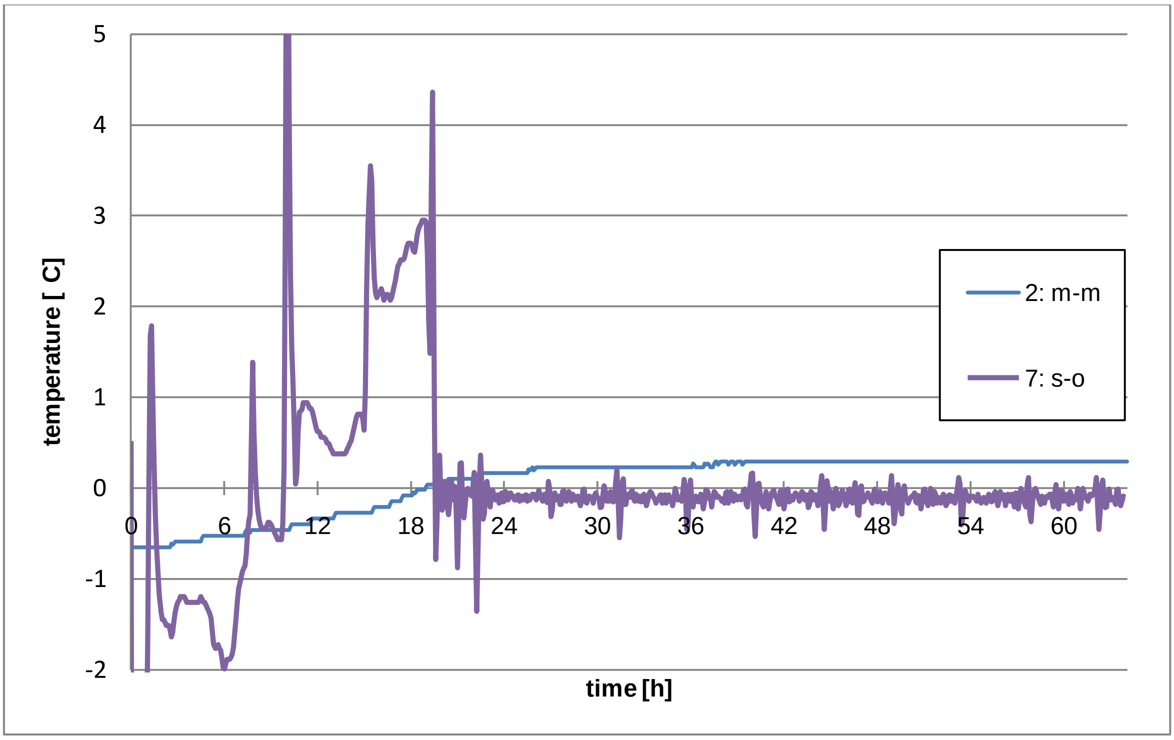

Figure 5: Temperature history of the group CBC-MAT-d08.

