Changes of Thaw-drip Loss and Cooking Loss of Baltic Cod *(Gadus morhua)* during Long Term Storage under Different Frozen Conditions

Jörg Oehlenschläger and Sabine Mierke-Klemeyer
Federal Research Centre for Fisheries (BFAFi), Institute for Fishery Technology and Fish Quality, Palmaille 9, D-22767 Hamburg, Germany

Summary
Studies on changes of thaw-drip loss, cooking loss and total drip loss as quality indicators of frozen storage of Baltic cod (*Gadus morhua*) at different temperatures were performed. Also the effect of double freezing was studied. The results are discussed considering different capture and storage conditions. Single frozen cod stored at −20 °C and −30 °C showed the lowest drip losses during the 12 months storage period. Cod stored at −10 °C showed the highest drip losses although the storage period was the shortest (6 months). Double frozen cod exhibited drip losses of the same size as cod stored at −10 °C. All single frozen cod showed at different storage temperatures an increase of drip loss parallel with storage time while drip loss of double frozen cod remained almost stable.

Zusammenfassung
Untersuchungen zu Veränderungen des Tauwasser-, Kochwasser-, und des daraus resultierenden Gesamtwasserverlustes als Qualitätsindikatoren für bei unterschiedlichen Temperaturen gefriergelagertem Ostsee-Dorsch (*Gadus morhua*) wurden durchgeführt. Die Ergebnisse werden diskutiert. Die bei −20 °C und −30 °C gelagerten einmal gefrorenen Fische zeigten während des ganzen Versuchs immer die niedrigsten Tropfverluste. Die Verluste bei Kabeljau, der bei −10 °C gelagert wurde waren die höchsten, obwohl der Versuch hier nur 6 Monate dauerte. Doppelt gefrorener Kabeljau wies Tropfverluste auf, die denen von bei −10 °C gelagertem glichen. Alle einfach gefrorenen Kabeljaus zeigten einen Anstieg des Tropfverlustes parallel mit der Lagerzeit, doppelt gefrorener Kabeljau dagegen zeigte während des Lagerzeitraumes einen fast konstanten Tropfverlust.

Keywords: Baltic cod, thaw-drip loss, cooking loss, total drip loss / Ostsee-Dorsch, Tauwasserverlust, Kochwasserverlust, Gesamtwasserverlust

Introduction

A lot of quality factors contribute to the overall quality of seafood[1], as freshness, sensory properties and nutritional properties. Many approaches have been made to describe fish quality in an objective, extensive manner by determination of volatile compounds[2,3], microbiological parameters[4], changes in proteins, lipids and ATP metabolites[5] and physical measurements[6]. Sensory evaluation with a well trained panel is still the most important and reliable method for quality evaluation in fish research[7]. In frozen fish chemical, biochemical and physical processes leading to irreversible changes in sensory attributes occur at a slow rate, and deterioration during frozen storage is inevitable. The rate at which protein denaturation takes place in frozen fish depends largely on the temperature and will slow down as the temperature is reduced.
The proteins changes in fish stored under poor conditions (e.g. at too high temperature) can be recognised in the thawed fish. The normally bright, firm and elastic product becomes dull and spongy. The flesh tends to sag and break and there will be substantial losses of fluid, which can be squeezed out easily. When cooked the fish will be dry and fibrous[8]. In this paper the changes of drip loss and cooking loss and the overall loss of moisture as quality indicators at different storage conditions were studied.

Material and Methods

Acquisition and freezing of Cod

Baltic cod of known history was stored at −10, −20 and −30 °C. An experiment with double frozen cod stored at −20 °C was performed too. The experiments with cod stored at −20 °C and −30 °C started on January, 2002, the experiments with the double frozen cod started in March, 2002, with cod stored at −10 °C in April, 2002, because there was not enough fish with well defined history available in January. The sample preparation was carried out for water content, drip loss and cooking loss determination.

