Nitrogen Factors for Cod Ingredient in Fish Products

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Summary

A Code of Practice on the declaration and the labelling of fish content in fish products was drawn up by participants from Industry and Enforcement Agencies. The Code currently contains interim nitrogen factors to calculate the amount of fish ingredient which have been obtained by considering the available data on nitrogen content of fish straight from the sea and the effects of good manufacturing practice (GMP). There was a need to carry out experimental trials to determine the actual nitrogen content of GMP products to verify or replace these interim values.

This paper reports the trials carried out between December 2001 and September 2003 to determine the nitrogen factor of fish ingredient, in double frozen fillet and mince blocks produced under GMP in the UK. Sampling took into account both seasonality and raw-material catch area. In addition, samples were taken at key stages of fish block manufacture to determine the effect of processing. Trials were also carried out to determine the nitrogen factors of the equivalent single and double frozen blocks imported into the UK from five different countries.

Processing had a significant effect on nitrogen contents which followed a consistent pattern within a given sample type. In fillet block production, the conversion from a raw material control fillet to a commercial fillet ingredient resulted in no change or an increase in nitrogen content, whilst the conversion of commercial fillet ingredient to final block resulted in a decrease in nitrogen content. Mince block production showed a different pattern. The conversion from raw material control to mince ingredient resulted in a decrease in nitrogen content, whilst the conversion of mince ingredient to the final block resulted in an increase in nitrogen content.

For UK manufactured blocks the nitrogen content of fillet and mince ingredient was found to be 2.88% and 2.74% respectively.

For imported blocks the overall nitrogen content for those made from fillet or mince was found to be 2.74% and 2.67%. There was no statistically significant difference between single or double frozen blocks. Although the values for imported blocks were lower than those produced in UK, these differences were not significantly different.

Based on these findings, recommended values for the nitrogen factor for cod ingredient in cod products have been agreed by the Nitrogen Factors Sub-Committee.

The Analytical Methods Committee has received, and approved for publication, the following report from its Nitrogen Factors Sub-Committee.

Report

The constitution of the Sub-Committee responsible for the preparation of this report was: Prof. R. A. Lawrie (Chairman), Dr. M. Anyadiegwu (until August, 2003), Mrs. S. Elahi, Mr. D. J. Favell, Mr. M. W. Fogden, Mr. J. Grant, Mr. A. J. Harrison (until October, 2001), Mr. N. Harrison (until October, 2002), Mrs. D. B. Homer, Dr. R. B. Hughes, Mr. R. S. Kirk (until August, 2003), Mr. P. Mayes (from October, 2001), Mr. C. R. Morrison, Mr. T. O'Dea, Dr. P. I. Smith (from October, 2001), Mr. J. Tippett (until August, 2003), Dr. G. S. Tullett (until August, 2003), Mrs. P. Urwin (from August, 2003), Mr. R. Watson, Dr. R. Wood (Food Standards Agency, Project Officer), Dr. M. L. Woolfe (Food Standards Agency, Project Officer), the late Mr. J. J. Wilson (Secretary until April, 2004) and Dr. E. J. Newman (Secretary from April, 2004).

The work involved in the investigations upon which the report is based was organized by a Working Party, the members of which were: Mr. J. Grant (Chairman), Mr. R. Watson, Dr. R. B. Hughes and Mrs. D. B. Homer, who was responsible for the statistical evaluation of the results.

Introduction

A Code of Practice on the declaration and the labelling of fish content of fish products was drawn up by representatives from retail and processing industries and enforcement authorities1. This Code covers the labelling and declaration of fish content of different fish ingredients with respect to the relevant labelling legislation. It defines fish ingredient in terms of fish which has been prepared under good manufacturing

practice (GMP), and good hygienic practice, to minimize the amount of water incorporated into the fish. It aims to assist in establishing a due diligence defence and to define enforcement procedures. Industry and enforcement officers will use this Code of Practice wherever there is a need to consider the correct declaration of fish content in fish products. This Code contains interim nitrogen factors for fish ingredient (used to determine fish content) which have been obtained from commercial sources by reducing the available data on nitrogen content of fish straight from the sea by amounts thought to accord with the effect of GMP.

Since the effect of water uptake and/or nitrogen loss during GMP, and those of other circumstances such as the fishing ground and seasonality, are not easily quantified, the interim factors are being used only pending the results of further work. The Code of Practice Nitrogen Factors Working Group asked the Nitrogen Factors Sub-Committee of the Royal Society of Chemistry to carry out such work on their behalf. The nature of this investigation and the results obtained are described in the present report.

Specifically there is a need to determine the nitrogen factor for cod fish fillet ingredient and mince cod fish ingredient which are used as the raw material for making frozen fish blocks. These, in turn, are used to make many types of processed fish products.