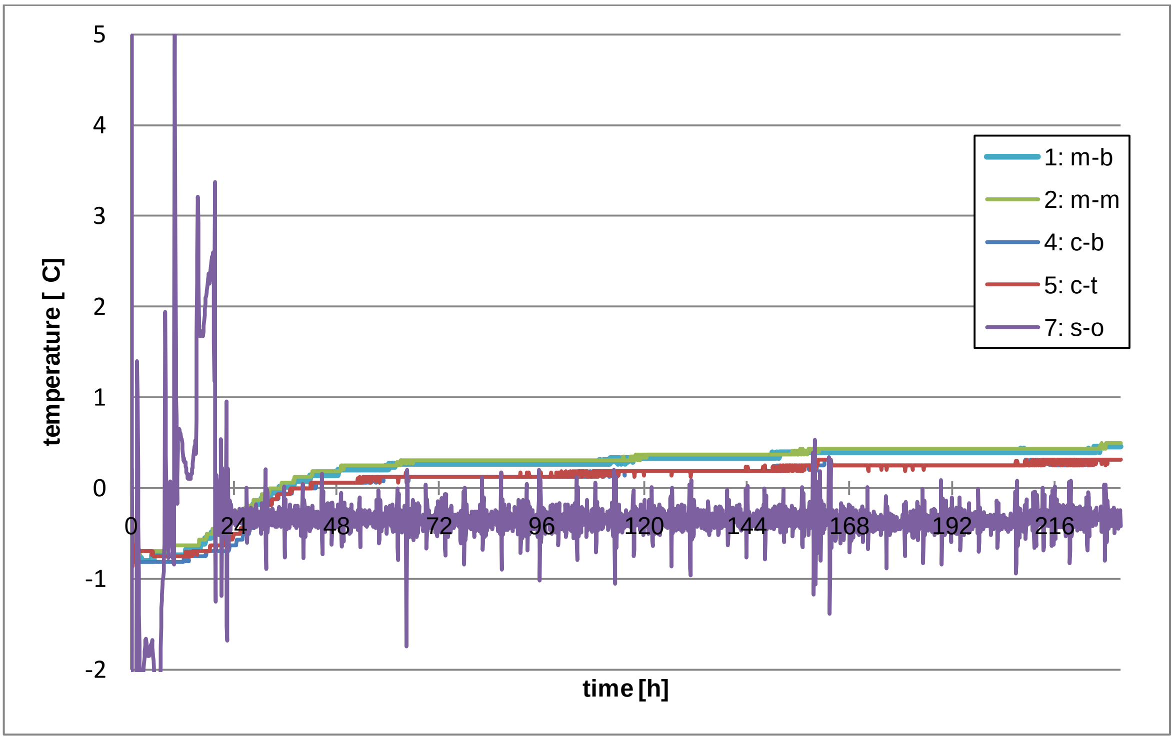

Figure 6: Temperature history of the group CBC-MAT-d15.

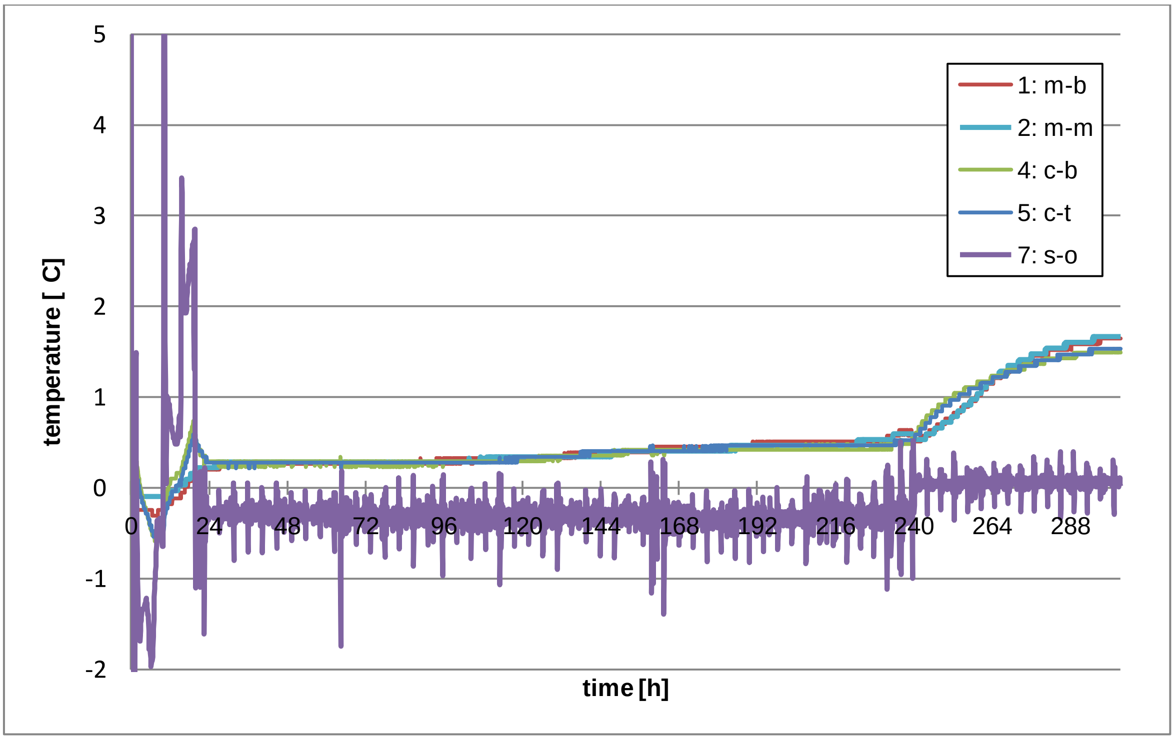

Figure 7: Temperature history of the group CBC-MAT-d18.

Figures 4-6 show the temperature development of three groups which all use cooling mats. The temperature distribution inside the box seems much more homogenous in the groups without a cooling mat. The temperature increase during the storage period seems to be slower than in the groups without a cooling mat. The temperature after 240 hours storage is 0.5°C in the group with a cooling mat while it is 1°C in the group with a cooling mat. It is also interesting to see the same feature in figures 3 and 6 where an increase of 0.25°C in ambient temperature after 240 hours results in a jump in temperature. At the end of the storage period, or at 300 hours, the average temperature in the group without a cooling mat is 1.9°C while the group with a cooling mat ends at 1.6°C.