Storage experiment at −20 °

This experiment started on January 8, 2002. Immediately after arriving in the laboratory the cod (size: 50 cm ± 7 cm) was filleted and the bones were removed carefully. The cod was in the pre rigor state when it arrived but rigor mortis started while filleting the fishes. For each measuring date 5 x 200 g bone-free cod fillets were packed in double PE pouches with a zip-fastener. Immediately after packaging the cod-fillets were shock frozen by liquid CO_2 with an apparatus from *Air Liquide GmbH*. After shock-frosting the samples were stored at −20 °C.

Storage experiment at −30 °

The cod for the freezing experiment at −30 °C was delivered on January 22, 2002. The cod (size: 51 cm ± 9 cm) was treated in the same manner as described for the −20 °C-experiment. This time the frozen cod was stored at −30 °C just after the shock freezing process. The yield for the −30 °C experiment after filleting was 16.75 kg of fillet (20.6 % of gutted fish).

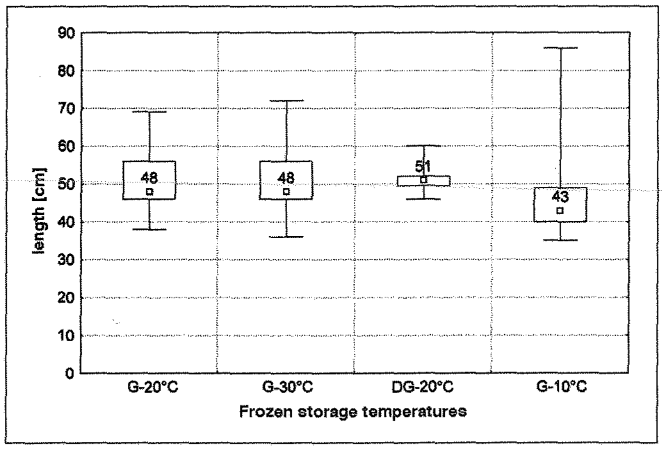

Fig. 1 Length of Baltic cod filleted for frozen storage experiments at different temperatures, median, min and max, 25 % and 75 % percentiles

Storage experiment at – 10 °

The cod for the freezing experiment at –10 ° was delivered on April 5, 2002 from Saßnitz (the cod were fished by the fishery research vessel „Solea“ in the Baltic Sea on April 3). The cods (size: 45.5cm ± 9.3cm) were still in rigor when they arrived and were treated in the same manner as described for the – 20 °C-experiment. This time the frozen cod was stored at – 10 °C just after the shock freezing process.

Storage experiment at – 20 °, double frozen

The cod for the double freezing experiment at – 20 °C was supplied on March 21, 2002. The whole gutted cods were shock frosted and stored at – 25 °C for 2 weeks until further preparation on April 4, 2002. After thawing the length of 40 gutted fishes (50.1 kg) was measured. The average length was 50.9 cm ± 2.6 cm. After filleting and removal of bones the cod fillets were packed in double PE pouches with a zip-fastener. The cods yielded 21.3 kg of fillet. Immediately after shock frosting as previously described the cod-fillets were stored in a freezer at – 20 °C.

The average lengths of the cod used in the four different experiments are given in Fig 1.

In all figures the letter „G“ indicates „frozen“, „DG“ „double-frozen“ to distinguish the different conditions.

Design of experiment

The examinations for cod stored at –10 °C were performed every month for 6 months. Cod stored at –20 °C and double frozen cod, were removed from the cold-storage for determination of thaw-drip loss and cooking loss in intervals of about 2 months. The experiment with double frozen cod went on for nine months, until the sensory quality became very bad. The storage experiment at –20 °C went on for one year. The intervals of measurements for cod stored at –30 ° were 3 months for a period of 9 months. The samples were taken out of the freezer one day before the analyses and assessments and were thawed in the refrigerator.

Determination of thaw-drip loss

For determination of drip loss, the pouches with the fish were weighted correctly to one decimal place and a corner of the pouch was cut off so that the water could drip out of the pouch. Then the fish was taken out of the pouches, carefully allowed to drip completely and weighted again. The thaw-drip loss was calculated as the percentage of drip moisture referring to the initial weight of fish fillets.

