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Double freezing of redfish (*Sebastes* spp.) fillets and minces: influence on sensory, physically and chemically assessed quality attributes of coated portions

Doppelgefrieren von Filet und Farce aus Rotbarsch (Sebastes spp.): Einfluss auf mit sensorischen, physikalischen und chemischen Methoden bewertete Qualitätsparameter panierter Portionen

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Summary

The quality of coated portions produced by a German processor from both single (SF) and double frozen (DF) redfish (Sebastes spp.) fillets and minced material was compared at distinct intervals during storage. Fillets and minces have been processed pre and post rigor on board a research vessel and stored frozen at –24 °C for one year. Sensory, physical and chemical methods were used with the aim to differentiate between SF and DF if possible. In sensory evaluation, a clear distinction between SF and DF samples was only possible for portions from mince, pre rigor, using a Paired Comparison Test (PCT). Measuring tensile strength on fish portions revealed some potential for distinguishing once and twice frozen redfish products. It can be stated, that at least when using redfish as base material for the production of coated portions, the different methods of preparing the fillet blocks (SF or DF) will not significantly affect the quality of the final products.

Keywords: fish, fillet, mince, double freezing, quality

Zusammenfassung

Ein Vergleich der Qualität panierter Portionsstücke, die bei einem deutschen Verarbeiter aus einfach (SF)- und doppelgefrorenen (DF) Rotbarschfilets bzw. Rotbarschfarce hergestellt wurden, erfolgte nach definierten Gefrierlagerzeiten. Filets und Farce wurden aus Rohware im prae rigor und post rigor an Bord eines Fischereiforschungschiffes hergestellt und bei –24 °C über ein Jahr gefriergelagert. Sensorische, physikalische und chemische Methoden wurden mit dem Ziel angewendet, möglicherweise bestehende Unterschiede zwischen SF- und DF-Portionsstücken nachzuweisen. Mittels Sensorik bei Anwendung einer Paarweisen Unterschiedsprüfung konnte lediglich an den aus Fischfarce, prae rigor, hergestellten Portionsstücken ein signifikanter Unterschied zwischen SF und DF nachgewiesen werden. Die Bestimmung der Zerreißfestigkeit zeigte generell ein gutes Potential, SF- und DF- Portionen zu unterscheiden. In allen anderen untersuchten Qualitätsparametern ergaben sich dagegen keine signifikanten Unterschiede zwischen einfach- und doppelgefrorenen Portionsstücken. Daher kann geschlussfolgert werden, dass bei Verwendung von Rotbarsch als Rohware für die Herstellung von panierten Portionsstücken die Unterschiede in der Herstellung der Filetblöcke (SF und DF) die Qualität der Enderzeugnisse nicht signifikant beeinflussen.

Schlüsselwörter: Fisch, Filet, Farce, Doppelgefrieren, Qualität

Introduction

Double frozen blocks of fish fillet are produced ashore by thawing the frozen round or gutted fish and refreezing them after filleting and skinning. Besides blocks of frozen fish produced on board fish processing trawlers, the international trade in double frozen blocks of fish fillet has become more and more common (Anonymous, 2008). Current German food regulations do not require labelling of these different processing techniques for the production of deep-frozen blocks of fish fillet that are to be used as raw material for fish fingers and other types of coated fish products. No information is available for the consumer as to whether the final product is produced from sea-frozen fillet or from double frozen fish. This was the reason for investigating the effect of different processing techniques of the raw material on the quality of frozen final products.

The German fish processing industry is considered to be one of the most important processors of frozen coated portions of fish fillet worldwide and is highly depending on the import of raw material. For instance, approximately 270 000 t mostly of frozen, lean fish fillets were imported in 2006, an increase of approximately 8 % compared to 2005. The production of deep-frozen fish products, including fish fingers and other battered and breaded products, increased by 0.7 % in 2006 compared with 2005 and amounted to 219 284 t. Deep-frozen products had a market share of approximately 36 % in 2006 and were therefore the most popular fish products in Germany (BMELV, 2008).

Previous results on both saithe and cod fillets, as well as on commercially processed samples from cod and Alaska pollack *(Theragra chalcogramma)* revealed differences in quality attributes (e. g. sensory, texture, colour, water holding capacity, chemical composition, electrophoretic pattern of sarcoplasmic proteins) depending on refreezing and rigor states (Schubring, 1999a, 1999b, 2000a, 2001a, 2002). The quality attributes influenced differed between species and even within the same species (saithe) when sampling was done under almost comparable conditions (catching ground, season and protocol) but in different years (Schubring, 1999a, 2000a, 2001a). For example, for haddock drip loss after cooking was greatly influenced by double freezing, whereas for saithe almost no influence was detected (Schubring, 2001b). However, all the effects measured did not allow a clear differentiation between single and double frozen products. Even the thermoanalytical behaviour of SF samples was not distinct from DF samples, when measured by differential scanning calorimetry (Schubring, 1999c). These results lead to the conclusion that at least when using the above mentioned species as raw material for processing coated portions, the different styles for preparing the fillet blocks will, if at all, not significantly affect the quality of the final products.

The aim of this study was to monitor the effect of double freezing on the quality of coated portions of redfish fillets which were prepared in pre and post rigor states. Knowing that freeze denaturation causes much greater alterations in minced fish flesh compared to fillet, portions were also prepared from single and double frozen mince blocks produced from skin-on fillet, pre as well as post rigor. The investigation of fish mince made from fillets is also of commercial importance, as the guidelines of the German Food Code allow the inclusion of 25 % of fish mince prepared from V-cuts when producing fish fingers. In the present study, mince prepared from skin-on fillet was used as a model for mince prepared from V-cuts. Redfish can be seen as commercially important and are found throughout the North Atlantic from the coast of Norway to Georges Bank at relevant depth and/or temperatures. In 2006, approximately 5 % of fish used in Germany for processing frozen products was redfish and it was thus the fourth most important fish species after Alaska pollock, hake and saithe.