Industry has stated that the principal manufacturers of processed and breaded fish products use mainly frozen blocks of cod fillet ingredient. Since the introduction of the Fish Code of Practice, blocks consisting of 80% fillet, 10% fish mince and 10% polyphosphate solution are not normally used. However, blocks made from minced cod are used for the production of 'economy' or 'value' processed and breaded fish products. (During this survey no attempt was made to ascertain whether any of the frozen imported blocks sampled contained polyphosphate).

Over the past few years, fillet and mince block manufacture in the UK has been in a state of flux. During the planning stage of this project, two of the large-scale UK block producers closed down, and there were also frequent changes in the raw material used in block production. At this time only one large-scale UK block manufacturer exists, and the majority of the fish blocks are imported.

This report is concerned with trials carried out between December 2001 and September 2003 to determine the nitrogen content[#] of fish ingredient in the production of both double frozen fillet and mince blocks under GMP in the UK. Sampling took into account both seasonality and the area in which the raw material fish was caught. In addition, samples were taken at key stages to determine the effect of processing. Trials were also carried out to determine the nitrogen content of the equivalent single and double frozen blocks imported into the UK from five different countries.

Experimental

1. General Procedure

The Working Group had close contact with industry in order to facilitate this study. Collection of blocks produced commercially in UK, and the facilities for the preparation of samples for analysis were both provided by a Humberside fish processor. Filleted and minced blocks imported from abroad were sourced, sectioned and distributed by Young's Bluecrest Seafood Ltd, Grimsby. The Seafish Industry Authority carried out the collection and distribution of samples to five accredited laboratories for chemical analysis. These were the LGC, two public analysts' laboratories and two commercial laboratories.

The importance of this investigation, as in those previously undertaken by the Nitrogen Factors Sub-Committee, was further recognized by the use of written protocols which that body had devised. These covered the proceedings for sample acquisition, the preparation of samples, and their analysis by BS4401 methods, the tolerance limits used in assessing the results (Appendix 1) and the strategy employed for determining their acceptability or rejection.

2. Blocks Produced in UK

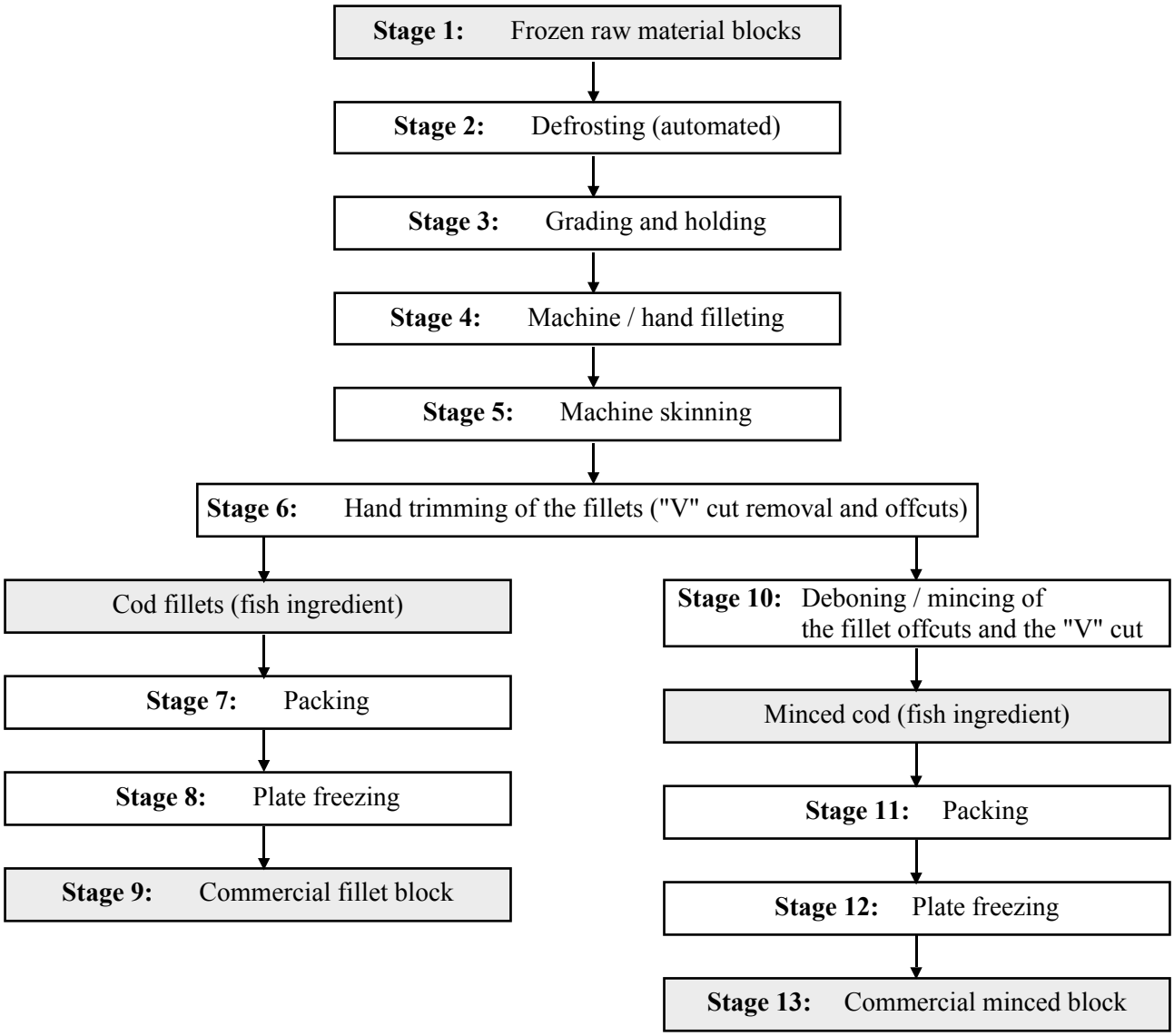
For trials using spent (post-spawning) fish, it was essential to obtain blocks with the highest practically possible proportion of spent fish. As fish generally remain in spent condition for approximately 2 months after spawning, it was proposed to obtain samples of fish blocks made from spent fish caught approximately 1 month after the end of the peak spawning season for each ground. The International Council for Exploration