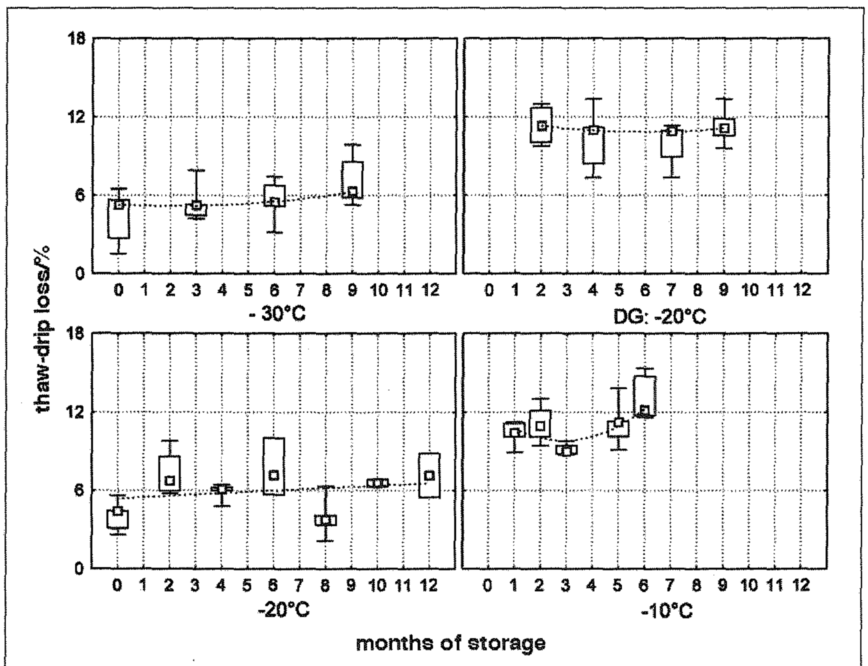

Fig. 2 Comparison of thaw-drip loss for Baltic cod fillets stored at different temperatures, median, min and max, 25 % and 75 % percentiles, – 10 °C, – 20 °C and – 30 °C are single frozen, DG: – 20 °C double frozen

Determination of cooking drip loss

About 200 g of cod-fillets weighted correctly to one decimal place were put in a cooking pouch for 10 min into water of 90 °C. The cooking loss was determined by cutting off a corner of the pouch and weighting the dripped off fish in the cooking pouch. The cooking loss was calculated as the percentage of cooking drip referring to the weight of the fish put into the cooking pouch.

Determination of total loss

The total loss was calculated as the percentage of water lost during thawing and cooking referred to the weight of the frozen fish fillets.

Results and Discussion

The development of thaw-drip loss is shown in figure 2 and of cooking loss in figure 3 and of total loss in figure 4. In these Box-Whisker-Plots the graphs showing the development of the medians can be described by an exponential function.

The thaw-drip loss as well as the cooking loss and the resulting total loss are even at the beginning of the experiments remarkably higher for the cod fillets stored at −10 °C and the double frozen fillets stored at −20 °C than for cod stored at −20 °C and −30 °C. The cod for double frozen and −10 °C-experiment were caught in March/April, the others in January. As there is a small variation in the water content of the Baltic cod investigated (as shown in Table 1) which was also reported in literature[9] this might have been influenced the moisture losses reported here. The Baltic cod caught in March and April seems to have starved during the hard winter which is indicated by the higher water content.

It was reported earlier[10] that in North Sea Cod the water content of the muscle prior to spawning increases and the protein content decreases. In extreme cases the water content of very large cod can attain 87 % of the body weight prior to spawning[11].

The cod for the −10 °C-experiment were filleted when they were still in rigor. In literature it is reported, that filleting in rigor may cause a very poor filleting yield and if the fish was rough handled it can cause gaping[12]. Some negative influences on several quality and sensory parameter might be slightly affected by this. These experiments were performed to elucidate the influences of different storage conditions on the development of „moisture losses" as quality indicators.