Despite the economic importance, a survey of the literature makes it clear that only few papers have been published dealing with quality and technological aspects of quality of redfish (Rehbein and Oehlenschläger, 1983; Oehlenschläger, 1989; Ravesi and Krzynowek, 1991; Rehbein et al., 1994; Magnusson and Martinsdottir, 1995). There appears to be a lack especially on the influence of freezing on quality parameters of products processed from redfish (Dyer et al., 1956; MacCallum et al., 1967; Lauder et al., 1970; Hsieh and Regenstein, 1989). Therefore, the present paper deals with the influence of repeated freezing on the quality of frozen coated portions made from fillets and minces. Particular attention was paid to quality attributes evaluated by sensory, physical and chemical methods.

Material and Methods

Sample preparation

The blocks of frozen fish were produced on board the FRV “Walther Herwig III” during the 232nd cruise in the autumn of 2001 using redfish *(Sebastes marinus)* caught west of the Shetland Islands. The length of fish used ranged from 40 to 80 cm, the majority varied from 65 to 70 cm.

Measurements were made on SF and DF batches of fish samples in two stages of rigor, i. e. in pre and post rigor. The preparation of the samples explained in detail earlier (Schubring, 1999a, 2001a) is shown in Figure 1. In addition,

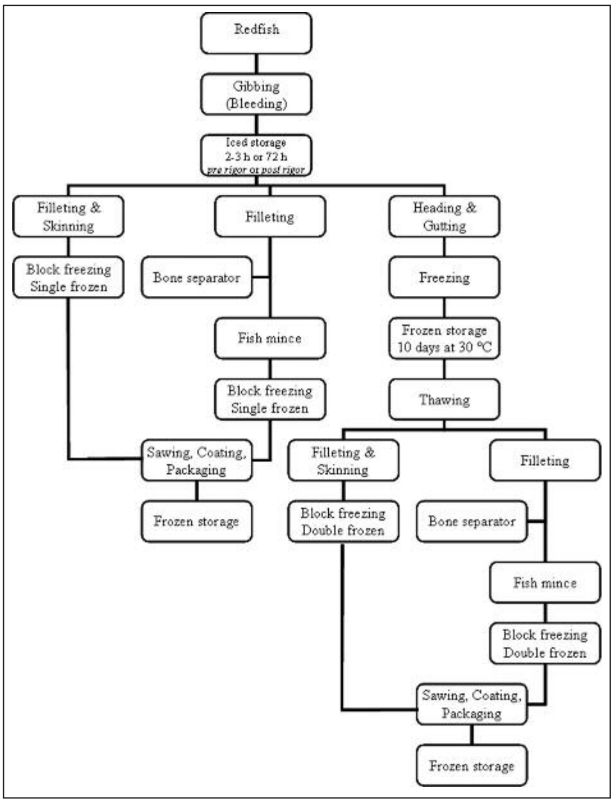

FIGURE 1: *Flow diagram of sample preparation.*

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blocks of minced material were made from skin-on pre and post rigor fillet using a Baader 694 bone separator (Baader, Lübeck) and frozen under conditions comparable to those for the fillets. The intermediate products subjected to double freezing were stored frozen for ten days at –30 °C. Sea water was used for immersion thawing. After twelve weeks of frozen storage, coated portions of both fish fillet and mince were prepared by a German processor using both SF and DF blocks. These portions were packaged in cardboard boxes and stored at –24 °C until analysis after different times of frozen storage (0, 6, 12 months).

Methods

The sensory evaluation of the quality of fried portions prepared under standardised conditions as described earlier (Schubring, 1996) was performed as Quantitative Descriptive Analysis (QDA) by estimating the intensity of the parameters (0 – very small or nothing, 100 – very strong). The flavour parameters (fresh, stale, fishy, rancid, strange), as well as the texture parameters (firm, flaky, springy, fibrous, cohesive, gummy, watery, juicy) were evaluated in duplicate by a sensory panel consisting of nine trained assessors using two coated portions of the same type for each assessor, the parameters being defined in detail elsewhere (Schubring, 2000b). Additionally, a Paired Comparison Test (PCT) in combination with a Paired Preference Test was applied to determine differences of the different coated portions for particular sensory characteristics, e. g. stale/fishy and firm according to the German standard method (Schubring, 2001b). Colour was measured on the homogenate prepared from the thawed product after removing coating, a tristimulus colorimeter Chroma Meter CR 300 (Minolta, Ahrensburg, Germany) being used as previously described (Schubring, 2002). The colour differences ΔE^*, i. e. the square root of ($\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}$), between SF and DF samples were computed. The texture was instrumentally evaluated by measuring both the tensile strength and the force needed to penetrate coated portions of fillets and mince using a TA.XT 2/25 Texture Analyser (Stable Micro Systems, Godalming, England) (Schubring 2000b, 2001b). The tensile force measurements using a modified Pizza Tensile Rig and a test speed of 1.2 mm/s were repeated 15 times. The penetration force was measured on homogenised portions after their coating had been removed prior to comminution at a test speed of 0.8 mm/s and applying a strain of 80 % using a Spiked Aeration Plunger equipped with eight small cylinders (Ø 3 mm) which are arranged in two different squares and was repeated ten times. Furthermore, instrumental Texture Profile Analysis (TPA) was also made using a cylindrical flat-ended probe of 5.0 cm diameter with a test speed of 0.8 mm/s (Schubring, 2001a), the measurement being repeated 15 times. Water holding capacity (WHC) was measured a similar number of times with slight modifications (Schubring et al., 2003) according to the filter paper press method described by Detienne and Wicker (1999). Samples were pressed between paired filter sheets (Schleicher & Schuell 2043 A, 7 x 7 cm; Schleicher & Schuell, Dassel) and parallel plates using the above mentioned texture analyser TA.XT2. A 25 kg load cell with a crosshead speed of 1.7 mm/s was used. Samples were pressed to 75 % deformation and held at that point for 15 s. WHC was defined as the expressible moisture, calculated as % = 100 (initial weight – final weight) / initial weight. Formaldehyde content and pH values as well as TVB-N (total volatile nitrogen), DMA-N (dimethylamine nitrogen) and TMAO-N (trimethylamine-N-oxide) were measured twice according to Oetjen and Karl (1999).