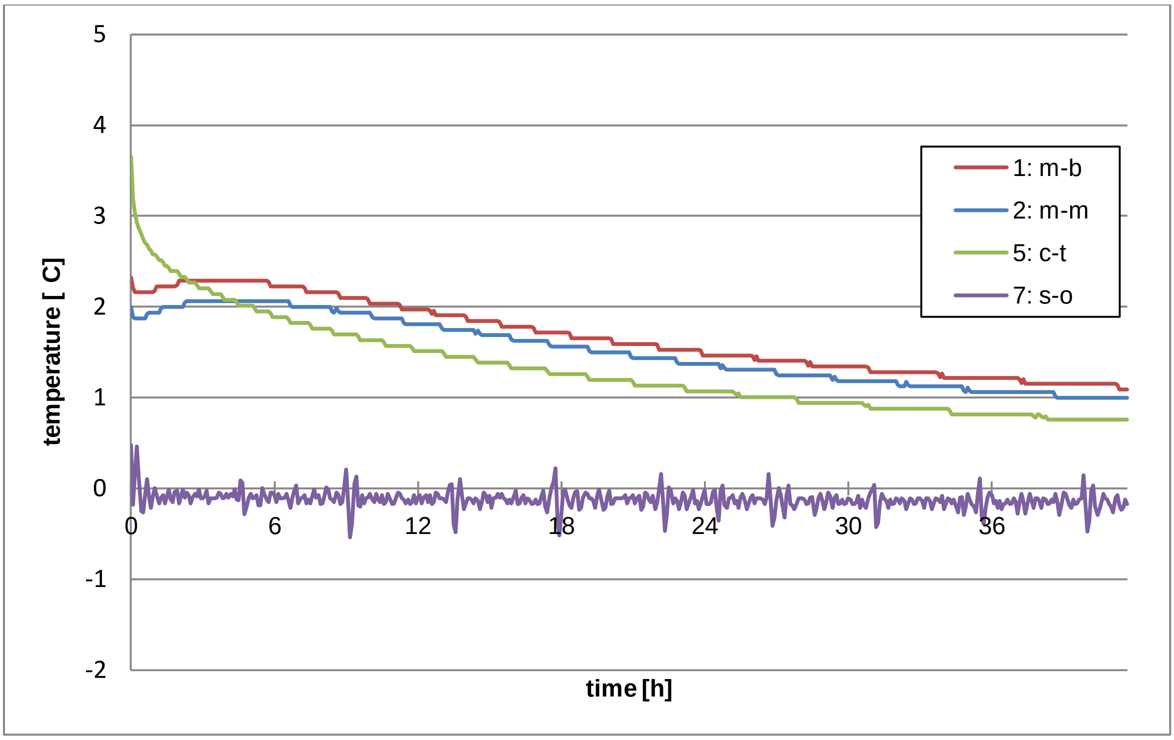

Figure 8: Temperature history of the group MAT-d08.

Figure 7 shows the temperature history of the group which was left without CBC-cooling. Temperature loggers were inserted into that group right before it went into the cooling chambers at Matís facilities. This group might have been subjected to more temperature load than the other groups prior to that since it was transported back to Matís facilities from Keflavík airport.

The temperature of the group which was left without CBC-cooling and then packed with a cooling mat seems to drop consistently during the storage period. The temperature is considerably higher in that group in the beginning of the storage period than the CBC-cooled groups or around 2.5°C. After 42 hour storage at 0°C the temperature has dropped to approximately 1°C which is considerably higher temperature than was seen in the CBC-cooled groups after the same time period.

Sensory evaluation

The sample without CBC cooling (MAT) was only evaluated on storage day 8 and is therefore only compared to other groups on that day. Figure 9 illustrates how the different samples were described by the sensory attributes. The first two principal components (PC1 and PC2) show the main structured information in the data and explain 88% (82% and 6% respectively) of the sensory variation between the samples.

The predominant difference between the samples was due to difference in freshness; attributes characteristic for cod at the beginning of storage time (such as sweet odour and flavour, metallic flavour) to the right, and attributes describing cod at the end of shelf life (such as sour and TMA odour and flavour) to the left in Figure 9b. No clear sensory differences appear to be between the three groups evaluated. At the beginning of storage, the samples stored six days are grouped together furthest to the right side, then the eight day samples, 12 days and then the samples stored 15 days furthest to the left side of Figure 9a.