The difference in total drip loss between the more stable samples (−20 °C and −30 °C) and the moisture losing samples (−10 °C and double frozen at −20 °C) amounted at the beginning of the experiment (after 1 month of storage) between 12 and 16 % and at the end of the experiment to ~14 %. These big differences cannot be explained by the slight variation in water content of the raw material (1.5 %) but are the effect of frozen storage temperature (−10 °C samples) and of poor freezing conditions (double freezing).

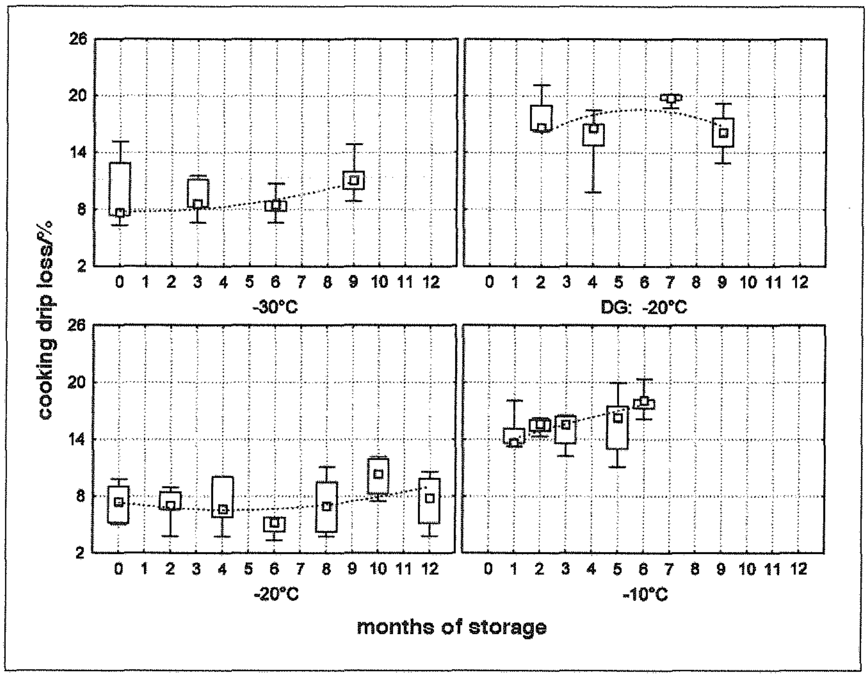

Fig. 3 Comparison of cooking drip loss for Baltic cod fillets stored at different temperatures, median, min and max, 25 % and 75 % percentiles, −10 °C, −20 °C and −30 °C are single frozen, DG: −20 °C double frozen