The results were statistically evaluated by applying STATISTICA (StatSoft Inc. (1996), Tulsa, OK, USA).

TABLE 1: *Trimethylamine oxide-N (mg/100 g) content measured on coated portions of redfish fillet and mince as a function of rigor state and refreezing.*

Sample	Storage time (months)		
	0	6	12
Fillet, pre rigor	127.2	92.0	107.5
Fillet, pre rigor, DF	98.7	39.8	84.3
Fillet, post rigor	116.6	76.8	103.0
Fillet, post rigor, DF	99.9	98.9	96.2
Mince, pre rigor	87.6	62.7	78.4
Mince, pre rigor, DF	82.0	70.5	74.4
Mince, post rigor	110.9	75.6	92.9
Mince, post rigor, DF	101.9	76.2	91.5

TABLE 2: *pH values measured on coated portions of redfish fillet and mince as a function of rigor state and refreezing.*

Sample	Storage time (months)		
	0	6	12
Fillet, pre rigor	6.74 (0.01)	6.73 (0.01)	6.62 (0.01)
Fillet, pre rigor, DF	6.75 (0.05)	6.70 (0.01)	6.73
Fillet, post rigor	6.60 (0.01)	6.67 (0.02)	6.56
Fillet, post rigor, DF	6.58	6.69 (0.01)	6.62 (0.01)
Mince, pre rigor	6.99	6.96 (0.01)	6.90 (0.01)
Mince, pre rigor, DF	6.85	6.80 (0.02)	6.80 (0.01)
Mince, post rigor	6.64 (0.01)	6.59	6.56 (0.01)
Mince, post rigor, DF	6.70 (0.01)	6.61(0.01)	6.59 (0.01)

( ) standard deviations.

Results and Discussion

Chemical composition

The proximate composition (%) for protein (16.2 ± 0.4), fat (3.0 ± 0.6) and water (79.7 ± 0.8) was in the normal range for redfish (Sidwell, 1981). The TVB-N content (mg/100 g) in fresh muscle was found to be 9.36 ± 0.9 and lay therefore at the lower end of the entire range of TVBN from 8.5 to 23.1 for freshly caught redfish (Oehlenschläger, 1989). According to Oehlenschläger (1989) the TVB-N values of freshly caught redfish vary over a broad range and can be influenced by catching area and other parameters. TMAO-N contents were found to be close to 100 mg/100 g, this value changing little as a result of refreezing and during frozen storage (Tab. 1). This is in agreement with earlier observations (Oehlenschläger, 1989), when it was found that the TMAO-N content in *S. marinus* was just under 100 mg/100 g, while that of *S. mentella,* living at greater depth, was above 100 mg/100 g. Furthermore, initial TMAO-N values of 87.9 to 96.5 mg/100 g for *S. marinus* were reported (Magnusson and Martinsdottir, 1995) without any breakdown during frozen storage. The DMA-N content was found in agreement with Oehlenschläger (1989) to be very low with < 0.3 mg/100 g, no changes being observed during refreezing and frozen storage. Since red-

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fish does not possess TMAO demethylase it is therefore unable to break down the TMAO enzymatically to DMA and formaldehyde (Rehbein and Schreiber, 1984). So, naturally no formaldehyde could be detected in redfish muscle after the fish were caught. The pH values (Tab. 2) were found to be slightly influenced by refreezing. However, prolonged frozen storage appears to result mainly in a slight decrease in pH. This agrees well with earlier findings (Lauder et al., 1970), which observed decreasing pH values with increasing time of frozen storage. Compared with unfrozen fish, pH was generally lower in frozen samples.

Sensory assessment

Sensory evaluated flavour and texture attributes are displayed in Tables 3 and 4, respectively. Double freezing appears to be without any significant ($p > 0.05$) influence on flavour attributes. Exceptions were found for "rancid" in samples processed from mince, pre rigor, after six and twelve months of frozen storage (increase), and for "strange" in those after six months of frozen storage (increase). However, the duration of storage at –24 °C itself influenced more pronouncedly some of the flavour attributes, e. g. "stale" (Tab. 3). The attribute "fresh" was significantly lowered ($p < 0.05$) in portions processed from both fillet and mince post rigor. As for "fishy", assessors found a significant increase for "stale" when samples from the beginning of frozen storage were compared to those stored twelve months at –24 °C. Surprisingly, trends were not consistent. Portions analysed after six months of frozen storage were often evaluated to be equal to or even better than those at the beginning of the trial. This leads to the conclusion that frozen storage of half a year at –24 °C did not invoke a lowering of the quality of coated fish samples when sensory assessed by flavour attributes.

In regard to texture (Tab. 4), it becomes obvious that only portions processed from mince, pre rigor, were affected by double freezing. The intensity of the texture attributes firm, cohesive

TABLE 3: *Sensory flavour attributes assessed on fried portions of redfish fillet (F) and mince (M) as a function of rigor state (PR, pre rigor; PO, post rigor) and refreezing (DF).*