Although the term "nitrogen factor" signifies the content of nitrogen (% N) expressed on a fat-free basis, it is customary to quote the nitrogen content of cod as the nitrogen factor since there is usually very little lipid present in the flesh of this species.

of the Seas (ICES) were contacted to get the most up-to-date information on the peak-spawning season for cod from both grounds2. Due to the potential for variation in peak spawning season, evidence from the supplier in the form of visual inspection and/or changes in filleting yield was used where possible in conjunction with peak spawning information. For trials using non spent fish, the raw material blocks were collected at least 4 months before or after the peak spawning period for the given capture area. However, because of uncertainties in respect of the precise spawning periods, the sampling seasons were referred to as spring (for spent fish) and autumn (for non-spent fish), in this report. Fish caught in the Barents Sea and Norwegian waters were sampled in both seasons. Numbers and origin of samples in relation to season, and processing stage, for both hand and machine-filleted are shown in Table 1: samples were prepared from 1000 lb frozen blocks of headed and gutted fish at the points indicated in Fig. 1.

FIGURE 1

A Schematic Diagram Showing the Commercial Production of Fish Fillet and Minced Fish Ingredient



Note : Shaded boxes show stages of the process where samples were removed for analysis

To obtain raw material control samples, five 20 kg headed and gutted frozen cod blocks were defrosted in air (below 10°C to minimise drip loss). A 20 kg sample of defrosted fish was randomly selected, dry filleted, de boned (using the 'V' or 'J' cut method) and skinned by experienced hand filleters. Twenty, 300 gram samples (4 per laboratory) were then created by taking random fillets, which were then double bagged in heat sealed polyethylene bags.

Table 1

Summary of the Number of Samples of UK Produced Fish Blocks Collected for Laboratory Analysis

UK Produced blocks	Barents Cod				Norwegian Cod		Total Samples
	Spring Season		Autumn Season		Spring Season	Autumn Season	
	Hand filleted	Machine filleted	Hand filleted	Machine filleted	Hand filleted	Hand filleted	
Control (Dry filleted raw material)	20		20		20	20	400
Cod fillet ingredient	10	10	10	10	20	20	
Minced cod ingredient	10	10	10	10	20	20	
Commercial cod fillet block	10	10	10	10	20	20	
Commercial minced cod block	10	10	10	10	20	20	

When processing fish from the Barents Sea, it is normal practice to both machine fillet and hand fillet. To obtain samples for cod fillet fish ingredient and minced cod fish ingredient, approximately 5 kg of material was removed at each stage for both hand filleted and machine filleted material. From each five kilogram batch, ten 300 g samples were collected and double bagged. During minced cod fish ingredient production (after stage 10) liquor separation from the minced fish ingredient can occur. Care had thus to be taken to collect a representative sample.

To obtain samples from stages 9 and 13, five hand filleted and five machine filleted 7.5 kg blocks were collected. For each filleting treatment the five blocks were band-sawed into approximately 10 pieces. Samples were then selected, (two from each block) and double bagged.

Each sample was labelled with an identification code (randomly generated and recorded by Seafish) and immediately frozen, and stored below –18°C. Duplicate samples were retained by Seafish.

The work was repeated with headed and gutted fish caught from Norwegian waters, all being hand filleted.

All samples were dispatched to laboratories by courier in an expanded polystyrene box with dry ice with instructions to be stored at –18°C or below. Each laboratory received samples from the different stages and sources.

3. Blocks imported from abroad

The original protocol proposed to study frozen mince and fillet blocks from the five countries which commercially export these to UK viz. Denmark, China (including those blocks consisting of Gadus macrocephalus), Iceland, Norway and Poland. These would be derived from fish caught during both spring and autumn seasons; and would allow comparison with fillet and mince blocks produced in UK. Appropriate documentation from the manufacturing plants involved ensured that the origin and history used to make the blocks was known.