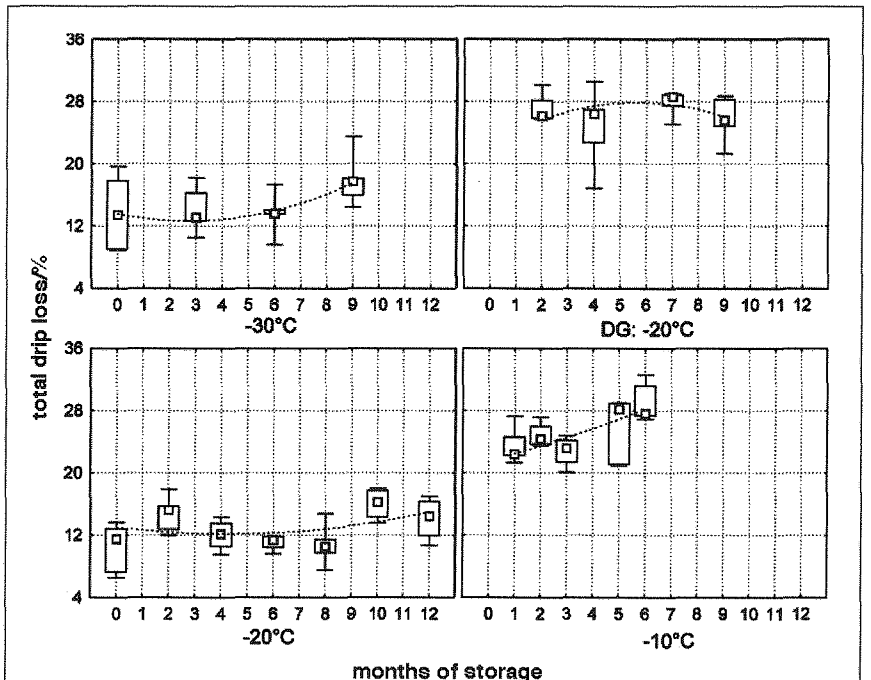

Fig. 4 Comparison of total drip loss for Baltic cod fillets stored at different temperatures, median, min and max, 25 % and 75 % percentiles, −10 °C, −20 °C and −30 °C are single frozen, DG: −20 °C double frozen

It can be stated that the slope of the graph of −10 °C storage is significant higher than of the others. This means that the quickest changes occurred at that storage. For all temperatures (except the double frozen conditions) the average drip loss, cooking loss and total loss showed little changes in the first half of the total storage-period and increased clearly in the second half of storage-period.

Tab. 1 Average water content of the Baltic cod fillets for different storage-conditions

Storage and freezing conditions of cod	Capture date	Average water content of the fillets [%]
Single frozen, −10 °C	April 3rd, 2002	81.7
Single frozen, −20 °C	January 8th, 2002	80.8
Single frozen, −30 °C	January 22nd,2002	80.2
Double frozen, −20 °C	March 21st, 2002	81.7

The double frozen samples exhibited a complete different behaviour throughout the entire storage experiment. The thaw-drip loss was the highest at the start of the experiment (~ 12 %) The thaw-drip loss remained stable at this level or decreased slightly. The cooked drip loss was the highest of all initial losses and remained for the whole storage period on this level (17 %) with considerable scattering around the median. The total drip loss also showed no change in amount during storage time and remained constant at a level of ~ 28 %.

Generally it can be stated that cod stored at −30 °C and at −20 °C exhibited an almost equal total drip loss on the lowest level observed (12 % at the beginning) with a moderate increase up to 16 % after 9 and 12 months of frozen storage, respectively. The thaw-drip losses found are similar or higher compared to experiments performed with Atlantic cod from Newfoundland[13] where in *pre rigor* frozen fillets after 1 week of frozen storage at −20–21°C a thaw-drip loss of ~ 9 % was found. In Barents Sea cod after 12 months of frozen storage in a modified atmosphere (MAP) at −20 °C and −30 °C a thaw drip loss of only 5.3 % and 5.6 %, respectively, was found[14].

Single frozen cod stored at −10 °C showed the highest initial total drip loss of all single frozen experiments (~ 22 %) and the steepest increase in total drip loss throughout the storage period (in 6 months up to ~ 28 %). Double frozen cod showed no increase in total drip loss with time and is stable on a high level (~ 28 %). The maximum total drip loss observed was 29 %. The double freezing obviously damages the cells in the fish muscle to an extent which facilitates the cell liquid to be released upon thawing leading to the dramatic total drip losses observed.

Conclusion

These experiments were performed to show the influences of different storage conditions on the development of the drip loss, cooking loss and total loss as quality indicators. Although the results are a little affected by differing water contents (1.5 %) of the raw material due to season, clear conclusions on different total drip losses in dependence of storage temperature and freezing conditions (single and double) could be drawn. Based on the results it can be recommended to store Baltic cod at −20 °C or −30 °C. Storage at higher temperatures should be avoided because leading to high moisture losses. Double freezing cannot be recommended since it leads to the utmost highest dripping losses from the beginning of the storage.

Acknowledgements

The work was partly granted by an EU project financed by the Commission under QLK1-CT-2001-01643 „A new method for the objective measurement of the quality of seafood“. The manual filleting of the cod by *Hans-Jürgen Knaack* and *Peter Schael* is greatly acknowledged.