Attribute	Storage time (months)	FPR	FPR DF	FPO	FPO DF	MPR	MPR DF	MPO	MPO DF
fresh	0	65.8	65.9	67.1	59.7^{a}	65.2	56.4^{a}	54.6	55.2
	6	63.3	57.6	61.9	52.2^{a}	60.4	48.1^{a}	48.7	48.6
	12	65.6	59.4	53.8	46.5^{b}	58.5	43.7^{b}	45.1	49.1
stale	0	20.8	21.4	17.4^{a}	22.8^{a}	17.6^{a}	26.1^{a}	27.6	25.0^{a}
	6	22.4	23.8	26.1^{a}	29.0^{a}	16.0^{a}	36.5^{a}	34.5	39.3^{b}
	12	22.3	39.4	38.9^{b}	43.0^{b}	29.2^{ab}	47.9^{b}	44.6	42.2^{b}
fishy	0	17.3	21.3	13.2^{a}	17.9	9.2	18.6^{a}	17.8^{a}	19.3
	6	14.1	17.3	11.1^{a}	16.1	5.9	17.2^{a}	14.3^{a}	22.9
	12	16.9	26.5	30.2^{ab}	29.4	15.7	33.4^{ab}	28.3^{ab}	27.0
rancid	0	12.4	14.0	11.4	18.2	9.4^{a}	16.0	19.8	19.1
	6	11.1	13.6	14.3	14.2	3.2^{b} *	17.7**	13.3	21.2
	12	16.8	21.9	18.6	26.7	7.7^{ab} *	26.1**	23.3	24.4
strange	0	7.3	6.9	8.2	7.5	7.4	11.4	10.9	7.1
	6	6.2	9.5	4.8	8.2	6.5*	16.0**	8.8	10.9
	12	8.0	14.2	7.3	16.7	10.3	21.6	13.6	12.4

a,b different superscripts indicate significant ($p < 0.05$) differences between storage time; *, ** different numbers of asterisks indicate significant ($p < 0.05$) differences between single and double frozen portions.

TABLE 4: *Sensory texture attributes assessed on fried portions of redfish fillet (F) and mince (M) as a function of rigor state (PR, pre rigor; PO, post rigor) and refreezing (DF).*

Attribute	Storage time (months)	FPR	FPR DF	FPO	FPO DF	MPR	MPR DF	MPO	MPO DF
firm	0	46.4	48.2^{a}	55.7	48.3	34.0*	55.8**	47.4	49.5
	6	49.4	41.9^{a}	47.2	51.9	29.7*	45.5**	40.8	40.8
	12	44.5	40.1^{ab}	45.0	48.5	31.4*	54.8**	41.3	43.8
flaky	0	61.8	58.1	56.9	52.0	41.6^{a}	35.2	41.5	42.7
	6	57.7	58.8	57.0	52.7	49.2^{a}*	33.5**	36.6	34.7
	12	61.0	59.7	58.5	48.3	53.9^{ac}	39.7	42.4	44.7
springy	0	42.8	39.5	48.7*	34.8**	25.8*	47.0**	37.5	36.7
	6	45.6	40.5	44.1	47.0	34.7	48.5	40.2	43.2
	12	45.9	42.1	46.0	46.3	26.7*	49.7**	43.6	41.4
fibrous	0	51.0	47.6	52.9^{a}	50.4	49.9^{a}	49.7	50.7	51.3^{a}
	6	47.7	42.8	46.1^{a}*	56.3**	35.8^{b}	35.7	42.7*	33.1^{a}**
	12	52.5	47.1	58.0^{ab}	54.6	54.0^{a}	45.5	53.1	54.8^{ab}
cohesive	0	43.7	40.5	48.7*	38.8^{a}**	22.1*	42.0**	35.2	36.0
	6	39.9	36.6	42.8*	54.9^{ab}**	30.4*	44.3**	37.6	40.8
	12	45.7	43.4	43.7	49.0^{a}	26.9*	52.2**	41.2	40.8
gummy	0	27.2*	17.2**	25.6	22.9	13.8^{a}*	31.6**	22.8^{a}	21.8^{a}
	6	18.5	15.4	19.8	30.2	13.3^{a}*	29.1**	23.5^{a}	23.7^{a}
	12	28.8	26.6	29.8	31.5	18.6^{ab}*	45.4**	37.8^{b}	38.9^{b}
watery	0	47.2	46.4	48.3	49.4	54.9	51.9	56.0*	50.2**
	6	41.0	39.9	47.4	43.8	47.3	45.2	44.2	46.4
	12	45.2	44.9	47.4	42.6	52.4	49.5	44.0	41.0
juicy	0	52.3	49.8	49.2	43.5	42.6^{a}	40.1	45.6^{a}*	38.9**
	6	56.8	51.8	49.6	46.8	48.1^{a}	44.5	44.7^{a}	44.3
	12	50.1	48.2	48.4	44.1	48.6^{ab}	43.2	33.3^{b}	36.6

a, b, c different superscripts indicate significant ($p < 0.05$) differences between storage time; *, ** different numbers of asterisks indicate significant ($p < 0.05$) differences between single and double frozen portions.

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TABLE 5: *Sensory assessment (%) by paired comparison of fried coated portions processed from single (SF) and double frozen (DF) redfish fillet and mince.*

Item	Storage time (months)	preference		stale/fishy		firm	
		SF	DF	SF	DF	SF	DF
fillet,	0	42.5	57.5	50.0	50.0	45.0	55.0
pre rigor	6	52.8	47.2	55.6	44.4	69.4	30.6
	12	57.5	42.5	45.0	55.0	57.5	42.5
fillet,	0	57.5	42.5	43.8	56.2	60.0	40.0
post rigor	6	55.6	44.4	47.2	52.8	27.8	72.7
	12	57.5	42.5	42.5	57.5	40.0	60.0
mince,	0	80.0***	20.0***	80.0***	20.0***	15.0***	85.0***
pre rigor	6	83.3**	17.7**	22.8*	77.2*	27.2*	72.8*
	12	75.0*	25.0*	12.5**	87.5**	7.5***	92.5***
mince,	0	50.0	50.0	46.3	53.7	48.8	51.2
post rigor	6	72.2*	27.8*	30.6	69.4	33.3	66.7
	12	40.0	60.0	57.5	42.5	42.5	57.5

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

TABLE 6: *Colour values measured on untreated and fried (f) portions of redfish fillet (F) and mince (M) as a function of rigor state (PR, pre rigor; PO, post rigor) and refreezing (DF).*