Due to changes in the conditions of supply, difficulties were encountered in sourcing blocks with the parameters which had originally been specified in the protocol. A total of seventeen blocks were obtained, however, which were considered by industry to be representative of the blocks available. These were derived from the five countries above and also from Russia and Lithuania and included single or double frozen blocks of fillet and mince cod ingredient. They were regarded by the Nitrogen Factors Sub-Committee as acceptable for the purposes of this study. Sampling was carried out using the methods employed with the UK blocks at stages 9 and 13 (Fig. 1).

4. Statistical methodology

The trial was set up as a balanced factorial design with factors for seasons, ground and processing. The data was analysed by least squares means and will be presented for each level through the processing chain. The sample size was determined to detect a difference in nitrogen content between the levels of processing of approximately 0.05 (80% probability of detection at the 5% level if such a difference exists).

Analysis of variance models were fitted to each of the chemical components with terms for each of the main components as follows:

Imported samples

Blocks : fillet, mince
Freeze : single or double frozen

UK produced blocks

Ground : Barents, Norwegian
Season : spring (spent), autumn (non-spent)
Processing stage : control, fillet ingredient, mince ingredient, commercial fillet block, commercial mince block

In addition the following interactions were tested for inclusion in the statistical model

Ground × Season
Ground × Processing stage
Season × Processing stage

The criterion for including any of these interactions in the statistical model was significance at the 5% level.

Results

(a) Blocks produced in UK

All proximate analysis results are shown in Appendix 2.

Table 2 shows the significance levels for the statistical models fitted to the chemical components. A significant effect of season, ground and processing on nitrogen content was found (at 0.1% significance). Unusually, the spring samples showed a higher nitrogen content than the autumn samples. This suggests that the peak spawning period was delayed, resulting in samples being taken just prior to spawning.

There was no significant difference between the spring season samples by ground (Table 3). However, Norwegian samples from the autumn season had a significantly higher nitrogen content than autumn samples from the Barents Sea (at 0.1% significance).

The nitrogen values were significantly affected by processing, and the processing stage affected the samples in a consistent manner, regardless of the origin of the sample with respect to different grounds or seasons. Table 4 shows the nitrogen values by catch area, season and processing stage.

The overall means for moisture, fat and ash were 81.5, 0.54 and 1.1 respectively.

Table 2

Significance Levels of Chemical Components – UK Produced Blocks

	Fat	Moisture	Ash	Nitrogen
Ground	ns	ns	p<1.0%	p<0.1%
Season	p<0.1%	ns	ns	p<0.1%
Processing stage	ns	ns	p<0.1%	p<0.1%
Ground X season	ns	ns	ns	p<0.1%
Ground X processing stage	ns	ns	p<0.1%	ns
Season X processing stage	ns	ns	p<0.1%	ns

Table 3

Least Square Means for Nitrogen (% of cod sample) by Catch Area and Season

	Barents	Norwegian	Overall
Spring	2.88	2.88	2.88
Autumn	2.68	2.81	2.74
Overall	2.78	2.84	2.81

Least significant difference (LSD) for any comparison is approx. 0.02 (smallest difference that is significant at the 5% level).

Table 4

Nitrogen* Least Squares Means by Catch Area, Season and Processing Stage

	Barents		Norwegian		Process Stage
	Spring (1st-10th May 2001)	Autumn (Mid August 2003)	Spring (1st week of May 2001)	Autumn (Mid October 2003)	
Control	2.93	2.74	2.93	2.86	2.86
Fillet ingredient	2.93	2.77	2.93	2.88	2.88
Mince ingredient	2.81	2.61	2.81	2.74	2.74
Commercial fillet block	2.85	2.66	2.85	2.78	2.78
Commercial mince block	2.85	2.66	2.85	2.78	2.78

** N as % of cod sample*
Approx. least significant difference = 0.06

(b) Imported blocks

All proximate analysis results are shown in Table 5. One sample of imported fillet blocks and three imported mince blocks appeared to have abnormal moisture and ash values, possibly due to the presence of polyphosphate. One sample from Iceland was not included in the statistical analysis as the nitrogen content was very low. These are indicated in Appendix 2, Table A-5. No significant differences were found (at the 5% level) between the proximate analysis components (fillet/mince, single/double frozen); and these have not been tabulated. The least mean squares for the nitrogen contents of the samples were as follows: fillet, 2.74, mince, 2.67, single frozen, 2.64 and double frozen 2.76, these values being lower than those for corresponding samples produced in UK. The overall mean for the imported blocks was 2.70.