References

1) *Oehlenschläger, J.:* Criteria of seafish freshness and quality aspects, in: Methods to determine the Freshness of Fish in Research and Industry. Proceedings of the Final Meeting of the Concerted Action „Evaluation of Fish Freshness“, 30–35 (1997).
2) *Olafsdottir, G.* and *J. Fleurence:* Evaluation of fish freshness using volatile compounds in fish, in: Methods to determine the Freshness of Fish in Research and Industry. Proceedings of the Final Meeting of the Concerted Action „Evaluation of Fish Freshness“, 55–69 (1997).
3) *Oehlenschläger, J.:* Suitability of ammonia-n, dimethylamine-n, trimethylamine-n, trimethylamine oxide-n and total basic nitrogen as freshness indicators of seafood, in: Methods to determine the Freshness of Fish in Research and Industry. Proceedings of the Final Meeting of the Concerted Action „Evaluation of Fish Freshness“, 92–99 (1997).
4) *Dalgaard, P.:* Photobacterium phosphoreum – A microbial parameter for prediction of remaining shelf life in map cod fillets, in: Methods to determine the Freshness of Fish in Research and Industry. Proceedings of the Final Meeting of the Concerted Action „Evaluation of Fish Freshness“, 166–174 (1997).
5) *Henehan, G., M. Proctor, N. Abu-Ghannam, C. Wills* and *J. V. McLoughlin:* Adenine nucleotides and their metabolites as determinants of fish freshness, in: Methods to determine the Freshness of Fish in Research and Industry. Proceedings of the Final Meeting of the Concerted Action „Evaluation of Fish Freshness“, 266–272 (1997).
6) *Sigernes, F., M. Esaiassen, K. Heia, J. P. Wold, G. Eilertsen* and *N. K. Sörensen:* Assessment of Fish (Cod) Freshness by VIS/NIR Spectroscopy, in: Methods to determine the Freshness of Fish in Research and Industry. Proceedings of the Final Meeting of the Concerted Action „Evaluation of Fish Freshness“, 369–375 (1997).
7) *Martinsdottir, E.:* Sensory evaluation in research of fish freshness, in: Methods to determine the Freshness of Fish in Research and Industry. Proceedings of the Final Meeting of the Concerted Action „Evaluation of Fish Freshness“, 306–312 (1997).
8) *Johnston, W. A., T. J. Nicolson, A. Roger* and *G. H. Strout:* Freezing and refrigerated storage in fisheries. FAO Fisheries Technical Paper No. 340, Rome, FAO, 8f (1994).
9) *Börresen, T.:* Quality aspects of wild and reared fish in: *Huss, H. H., M. Jacobsen* and *J. Liston:* Quality Assurance in the Fish Industry. Proceedings of an International Conference, Copenhagen, Denmark, August 1991. Elsevier, Amsterdam, 1–17 (1992).
10) *Huss, H. H.:* Quality and quality changes in fresh fish. FAO Fisheries Technical Paper No. 348, Rome, FAO, 18ff, (1995).
11) *Love, R. M.:* The Chemical Biology of Fishes. Academic Press, London (1970).
12) *Huss, H. H.:* Quality and quality changes in fresh fish. FAO Fisheries Technical Paper No. 348, Rome, FAO, 35ff (1995).
13) *Chalker D. A., W. A. Maccallu* and *D. R. Idler:* Studies on quality of Newfoundland cod. 2. Thaw-drip in polyphosphate-treated and untreated fillets. J. Fish Res. Bd. Canada **22** (3), 783–804 (1965).
14) *Boknaes N., K. N. Jensen, H. S. Guldager, C. Osterberg, J. Nielsen* and *P. Dalgaard:* Thawed chilled Barents Sea cod fillets in modified atmosphere packaging – application of multivariate data analysis to select key parameters in good manufacturing practice. Lebensm.-Wiss. Technol. **35** (5), 436–443 (2002).