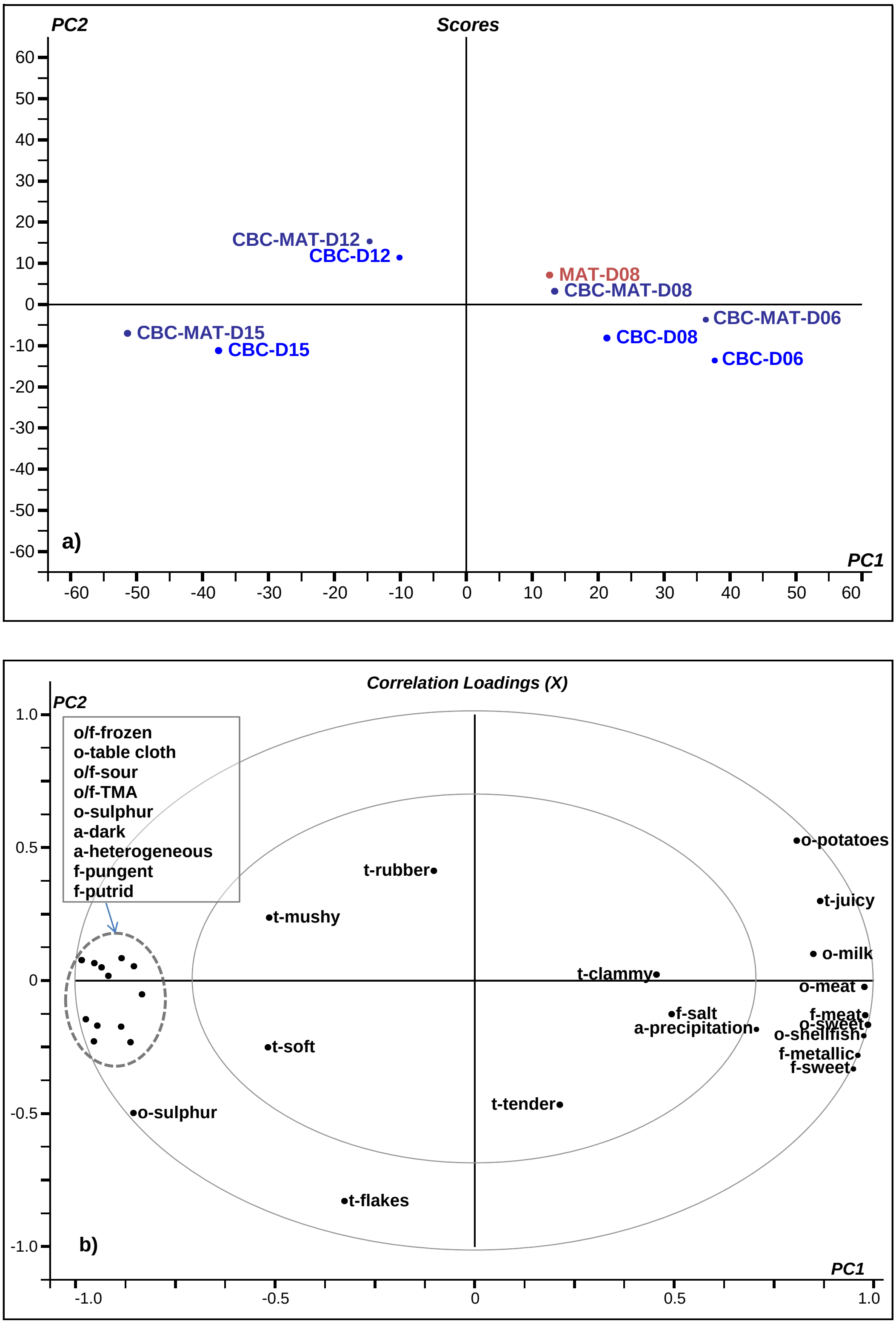

Figure 9: PCA describing sensory quality of the products as evaluated by a trained sensory panel. a) Scores; b) correlation loadings. PC1 vs PC2 (X-expl.: 82%, 6%). Ellipses mark the 50% and 100% explained variance limits. o = odour; a = appearance; f = flavour; t = texture

The sample groups were different with regard to most sensory attributes (Table 7). The sample with no CBC cooling (MAT) was very similar to the CBC and CBC-MAT with regard to all sensory attributes.

Table 7: Average sensory scores (QDA scale 0-100%) for the tree groups. D=days of storage. Different letters show significant differences within a line