Table 5

Average Proximate Analysis Results – Imported Blocks

	Mode of freezing	Type of block	Components			
Sample	**Single/double frozen**	**Fillet/mince block**	**% Fat**	**% Moisture**	**% Ash**	**% Nitrogen**
Denmark (Barents)	Double	Fillet	0.47	82.10	1.31	2.75
Poland (Baltic Sea)	Single	Fillet	0.49	82.60	1.22	2.53
Poland (Baltic Sea)	Single	Fillet	0.39	82.70	1.10	2.58
Poland (Barents Sea)	Double	Mince	0.53	82.50	1.08	2.68
Poland (Baltic Sea)	Single	Fillet	0.45	83.60	1.16	2.42
Iceland (Icelandic Waters)	Single	Fillet	0.50	81.80	1.00	2.73
Iceland (Icelandic Waters)	Single	Mince	0.42	83.20	1.01	2.52
Iceland (Icelandic Waters) *	Single	Mince	0.34	86.00	1.15	2.10
Iceland (Icelandic Waters)	Single	Mince	0.40	81.20	0.92	2.78
Norway (Norwegian)	Single	Fillet	0.49	80.10	1.05	3.08
Norway (Norwegian)	Single	Mince	0.53	80.70	1.05	2.81
Norway (Norwegian)	Single	Mince	0.53	82.90	1.32	2.40
Norway (Norwegian)	Single	Fillet	0.59	81.90	1.08	2.61
China (Barents Sea)	Double	Fillet	0.55	81.50	0.93	2.79
China (Bering Sea)	Double	Fillet	0.55	80.20	0.86	2.94
Russia (Barents Sea)	Double	Fillet	0.46	82.10	0.97	2.81
Lithuania (Baltic)	Double	Fillet	0.38	81.70	1.01	2.74

** data removed because of abnormally high moisture content.*

Discussion

For UK processed blocks the overall nitrogen content for fillet ingredient and mince ingredient was found to be 2.88% and 2.74% respectively. These values are 8.2% and 5% higher than their respective values in the Code of Practice. This coincides with earlier work on Nephrops norvegicus where a 5.1% increase in the Code value was found[3]. The overall nitrogen content of both final commercial fillet and mince blocks was found to be the same (2.78%).

Nitrogen content was affected by catch area, season and processing stage. The overall nitrogen content was found to be higher for Norwegian than for Barents fish (but only in autumn samples). This is supported by the findings of industry[4] and Torry[5] and previous work by the Analytical Methods Committee[6]. The nitrogen content was found to be higher in the spring (spent) than the autumn (non-spent) samples. Earlier work by Torry5 and Public Analysts6 derived mean nitrogen contents of 2.90% and 2.85% respectively for fish from the sea. The values found for controls (2.93%–2.74%) in the present work compare favourably, but cannot be compared directly as they had undergone freezing. The results can also be compared with a similar trial carried out by Ross Foods[4] where a mean of 2.82% and 2.96% was found for dry filleted Baltic and Icelandic fish raw material control, respectively.

Processing had a significant effect on nitrogen content; the % nitrogen followed a consistent pattern through the processing stages regardless of ground and season. The conversion of raw material control to commercial fillet ingredient resulted in no change or an increase in nitrogen whilst the conversion of fillet ingredient to final block resulted in a decrease in nitrogen, as a result of protein being lost during pressing and freezing. Mince block production shows a different pattern. The conversion of control to mince ingredient resulted in a decrease in nitrogen content, whilst the conversion of mince ingredient to the final block resulted in an increase

in nitrogen content. This may be due to mincing damaging the cells, allowing more water than protein to be lost during pressing and freezing.

For imported commercial blocks the overall nitrogen content for fillet and mince blocks was found to be 2.74% and 2.67% respectively. Single frozen blocks had a lower nitrogen content than double frozen blocks at 2.64% and 2.76% respectively, although this could be explained by the source of the sample since there was a high proportion of single frozen fillet block samples from the Baltic Sea.

Although the nitrogen content of samples from imported blocks were lower than those for corresponding samples from blocks produced in UK, it was not feasible to make a valid statistical assessment of the significance of the differences.

Conclusion

Although the above investigations obtained reliable data from frozen blocks of cod fish ingredient, for both those produced in UK and those imported, present market information[7] indicates that currently only imported blocks are being used by industry. Accordingly, the Nitrogen Factors Sub-Committee recommends the following nitrogen factors* for cod fish ingredient (obtained from imported frozen blocks).

a) 2.75: if it is known that cod fillet fish ingredient has been used in a fish product

b) 2.65: if it is known that cod mince fish ingredient has been used in a fish product

c) 2.70: when it is not known whether fillet or mince fish ingredient has been used

If fish blocks from UK were to be used again in the future, it would be appropriate to derive appropriate nitrogen factors by combining the separate values for UK and imported blocks, as obtained in the present study, in the ratio of the relative use of the two sources by industry at that time.

Acknowledgements

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* As in the recommendations hitherto published, nitrogen factors have been rounded to the nearest 0.5.