Attribute	Storage time (months)	FPR	FPR DF	FPO	FPO DF	MPR	MPR DF	MPO	MPO DF
L^*	0	71.6^{a}	71.2^{a}	75.9^{a}	75.0	58.2^{a*}	66.4**	73.9^{a}	73.9^{a}
	6	74.4^{b}	73.8^{b}	74.0^{b*}	75.7**	57.9^{a*}	67.7**	72.0^{b}	72.3^{b}
	12	72.4^{a*}	70.9^{a**}	76.3^{a*}	75.1**	58.8^{ab*}	63.7**	68.9^{c*}	70.4^{c**}
a^*	0	–0.02^{a}	–0.01	0.87^{a*}	0.71^{a**}	3.83^{a*}	1.54**	0.60^{a*}	0.95^{a**}
	6	1.03^{b*}	0.12**	0.33^{b}	0.19^{b}	3.41^{b*}	1.79**	0.58^{a*}	0.76^{b**}
	12	0.82^{c*}	–0.03**	0.40^{b*}	–0.09^{c**}	3.43^{b*}	1.41**	0.99^{b*}	0.69^{b**}
b^*	0	6.75^{a}	6.98^{a}	9.03^{a*}	9.93^{a**}	11.3^{a*}	9.55**	10.1^{a}	10.1^{a}
	6	7.85^{b}	7.84^{b}	7.79^{b*}	8.43^{b**}	10.7^{b*}	9.76**	9.27^{b*}	10.2^{a**}
	12	8.77^{c*}	6.96^{a**}	7.73^{b*}	7.23^{c**}	10.7^{b*}	8.69**	8.94^{b}	9.13^{b}
L^*f	0	76.5a*	74.5a**	77.0a*	77.8a**	70.0a*	71.6a**	76.4a*	74.8^{a**}
	6	75.6b*	74.4a**	77.6b*	79.2b**	69.3b*	70.3b**	76.6a*	74.7^{a**}
	12	77.3c*	75.4b**	80.2c*	78.8c**	69.4c*	74.0c**	77.1b*	76.7^{b**}
a^*f	0	–0.94^{a*}	–0.32^{a**}	–0.18^{a*}	–1.00^{a**}	3.25^{a*}	1.45^{a**}	–0.70^{a*}	–0.42^{a**}
	6	–0.80^{b*}	–0.68^{b**}	–0.31^{b*}	–1.33^{b**}	3.06^{b*}	1.33^{b**}	–0.76^{b*}	–0.84^{b**}
	12	–0.17^{c*}	0.22^{c**}	–0.90^{c}	–0.85^{c}	3.53^{c*}	1.50^{a**}	–0.57^{c*}	–0.34^{c**}
b^*f	0	9.65^{a*}	11.1^{a**}	12.0^{a}	12.1^{a}	14.8^{a*}	13.5^{a**}	13.4^{a}	13.6^{a}
	6	12.0^{b*}	13.2^{b**}	12.4^{b*}	12.6^{b**}	17.7^{b*}	15.2^{b**}	14.7^{b}	14.7^{b}
	12	11.0^{c*}	11.4^{c**}	10.2^{c*}	10.5^{c**}	15.1^{c*}	13.0^{c**}	13.0^{c*}	12.2^{c**}

$^{a, b, c}$ different superscripts indicate significant ($p < 0.05$) differences between storage time; *, ** different numbers of asterisks indicate significant ($p < 0.05$) differences between single and double frozen portions.

and gummy increased irrespective of storage time. On the other hand, the duration of storage appears to be of minor importance for all textural attributes evaluated. The only tendency to be seen was an increase in "gummy" with prolonged storage time irrespective of processing style.

No significant differences between SF and DF samples were found by PCT except for those processed from mince, pre rigor, irrespective of the duration of frozen storage (Tab. 5). There is no explanation for this exception so far. For all other portions, the assessors were unable to discriminate between SF and DF samples.

These sensory results agree well with earlier findings (MacCallum et al., 1967). They found that redfish, similarly frozen before and during rigor and later processed and refrozen, maintained a very acceptable quality up to 28–34 weeks. No influence of both thawing procedures (water as well as dielectric thawing was compared) and state of rigor at freezing was noticed. DF samples were equal in quality to samples frozen once. Furthermore, there are reports on good long-term frozen storage ability of redfish (Dyer et al., 1956; Lauder et al., 1970). Redfish fillets stored at –12 °C remained in good condition for 17 to 22 weeks, but became unacceptable in seven months, while when stored at –23 °C, this applied after 30 to 80 weeks (Dyer et al., 1956). The effect of various periods of pre-freeze storage for iced, whole redfish on the shelf life (at –23 °C) of the fillets were reported (Lauder et al., 1970). Fish iced for two days, then processed and frozen, were of acceptable quality for 83–94 weeks; those iced for twelve days, then filleted and frozen, had a storage life to unacceptability of 51 weeks. Fish iced 15 days were unacceptable for freezing. Freshly caught redfish fillets were sensory evaluated on board ship within 24 hours after capture (Oehlenschläger, 1984). The results were compared favourably to those evaluated after five months of frozen storage at –30 °C. Frozen samples were scored significantly poorer in quality than fresh ones. Differences in appearance were comparably small, while those in odour and taste were pronounced. Texture became mushy and soft after frozen storage. A further negative influence on quality of the different processing styles can be speculated as result from an increase in free fatty acids (FFA). The increase in FFA was found to be more pronounced in redfish mince compared to intact fillets and appeared to be inversely correlated to storage temperature (Fricke and Oehlenschläger, 1983; Oehlenschläger and Schreiber, 1988). When frozen/thawed and unfrozen redfish fillets were sensory evaluated during iced storage it became obvious that at the beginning of storage unfrozen fillets had significantly higher scores and maintained higher scores throughout most of the storage period (Magnusson and Martinsdottir, 1995).