Sample group	**CBC**				**CBC-MAT**				**MAT**	
Sensory attribute	**D06**	**D08**	**D12**	**D15**	**D06**	**D08**	**D12**	**D15**	**D08**	***p-value***
odour										
o-sweet	42 ^{a}	34 ^{ab}	18 ^{d}	12 ^{d}	40 ^{ab}	31 ^{bc}	17 ^{d}	10 ^{d}	30 ^{bc}	**0,000**
o-shellfish	30 ^{a}	26	17	12 ^{b}	29 ^{a}	23	16	11 ^{b}	22	**0,001**
o-meat	35 ^{a}	25 ^{ab}	18 ^{bc}	8 ^{cd}	35 ^{a}	23 ^{ab}	17 ^{bc}	7 ^{cd}	24 ^{ab}	**0,000**
o-milk	28	19	22	14 ^{b}	30 ^{a}	20	19	14 ^{b}	23	**0,028**
o-potatoes	26	23	24	15	28	23	25	15	28	0,119
o-frozen	3	6	4	6	3	7	6	5	5	0,720
o-table cloth	3 ^{b}	9 ^{b}	15 ^{b}	29 ^{a}	3 ^{b}	12 ^{b}	13 ^{b}	31 ^{a}	9 ^{b}	**0,000**
o-TMA	2 ^{cd}	4 ^{bc}	11 ^{b}	23 ^{a}	2 ^{cd}	6 ^{bc}	12 ^{b}	29 ^{a}	7 ^{bc}	**0,000**
o-sour	2 ^{b}	5 ^{b}	13 ^{b}	24 ^{a}	1 ^{b}	7 ^{b}	11 ^{b}	26 ^{a}	6 ^{b}	**0,000**
o-sulphur	1 ^{b}	1 ^{b}	2 ^{b}	13 ^{a}	1 ^{b}	2 ^{b}	1 ^{b}	15 ^{a}	2 ^{b}	**0,000**
appearance										
a-dark	20 ^{b}	20 ^{b}	25	38 ^{a}	23	24	28	38 ^{a}	26	**0,011**
a-heterogeneous	22	21	28	38	28	20 ^{b}	29	40 ^{a}	24	**0,018**
a-precipitation	24	23	20	21	26	20	18	20	25	0,868
flavour										
f-salt	16	12	9	9	20	12	10	9	12	0,174
f-metallic	34 ^{a}	26 ^{ab}	13 ^{cd}	10 ^{de}	30 ^{ab}	21 ^{bc}	14 ^{cd}	10 ^{de}	22 ^{bc}	**0,000**
f-sweet	34 ^{ab}	30 ^{ab}	15 ^{de}	13 ^{de}	34 ^{a}	22 ^{cd}	14 ^{de}	8 ^{ef}	23 ^{ac}	**0,000**
f-meat	31 ^{a}	27 ^{ab}	15 ^{bcd}	12 ^{ce}	33 ^{a}	23 ^{ac}	17 ^{bcd}	8 ^{def}	22 ^{ac}	**0,000**
f-frozen	4	4	7	9	6	7	7	6	6	0,210
f-pungent	1 ^{b}	2 ^{b}	6	10 ^{a}	3 ^{b}	3 ^{b}	7	9 ^{a}	3 ^{b}	**0,000**
f-sour	2 ^{cd}	7	11	15 ^{ab}	2 ^{cd}	8	10	17 ^{a}	6 ^{bc}	**0,001**
f-TMA	2 ^{de}	4 ^{de}	15 ^{bc}	15 ^{bc}	2 ^{de}	4 ^{de}	15 ^{c}	27 ^{a}	7 ^{bd}	**0,000**
f-putrid	2 ^{b}	6 ^{b}	12	10	3 ^{b}	6 ^{b}	11	20 ^{a}	7 ^{b}	**0,010**
texture										
t-flakes	48	47	38	54	39	44	40	52	43	0,498
t-soft	59	61	60	51	55	61	58	59	55	0,989
t-juicy	64	64	64	52	63	62	63	50	55	0,234
t-tender	67	63	67	64	64	67	64	67	60	0,956
t-mushy	37	32	33	36	35	43	50	45	41	0,283
t-meaty	36	41	37	40	38	35	34	29	34	0,902
t-clammy	15	12	17	14	20	11	14	7	18	0,852
t-rubbery	11	9	11	13	14	10	13	8	11	0,984
Torry score		8,0 ^{a}	5,7 ^{b}	4,8 ^{c}		7,8 ^{a}	5,9 ^{b}	4,6 ^{c}	7,6 ^{a}	**0,000**

On storage day six, the groups had a very characteristic sweet odour and obvious shellfish and meat odours. With the storage time, these characteristics become less evident and were hardly distinguishable on day 15 in both groups. Odours of vanilla/boiled milk and boiled potatoes were evident of the cod samples at the beginning of storage time, but diminished somewhat with storage time, on day 15 these odours were hardly distinguishable. Frozen storage odour was not detected in the samples. Table cloth, TMA and sour odours were not present in the samples on day 6 or 8. On day 12, hints of these odours were found, but on day 15 they had become obvious of both CBC groups. Sulphur odour was not detected in the samples until day 15, when only a hint of sulphur odour was detected.

Some differences in appearance were detected. Samples at the beginning of storage had more white and homogenous appearance, but became more dark and heterogeneous on day 15.

A hint of salt flavour was detected in all groups. At the beginning of storage, day six and eight, both groups had very characteristic metallic, sweet and meaty flavours which were not distinguishable on storage days 12 and 15. Frozen storage, and pungent flavours were not detected in the samples, but hints of sour and TMA odour were detected on day 12 in both groups. On day 15 however, TMA flavour had become obvious in group CBC-MAT. A hint of putrid flavour was detected in group CBC on day 12 and 15 and on day 12 in group CBC-MAT. Putrid flavour was distinguishable on day 15 in group CBC-MAT.

No statistical differences were found in texture. All groups were soft, juicy and tender and were rather flaky, mushy and meaty. The groups are neither clammy nor rubbery.