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Appendix 1

Methods for the Proximate Analysis of Cod Samples

Parameter	British Standard BS4401 #	Tolerance Value *
Fat	Part 4: 1970 (1993)	0.5
Moisture	Part 3: 1970 (1997)	1.0
Ash	Part 1: 1980 (1993)	0.1
Nitrogen	Part 2: 1980 (1993)	0.1

* The maximum tolerated difference between the results of two determinations carried out in the same laboratory for a particular parameter, expressed as an absolute percentage.

\# British Standards Institution, Analytical Methods for Meat and Meat Products

Part 1 1970 (1993) Determination of ash
Part 2 1980 (1993) Determination of nitrogen
Part 3 1970 (1997) Determination of moisture
Part 4 1970 (1993) Determination of total fat

Appendix 2

Results of Proximate Analysis

Table A-1. Proximate Analysis Results - Barents Cod (spring season)

	Lab Code	% Fat				% Moisture				% Ash				% Nitrogen			
Control (air defrosted)	X	0.4	0.5	0.4	0.2	81.6	80.6	81.4	80.9	1.1	1.1	1.1	1.1*	2.79	2.93	2.79	3.06
	V	0.8	0.8	0.7	0.6	80.2	80.8	80.3	80.8	1.10	1.13	1.14	1.11	2.95	3.01	2.90	2.84
	L	0.6	0.7	0.9	0.5	80.6	79.2	78.6	80.9	1.06	1.06	1.08	1.07	2.89	2.89	3.04	2.87
	M	0.5	0.4	0.3	0.3	81.0	81.5	81.6	81.0	1.12	1.11	1.10	1.14	3.06	2.93	2.89	3.02
	T	0.7	0.6	0.7	0.7	81.9	81.2	80.6	80.3	1.14	1.14	1.15	1.14	2.76	2.83	2.84	2.96
Hand & machine filleted	X	0.3	0.4	0.4	0.5	81.6	80.4	80.9	81.2	1.1	1.2	1.0	1.0*	2.98	2.83	2.94	3.00
fillet ingredient	V	1.0	0.9	1.2	0.9	80.0	80.8	80.3	80.5	1.25	1.21	1.10	1.14	3.00	2.74	2.88	2.95
	L	0.9	1.0	0.9	0.5	79.6	78.3	78.7	80.0	1.16	1.16	0.95	1.10	2.98	3.01	3.05	3.06
	M	0.3	0.3	0.4	0.4	80.7	80.7	80.4	81.0	1.24	1.22	1.15	1.11	3.00	2.98	3.00	3.00
	T	0.7	0.6	0.6	0.7	80.1	81.2	81.7	81.1	1.12	1.14	1.08	1.12	2.97	2.88	2.78	2.80
Hand & machine filleted	X	0.6	0.5	0.6	0.5	80.9	81.2	80.6	80.8	1.0	1.1	1.0	1.0*	2.80	2.77	2.92	3.01
mince ingredient	V	0.9	1.0	0.8	0.9	79.6	80.6	81.2	80.7	1.03	1.07	1.09	1.03	2.99	2.85	2.84	2.74
	L	0.6	0.7	0.7	0.4	81.1	81.3	80.4	81.7	1.01	0.98	1.06	1.09	2.77	2.64	3.13	2.69
	M	0.5	0.6	0.5	0.4	80.7	81.5	82.3	81.7	1.05	1.11	1.09	1.10	2.90	2.82	2.78	2.93
	T	0.7	0.4	0.4	0.4	81.1	83.1	82.1	83.1	1.08	1.10	1.09	1.10	2.76	2.62	2.62	2.62
Commercial fillet	X	0.5	0.5	0.3	0.6	80.7	81.7	81.4	81.0	1.1	1.1	1.1	1.1*	2.92	2.72	3.01	3.03
block	V	0.8	0.6	0.7	0.8	81.3	81.5	81.8	79.7	1.09	1.10	1.11	1.12	2.74	2.95	2.70	3.21
	L	0.6	0.7	0.5	0.6	80.0	80.2	81.1	80.0	1.06	1.11	1.05	1.17	2.60	3.11	2.97	2.96
	M	0.3	0.3	0.3	0.3	81.1	83.2	81.4	81.0	1.11	1.07	1.07	1.12	2.92	2.59	2.91	2.92
	T	0.5	0.6	0.4	0.5	80.3	80.7	81.1	81.3	1.12	1.11	1.12	1.12	2.96	2.90	2.82	2.93
Commercial mince	X	0.5	0.5	0.7	0.7	80.7	81.2	81.3	81.4	1.0	1.0	1.1	1.1*	2.92	2.91	2.84	2.82
block	V	1.0	1.0	0.8	0.9	80.9	81.1	81.3	80.0	1.08	1.06	1.09	1.09	2.83	2.80	2.73	3.01
	L	0.9	0.9	0.6	0.6	80.5	80.3	80.7	79.9	1.05	1.08	1.08	1.11	2.75	2.91	2.70	2.80
	M	0.3	0.3	0.4	0.4	81.1	81.3	81.5	80.8	1.09	1.09	1.14	1.11	2.83	2.87	2.89	2.97
	T	0.7	0.5	0.7	0.5	81.1	80.6	81.9	82.0	1.09	1.08	1.08	1.16	2.76	2.81	2.74	2.64