Colour measurement

Results of colour measurements taken on homogenised thawed as well as fried samples and colour differences ΔE* between SF and DF samples are shown in Tables 6 and 7, respectively. Colour differences caused by double freezing were comparatively low, except for those portions from mince, pre rigor, where ΔE* was very high for thermally untreated samples and high for fried samples. However, no clear influence of storage time on ΔE* was detectable. Almost all measurements taken on DF fried samples were significantly different ($p < 0.05$) compared to those taken on SF ones, irrespective of the colour value (L*, a*, b*). For thermally untreated samples, the most significant differences between SF and DF were found for fillet, post rigor, and mince, pre rigor. However, differences were small and the tendencies of changes were variable. Also, the duration of storage did not clearly influence the colour values. These findings support the conclusion that the samples, although quite different in processing (refreezing and storage time) did not differ markedly in colour. These results were surprising since double freezing was mainly connected with remarkable changes in colour, especially in L*, when applied to other fish species such as cod, saithe or haddock (Schubring, 2000a, 2001a, 2001b, 2002).

Instrumental texture measurements

Instrumentally evaluated texture parameters of coated portions of fillets and mince as affected by rigor state, refreezing and length of storage time are shown in Table 8. Post rigor samples were mostly harder and chewier compared to portions from pre rigor raw material irrespective of storage time and pre-processing. For cohesiveness and springiness, the same trends could be observed, although few exceptions were found, e. g. for cohesiveness (fillet, 12 months) and for springiness (fillet, 0 and 12 months). Adhesiveness of fillet portions measured on post rigor samples was slightly lower compared to pre rigor portions, while almost no difference was obvious between the same two types of mince portions. As with sensory assessment, on mince portions, pre rigor, the influence of refreezing became most obvious. Hardness, chewiness and cohesiveness increased significantly ($p < 0.05$) after refreezing. In almost all other cases refreezing did not cause significant differences in these texture attributes (Tab. 8). Surprisingly, one year of frozen storage at –24 °C did not cause clear tendencies in changes of the different texture attributes. However, trends indicating increases in both hardness and chewiness with increasing storage time were observed on mince portions. Adhesiveness measured on fillet portions

TABLE 7: *Colour differences (ΔE*) between single and double frozen untreated and fried portions of redfish fillet and mince as a function of rigor state.*

	Sample	Storage time (months)		
		0	6	12
Untreated	Fillet, pre rigor	0.5	1.1	2.5
	Fillet, post rigor	1.3	1.8	1.4
	Mince, pre rigor	8.7	9.0	5.7
	Mince, post rigor	0.4	1.0	1.5
Fried	Fillet, pre rigor	2.5	1.7	2.0
	Fillet, post rigor	1.1	1.9	1.5
	Mince, pre rigor	2.7	3.2	5.4
	Mince, post rigor	1.6	1.9	1.1

TABLE 8: *Texture parameters measured by Texture Profile Analysis on fried portions of redfish fillet (F) and mince (M) as a function of rigor state (PR, pre rigor; PO, post rigor) and refreezing (DF).*

Attribute	Storage time (months)	FPR	FPR DF	FPO	FPO DF	MPR	MPR DF	MPO	MPO DF
Hardness	0	54.1	49.0^{a}	44.7^{a*}	60.9^{a**}	70.5	75.7	75.4^{a}	74.5^{a}
(N)	6	61.8	61.0^{ab}	51.3^{ab*}	73.0^{b**}	65.9	66.4	85.5^{b*}	74.3^{a**}
	12	60.3	57.9^{a}	72.6	73.3	72.6^{a*}	76.2^{b**}	89.5^{b}	84.7^{b}
Chewiness	0	12.1	12.9^{a}	16.9	27.3	19.9^{a*}	20.3^{a**}	34.2^{a}	33.8^{a}
	6	15.2	20.2^{ab}	21.0	36.1	19.9^{b*}	19.6^{a**}	40.9^{b*}	34.5^{a**}
	12	14.5	15.6^{a}	20.2	21.8	20.2^{a*}	35.9^{b**}	43.6^{b}	40.1^{b}
Cohesiveness	0	0.496	0.539	0.664^{a*}	0.693^{a**}	0.530	0.496	0.675^{a*}	0.704^{**}
	6	0.538	0.583	0.694^{ab*}	0.731^{b**}	0.545	0.546	0.711^{b}	0.711
	12	0.559	0.573	0.670^{a*}	0.715^{c**}	0.522	0.532	0.703^{b}	0.704
Springiness	0	0.633	0.671^{a}	0.787	0.782	0.627	0.629	0.796	0.805
	6	0.615^{*}	0.687^{ab**}	0.789	0.795	0.650	0.641	0.808	0.804
	12	0.646	0.640^{a}	0.775	0.777	0.638	0.660	0.801	0.796
Adhesiveness	0	-0.48^{a*}	-0.32^{**}	–0.22	–0.18	–0.40	-0.40^{a}	–0.28	-0.24^{b}
(Ns)	6	-0.38^{a}	–0.25	–0.14	–0.14	–0.37	-0.42^{a}	-0.15^{*}	-0.20^{b**}
	12	-0.33^{ac}	–0.22	–0.29	–0.33	-0.29^{*}	-0.11^{ac**}	–0.19	-0.14^{bc}

$^{a, b, c}$ different superscripts indicate significant ($p < 0.05$) differences between storage time; *, ** different numbers. of asterisks indicate significant ($p < 0.05$) differences between single and double frozen portions.

TABLE 9: *Tensile force (N) measured on fried portions of redfish fillet (F) and mince (M) as a function of rigor state (PR, pre rigor; PO, post rigor) and refreezing (DF).*

Storage time (months)	FPR	FPR DF	FPO	FPO DF	MPR	MPR DF	MPO	MPO DF
0	2.31^{*}	3.46^{a**}	2.24	2.52^{a}	4.16^{a*}	7.23^{a**}	3.85^{a*}	4.43^{a**}
6	1.89^{*}	2.89^{a**}	1.51	1.58^{b}	3.17^{b*}	5.24^{b**}	2.70^{b*}	3.29^{b**}
12	2.18^{*}	3.77^{ab**}	1.61	2.22^{b}	3.31^{b*}	5.42^{b**}	3.22^{b*}	3.72^{b**}

$^{a, b}$ different superscripts indicate significant ($p < 0.05$) differences between storage time; *, ** different numbers of asterisks indicate significant ($p < 0.05$) differences between single and double frozen portions.