End of shelf life is usually determined when scores for the spoilage sensory attributes, such as table cloth odour, sour and TMA odours and flavours have become evident. When the average scores for those attributes are above 20, most panellists detect them and that indicates the sample is approaching the end of shelf life (Magnússon et al., 2006). According to this, both CBC and CBC-MAT are no longer fit for consumption on day 15. This is in good agreement with the sensory evaluation with the Torry freshness score sheet (Table 7, Figure 10). According to Torry, both groups are below the acceptable quality on day 15.

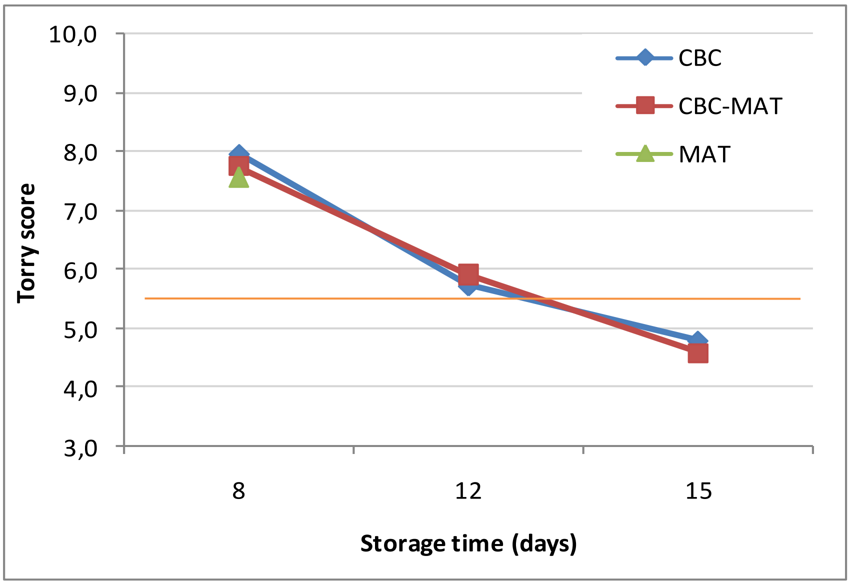

Figure 10: Average Torry scores.

Summary

No sensory differences were found between the CBC and CBC-MAT groups. Both groups were characterised with freshness sensory attributes on storage day six. The freshness characteristics became less evident as the storage time progressed and sensory attributes describing spoilage became more evident. Both groups had reached the end of shelf life on storage day 15. The sample without CBC cooling (MAT) was only evaluated on storage day eight, and was not different from the other two groups with regard to sensory characteristics on that sampling day.

Microbial measurements

Results from microbial counts are shown in Figure 11. Growth curves for total viable counts (TVC) and H_2S-producing bacteria were similar for both experimental groups. TVC at the beginning of the experiment on day 6 were rather high or between log 5-6/g and on days 12-15 close to log 8/g. On day 6, number of H_2S-producing bacteria were around log 3/g and between log 6-7/g on day 15. Experimental group with mat but no CBC on day 8 contained similar TVC numbers as the other two groups at that time (log 5.95/g) but H_2S-producing bacterial counts were slightly higher or log 4.3/g.

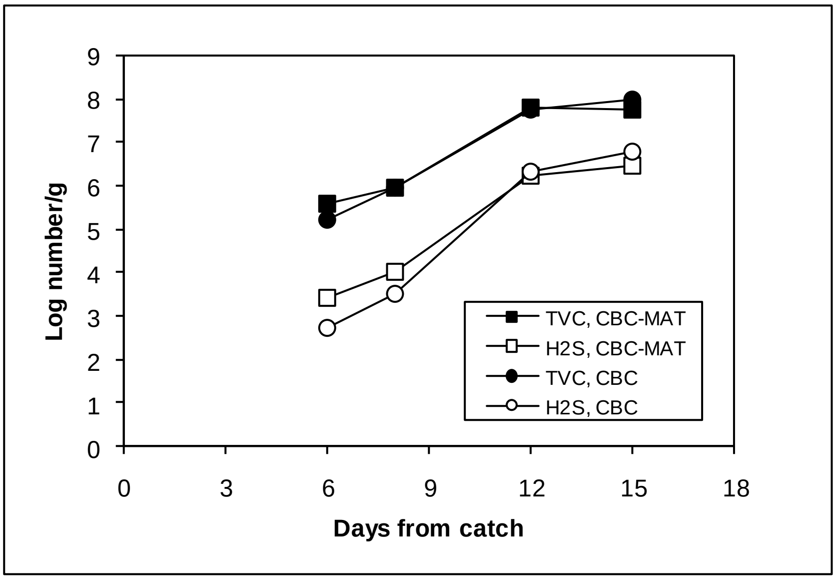

Figure 11: Total viable counts (TVC) and counts of H_2S-producing bacteria on Iron agar at 17°C.