* Missing data

Table A-2. Proximate Analysis Results - Barents Cod (autumn season)

	Lab Code	% Fat				% Moisture				% Ash				%Nitrogen			
Control (air defrosted)	X	0.2	0.2	0.1	0.1	82.3	82.8	82.1	82.5	1.2	1.1	1.2	1.2*	2.69	2.73	2.66	2.72
	V	0.7	0.8	0.5	0.8	82.6	80.4	83.4	82.1	1.15	1.16	1.13	1.12	2.75	3.09	2.71	2.82
	L	0.5	0.5	0.4	0.5	83.9	81.2	80.4	81.5	1.14	1.17	1.21	1.12	2.53	2.94	3.05	2.76
	M	0.2	0.2	0.3	0.2	82.3	82.5	81.6	82.6	1.16	1.15	1.16	1.18	2.75	2.70	2.86	2.67
	T	0.5	0.6	0.5	0.5	82.0	81.2	82.0	81.6	1.12	1.16	1.16	1.17	2.65	2.93	2.89	2.86
Hand & machine filleted fillet ingredient	X	0.3	0.2	0.3	0.3	82.0	81.4	82.2	82.4	1.1	1.1	1.1	1.1*	2.79	2.86	2.74	2.72
	V	0.6	0.6	0.7	0.7	82.4	82.5	82.5	82.8	1.09	1.04	1.07	1.09	2.75	2.67	2.70	2.79
	L	0.4	0.4	0.4	0.5	81.3	81.3	81.4	83.4	1.08	1.15	1.08	1.01	2.89	2.97	2.70	2.50
	M	0.2	0.2	0.4	0.3	82.1	81.6	82.4	83.0	1.09	1.10	1.09	1.12	2.79	2.85	2.75	2.63
	T	0.5	0.5	0.6	0.5	82.0	81.7	82.0	81.7	1.11	1.11	1.11	1.10	2.64	2.65	2.65	2.67
Hand & machine filleted mince ingredient	X	0.2	0.2	0.4	0.3	84.1	83.7	84.1	84.2	1.1	1.1	1.0	1.0*	**2.46**	**2.38**	**2.36**	**2.38**
	V	0.7	0.7	0.6	0.7	82.3	83.9	82.9	83.1	1.03	1.03	0.98	0.94	**2.76**	**2.51**	**2.31**	**2.64**
	L	0.4	0.4	0.4	0.4	84.1	84.2	83.5	84.6	1.04	1.05	0.89	1.05	**2.42**	**2.18**	**2.42**	**2.38**
	M	0.2	0.2	0.3	0.2	84.0	84.2	85.1	84.9	1.04	1.04	1.01	1.00	**2.36**	**2.35**	**2.25**	**2.33**
	T	0.5	0.6	0.5	0.5	83.1	83.4	84.0	83.9	1.04	1.04	0.98	0.99	**2.43**	**2.41**	**2.24**	**2.22**
Commercial fillet block	X	0.2	0.3	0.5	0.5	83.1	82.3	81.6	82.4	1.2	1.2	1.1	1.1*	2.56	2.67	2.73	2.63
	V	0.6	0.6	0.7	0.6	82.1	82.3	82.7	82.6	1.18	1.12	1.10	1.09	2.64	2.68	2.56	2.77
	L	0.7	0.5	0.5	0.7	83.3	82.7	82.4	82.1	1.21	0.71	1.10	1.04	2.64	2.70	2.81	2.54
	M	0.2	0.1	0.2	0.2	82.9	82.7	82.7	82.8	1.16	1.22	1.10	1.10	2.65	2.67	2.70	2.72
	T	0.8	0.8	0.8	0.7	82.4	82.0	82.8	83.7	1.21	1.18	1.11	1.08	2.41	2.74	2.52	2.34
Commercial mince block	X	0.3	0.2	0.3	0.5	83.0	82.4	83.5	83.0	1.1	1.1	1.1	1.1*	2.69	2.66	2.52	2.73
	V	0.6	0.6	0.6	0.6	82.6	83.2	83.4	82.3	1.13	1.15	1.15	1.26	2.60	2.45	2.52	2.68
	L	0.8	0.6	0.6	0.7	83.2	81.4	82.2	81.5	1.13	1.14	1.12	1.08	2.61	2.77	2.59	2.90
	M	0.1	0.2	0.2	0.2	83.1	82.9	82.5	83.2	1.14	1.13	1.10	1.10	2.60	2.59	2.66	2.59
	T	0.6	0.5	0.6	0.5	81.5	82.7	82.4	82.4	1.15	1.14	1.13	1.10	2.79	2.43	2.58	2.39