TABLE 10: *Penetration force (N) measured on untreated and cooked portions of fillet (F) and mince (M) as a function of rigor state (PR, pre rigor; PO, post rigor) and refreezing (DF).*

	Storage time (months)	FPR	FPR DF	FPO	FPO DF	MPR	MPR DF	MPO	MPO DF
untreated	0	1.75^{a*}	1.19^{a**}	1.69^{a*}	1.51^{a**}	2.91^{a*}	1.50^{a**}	2.30^{a*}	1.78^{a**}
	6	3.47^{b*}	2.74^{b**}	3.13^{b}	3.01^{b}	7.04^{b*}	4.59^{b**}	4.75^{b*}	3.60^{b**}
	12	2.75^{c*}	1.60^{c**}	2.26^{c*}	2.76^{c**}	4.98^{c*}	2.99^{c**}	2.26^{a*}	2.53^{c**}
fried	0	16.1^{a*}	6.82^{a**}	11.1^{a*}	8.55^{a**}	3.28^{a*}	3.83^{a**}	5.88^{a*}	5.36^{a**}
	6	14.4^{b*}	8.66^{b**}	8.07^{b*}	7.24^{b**}	3.57^{b*}	4.62^{b**}	4.01^{b*}	4.67^{b**}
	12	11.5^{c*}	7.36^{c**}	7.71^{c*}	6.54^{c**}	4.04^{c}	4.05^{c}	5.13^{c*}	4.93^{b**}

a, b, c different superscripts indicate significant ($p < 0.05$) differences between storage time; *, ** different numbers of asterisks indicate significant ($p < 0.05$) differences between single and double frozen portions.

TABLE 11: *Expressible moisture (%) measured on portions of fillet (F) and mince (M) as a function of rigor state (PR, pre rigor; PO, post rigor) and refreezing (DF).*

Storage time (months)	FPR	FPR DF	FPO	FPO DF	MPR	MPR DF	MPO	MPO DF
0	12.6	12.6	12.2^{a*}	9.78^{a**}	16.9^{a*}	11.7**	10.4^{a}	10.3
6	13.1*	11.9**	13.6^{b*}	10.4^{a**}	13.2^{b*}	10.7**	11.2^{b}	11.0
12	13.5	12.4	14.8^{b*}	10.9^{ac**}	15.9^{a*}	11.6**	12.7^{c*}	11.6**

a, b, c different superscripts indicate significant ($p < 0.05$) differences between storage time; *, ** different numbers of asterisks indicate significant ($p < 0.05$) differences between single and double frozen portions.

was remarkably higher compared to that of mince samples and decreased with increasing storage time. The changes in adhesiveness in mince samples were not so well defined.

Hsieh and Regenstein (1989) compared textural changes of both cod and redfish minces by TPA. They found that frozen minced cod degenerated faster than minced redfish, especially at higher storage temperatures.

The tensile strength of DF samples was significantly ($p < 0.05$) higher, except for post rigor fillet, when compared to those of SF samples (Tab. 9). This indicates a marked increase in toughness caused by refreezing. However, with increasing frozen time storage, tensile strength appears to decrease. This decrease was already at its maximum after six months and was followed by an increase after a further storage of six months at –24 °C.

In penetration force, the differences between SF and DF samples were significant ($p < 0.05$). Except for portions processed from fried mince, pre rigor, double freezing is connected with a decrease in penetration force (Tab. 10). However, the duration of frozen storage did not clearly influence penetration force. The penetration force measured on untreated samples after six months was highest. The increase in the penetration force observed in DF samples is not surprising and can be attributed to a slight freeze-induced hardening (Sikorski et al., 1976; Santos-Yap, 1996) of the double frozen samples. The same results were obtained when using cod fillet as raw material (Schubring, 2002).

Water holding capacity

WHC measured by expressible moisture (Tab. 11) appears to be influenced by refreezing. However, only for portions prepared from fillet, post rigor, as well as mince, pre rigor, differences were significant ($p < 0.05$). Surprisingly, DF caused a decrease in expressible moisture; this trend appears not to be influenced by time of frozen storage. However, possible changes in the total moisture content during thawing on board due to some drip loss have not been taken into account. In general, it can be concluded from the results displayed in Table 11 that refreezing does not cause detrimental alterations in water binding. It should, however, be taken into account that prolonged storage appears to be mainly accompanied by an increase in expressible moisture (decrease in WHC), which agrees with most observations reported in the literature (Mackie, 1993; Hurling and McArthur, 1996; Anese and Gormley, 1996). In a comparison of expressible moisture during frozen storage of minced cod and redfish, higher values were found for cod (Hsieh and Regenstein, 1989).

Conclusion

The quality of coated portions prepared from both SF and DF redfish fillet und mince processed pre and post rigor and stored frozen at –24 °C for one year was compared at distinct lengths of storage time. Sensory, physical and chemical methods were used with the aim to differentiate between SF and DF. Sensory evaluated flavour attributes did not show significant differences between SF and DF portions. Only the sensory assessed texture of mince portions, pre rigor, was significantly influenced by refreezing. The reason for this remains unclear. Good long-term frozen storage capability as reported in the literature was also found for portions from both redfish fillets and minces irrespective of rigor state. Surprisingly, colour differences between SF and DF samples, pronounced in other fish species investigated so far, were without significance for redfish. Double freezing was not connected with a decrease in WHC as revealed by measuring expressible moisture. However, prolonged frozen storage lead to a reduction in WHC. Instrumentally measured texture by tensile force revealed significant differences between SF and DF samples except for fillet portions, post rigor. On the other hand, differences in texture measured by penetration force as well as TPA were not consistent in their tendencies. Further research is needed for clarification of the pronounced quality changes in mince portions, pre rigor.

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References

Anese M, Gormley R (1996): Effects of dairy ingredients on some chemical, physico-chemical and functional properties of minced fish during freezing and frozen storage. LWT Food Sci Technol 29: 151–157.

Anonymous (2008): Frische und Qualität von Tiefkühl-Seafood. Fischmagazin Spezial, TK-Fisch Convenience Heft 5: 14–19.