Chemical measurements

Results from measurements of total volatile bases (TVB-N) and trimethylamine (TMA) are shown in Figure 12. Values of both TVB-N and TMA were very similar on days 6, 8 and 15 in both experimental group but at day 8 slightly higher values were obtained in the CBC-MAT group. Experimental group with mat but no CBC on day 8 contained similar TVB-N and TMA values as the other two groups at that time (13.4 and 1.1 mgN/100g). TVB-N and TMA values in all three experimental groups indicated that microbial spoilage had still not started to any extent on day 8. This is in line with results obtained from sensory evaluation.

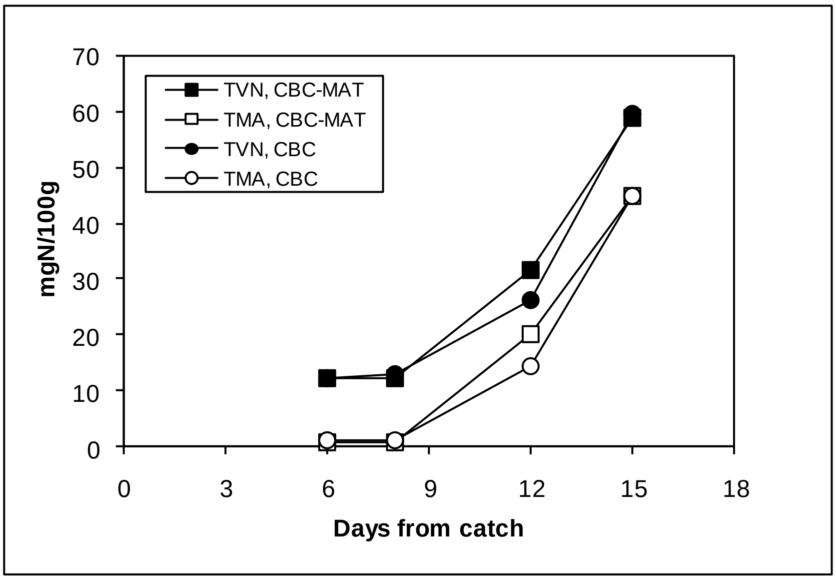

Figure 12: Total volatile bases (TVB-N) and trimethylamine (TMA) measurements.

Results from pH measurements are shown in Figure 13. After day 8, a rapid increase in pH occured in both experimental groups. These results are in good agreement with both microbial and chemical measurements. As spoilage proceeds, formation of volatile bases increases due to microbial spoilage. Most H_2S-producing bacteria are active reducers of trimethylamine oxide (TMAO) to TMA which is one of the main volatile bases measured as TVB-N. The pH in the experimental group with mat but no CBC on day 8 was 6.75.

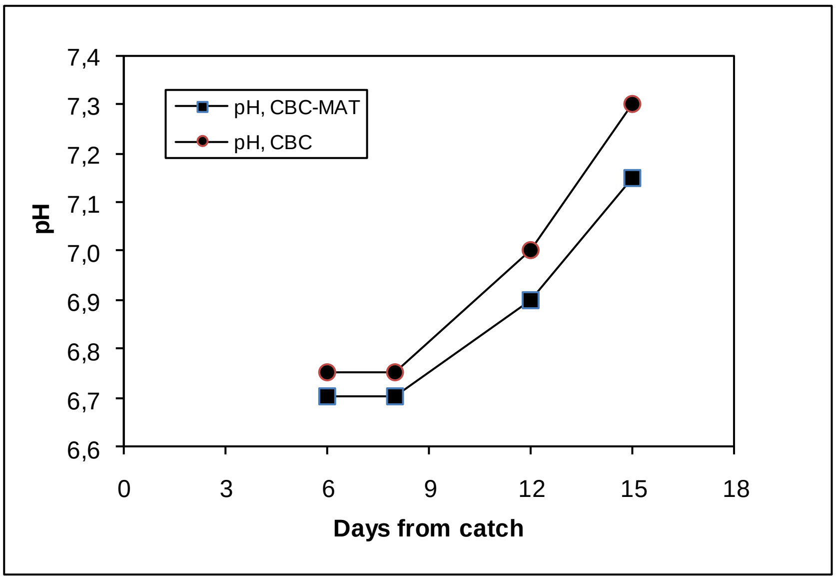

Figure 13: pH measurements.

Table 8: Water and salt measurements

		Water, %	WHC, %	Salt, %
Sample	**d f catch**	**CBC-MAT**	**CBC-MAT**	**CBC-MAT**
Cod+mat	6	81,5	90,7	0,3
Cod+mat	8	81,2	89,9	0,3
Cod+mat	12	81,3	91,1	0,4
Cod+mat	15	82,1	92,4	0,3
Sample	**d f catch**	**CBC**	**CBC**	**CBC**
Cod-mat	6	81,4	91,2	0,3
Cod-mat	8	81,4	90,2	0,2
Cod-mat	12	82,3	89,8	0,3

Cod-mat	15	82,2	94,6	0,3
Sample	**d f catch**	**MAT**	**MAT**	**MAT**
Mat-CBC	8	81,7	88,9	0,3

Cooking yield

Figure 14 shows the cooking yield of the loins where F is the front part of the loin, M the middle and T the tail. Generally the front gave the best cooking yield followed by the middle and finally the tail.