BMELV (2008): Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, Jahresbericht über die Deutsche Fischwirtschaft 2007. DCM Verlag, Meckenheim.

Detienne NA, Wicker L (1999): Sodium chloride and tripolyphosphate effects on physical and quality characteristics of injected pork loins. J Food Sci 64: 1042–1047.

Dyer WJ, Morton ML, Fraser DI, Bligh EG (1956): Storage of frozen rosefish fillets. J Fish Res Bd Can 13: 569–579.

Fricke H, Oehlenschläger J (1983): Changes in lipid class composition of homogenised redfish fillet (*Sebastes marinus* L.) during frozen storage at –12 °C as monitored by HPLC. Fette Seifen Anstrichmittel 85: 474–476.

Hsieh YL, Regenstein JM (1989): Texture changes of frozen stored cod and ocean perch minces. J Food Sci 54: 824–826, 834.

Hurling R, McArthur H (1996): Thawing, refreezing and frozen storage effects on muscle functionality and sensory attributes of frozen cod *(Gadus morhua)*. J Food Sci 61: 1289–1296.

Lauder JT, MacCallum WA, Idler DR (1970): Keeping time of frozen redfish *(Sebastes marinus mentella)* fillets in relation to handling of the raw material and storage temperatures after processing and freezing. J Fish Res Bd Can 27: 1589–1605.

MacCallum WA, Chalker DA, Dyer WJ, Idler DR (1967): Effects of water and dielectric thawing processes on shelf life of doublefrozen cod and redfish. J Fish Res Bd Can 24: 127–144.

Mackie IM (1993): The effect of freezing on flesh proteins. Food Rev Int 9: 575–610.

Magnusson H, Martinsdottir E (1995): Storage quality of fresh and frozen-thawed fish in ice. J Food Sci 60: 273–278.

Oehlenschläger J (1984): Sensory differences between fresh and frozen stored marine fish. Inf Fischw 31: 164–166.

Oehlenschläger J (1989): Contents of volatile amines and TMAO in freshly caught redfish (*Sebastes marinus* and *Sebastes mentella*) from different catching areas of the North Atlantic. Arch Lebensmittelhyg 40: 55–58.

Oehlenschläger J, Schreiber W (1988): Changes in lipid class composition of redfish (*Sebastes marinus* L.) during frozen storage: 2. Investigation in fillets. Fat Sci Technol 90: 38–41.

Oetjen K, Karl H (1999): Improvement of gas chromatographic determination methods of volatile amines in fish and fishery products. Dtsch Lebensm Rundsch 95: 403–407.

Ravesi EM, Krzynowek JJ (1991): Variability of salt absorption by brine dipped fillets of cod *(Gadus morhua),* blackback flounder *(Pseudopleuronectes americanus)* and Ocean perch *(Sebastes marinus).* J Food Sci 56: 648–652.

Rehbein H, Oehlenschläger J (1983): Differentiating between the red or rose-fish *(Sebastes marinus)* and its deeper sea-level variety *(Sebastes mentella).* Allg Fischwirtschztg 35: 397–398.

Rehbein H, Schreiber W (1984): TMAO-ase activity in tissues of fish species from the Northeast Atlantic. Comp Biochem Physiol 79B: 447–452.

Rehbein H, Martinsdottir E, Blomsterberg F, Valdimarsson G, Oehlenschläger J (1994): Shelf life of ice-stored redfish, *Sebastes marinus* and *S. mentella.* Int J Food Sci Technol 29: 303–313.

Santos-Yap EEM (1996): Fish and Seafood. In: Jeremiah LE (ed.), Freezing effects on food quality. Marcel Dekker, New York, USA, 109–134.

Schubring R (1996): Farbmessungen an panierten Fischerzeugnissen. Inf Fischw 43: 84–88.

Schubring R (1999a): Influence of double freezing on quality attributes of saithe *(Pollachius virens)* fillet during frozen storage dependent on rigor state. Dtsch Lebensm Rundsch 95: 161–171.

Schubring R (1999b): Comparison of the quality of coated portions of fish fillet produced from single and double frozen blocks. Inf Fischw Fischereiforsch 46: 52–56.

Schubring R (1999c): DSC studies on deep frozen fishery products. Thermochim Acta 337: 89–95.

Schubring R (2000a): Influence of double freezing on quality attributes of lean fish fillet during frozen storage as affected by rigor states. In: Advances in the refrigeration systems, food technologies and cold chain. Proceed Conf Comm B2 & C2 with D1 & D2/3, Sofia, Bulgaria 1998/6. IIR/IIF, Paris, 504–513.

Schubring R (2000b): Instrumental and sensory evaluation of the texture of fish fingers. Dtsch Lebensm Rundsch 96: 210–221.

Schubring R (2001a): Double freezing of saithe fillets. Influence on sensory and physical attributes. Nahrung/Food 45: 280–285.

Schubring R (2001b): Double freezing of fillets and minces prepared from saithe and haddock: influence on selected sensory and physical attributes. In: Gudjonsson A, Niclasen O (eds.), Proceedings of the 30th WEFTA Plenary Meeting, Torshavn, Faroe Islands, 19–22 June 2001, Anales Societatis Scientarum Faeroensis Supplement XXVIII, 169–179.

Schubring R (2002): Double freezing of cod fillets: influence on sensory, physical and chemical attributes of battered and breaded fillet portions. Nahrung/Food 46: 227–232.

Schubring R, Meyer C, Schlüter O, Boguslawski S, Knorr D (2003): Impact of high pressure assisted thawing on the quality of fillets from various fish species. Innovat Food Sci Emerg Tech 4: 257–267.

Sidwell VD (1981): Chemical and nutritional composition of finfishes, whales, crustaceans, mollusk and their products. NOAA Tech Memo NMFS F/SEC-11, 88–89.

Sikorski Z, Olley J, Kostuch S (1976): Protein changes in frozen fish. Crit Rev Food Sci Nutr 8: 97–129.

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