The groups which had a cooling mat and were CBC cooled gave a better cooking yield, except on sample day eight, which might partially be explained by the variation in the weight of individual fillets on that day.

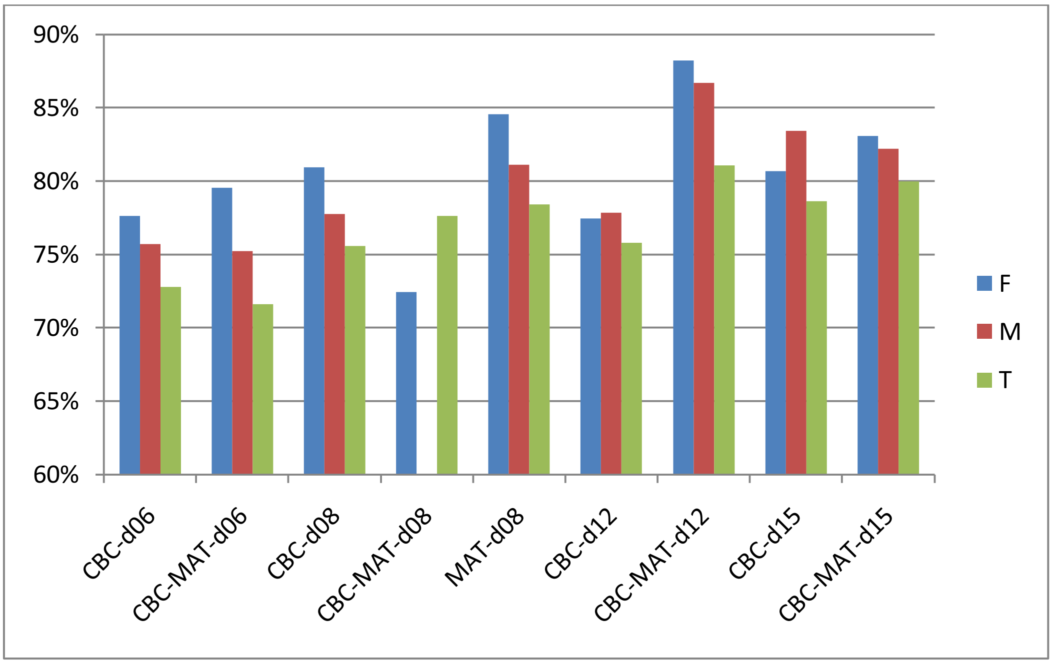

Figure 14: Cooking yield of all groups

References

AOAC Assn. Official Analytical Chemists. 2000. Official methods of analysis. 17th ed. Washington, D.C. (no. 976.18).

Eide O, Børresen T, Ström T. 1982. Minced fish production from capelin (*Mallotus villosus*). A new method for gutting, skinning and removal of fat from small fatty fish species. J Food Sci 47:347-354.

Gram L, Trolle G, Huss HH. 1987. Detection of specific spoilage bacteria from fish stored at low (0°C) and high (20°C) temperatures. Int J Food Microbiol 4:65-72.

ISO 8586-1. (1993). Sensory analysis general guidance for the selection, training and monitoring of assessors. Part 1: selected assessors. Geneva, Switzerland: The International Organization for Standardization.

ISO The Intl. Organization for Standardization. 1999. Animal feeding stuffs - Determination of moisture and other volatile matter content. 6496. Genf, Switzerland.

Kolbrún Sveinsdóttir, Emilía Martinsdóttir, Ditte Green-Petersen, Grethe Hyldig, Rian Schelvis, Conor Delahunty. 2009. Sensory characteristics of different cod products related to consumer preferences and attitudes. Food Quality and Preference, 20 (2) 120-132

Magnússon H, Sveinsdóttir K, Lauzon HL, Thorkelsdóttir Á, Martinsdóttir E. (2006). Keeping Quality of Desalted Cod Fillets in Consumer Packs. Journal of Food Science 71 (2): 69-76.

Malle P, Tao SH. 1987. Rapid quantitative determination of trimethylamine using steam distillation. J Food Protect 50(9):756-760.

Stone H, Sidel JL, (1985). Sensory evaluation practices. Orlando, Fla.: Academic press, Inc. 311p.

Thybo, A.K., & Martens, M. (2000) Analysis of sensory assessors in texture profiling of potatoes by multivariate modelling. Food Quality and Preference, 11(4), 283-288.