* Missing data

Data block in bold removed from statistical analysis

Table A-3. Proximate Analysis Results - Norwegian Cod (spring season)

	Lab Code	% Fat				% Moisture				% Ash				%Nitrogen			
Control (air defrosted)	X	0.4	0.7	0.6	0.5	81.5	80.5	80.8	80.3	1.2	1.2	1.2	1.2*	2.75	2.84	2.89	2.86
	V	0.7	0.6	0.9	0.8	80.9	79.7	81.2	79.5	1.27	1.25	1.19	1.30	2.79	2.92	2.95	2.86
	L	0.7	0.6	0.6	0.5	79.9	79.8	80.8	81.1	1.21	1.23	1.25	1.29	2.99	3.10	2.86	2.74
	M	0.3	0.4	0.4	0.3	81.2	80.3	80.0	80.9	1.27	1.31	1.30	1.28	2.84	3.01	3.04	3.05
	T	0.7	0.6	0.8	0.8	80.9	80.8	80.4	79.8	1.34	1.25	1.27	1.34	3.00	2.80	2.87	3.02
Hand filleted fillet	X	0.6	0.4	0.2	0.3	81.2	81.5	80.1	80.8	1.1	1.1	1.1	1.1*	2.82	2.90	3.05	2.91
ingredient	V	0.7	0.9	0.7	0.8	80.8	80.6	80.9	80.3	1.14	1.11	1.13	1.14	3.08	2.95	2.77	3.12
	L	0.6	0.5	0.5	0.4	80.7	79.1	79.4	80.1	1.12	1.07	1.08	1.07	2.82	3.00	3.09	3.02
	M	0.6	0.4	0.5	0.4	80.5	80.5	80.6	80.7	1.11	1.12	1.20	1.13	3.11	3.07	2.98	3.06
	T	0.7	0.6	0.6	0.7	80.1	81.2	81.7	81.1	1.12	1.14	1.08	1.12	2.97	2.88	2.78	2.80
Hand filleted mince	X	0.6	0.6	0.4	0.6	81.7	81.6	81.8	81.0	1.0	1.1	1.0	1.0*	2.81	2.68	2.90	2.87
ingredient	V	1.0	0.9	1.1	1.0	81.3	80.3	80.6	81.9	1.05	1.04	1.07	1.07	2.65	2.96	2.93	2.77
	L	0.5	0.5	0.4	0.7	81.8	81.6	81.6	81.9	1.06	1.01	1.06	1.09	2.79	2.91	2.88	2.63
	M	0.4	0.4	0.3	0.2	81.7	81.9	81.7	82.4	1.12	1.13	1.12	1.11	2.79	2.75	2.81	2.72
	T	0.7	0.7	0.8	0.7	81.8	81.7	81.0	81.6	1.11	1.11	1.10	1.12	2.72	2.79	2.76	2.69
Commercial fillet	X	0.1	0.6	0.4	0.4	81.2	83.9	82.6	81.4	1.1	1.0	1.0	1.0*	2.90	2.45	2.64	2.74
block	V	0.9	0.7	0.8	0.8	80.8	81.9	81.8	81.2	1.10	1.12	1.10	1.12	2.87	2.86	2.75	2.79
	L	0.7	0.6	0.6	0.8	81.4	80.9	81.4	80.6	1.07	1.10	1.10	1.07	2.86	2.84	2.58	3.00
	M	0.4	0.3	0.3	0.4	81.3	81.4	80.7	80.6	1.10	1.10	1.09	1.10	2.94	2.91	2.97	3.04
	T	0.7	0.6	0.6	0.7	80.6	80.6	81.2	80.4	1.08	1.11	1.09	1.10	2.82	2.78	2.62	3.03
Commercial mince	X	0.7	0.5	0.5	0.6	80.9	80.8	81.3	81.2	1.0	1.0	1.0	1.1*	2.88	3.03	2.89	2.86
block	V	0.9	0.9	0.9	0.8	81.7	80.9	80.7	81.4	1.09	1.07	1.08	1.07	2.85	2.85	2.90	2.75
	L	0.9	1.0	0.9	1.0	80.8	79.4	79.6	80.4	1.10	1.04	1.02	1.02	2.87	2.97	2.98	2.92
	M	0.4	0.4	0.3	0.3	80.8	80.8	81.1	80.5	1.09	1.09	1.10	1.07	2.90	2.90	2.88	3.00
	T	0.7	0.9	0.9	0.8	81.4	80.5	79.7	81.4	1.06	1.10	1.08	1.04	2.71	3.09	3.02	2.85

* Missing data

Table A-4. Proximate Analysis Results - Norwegian Cod (autumn season)

	Lab Code	% Fat				% Moisture				% Ash				%Nitrogen			
Control (air defrosted)	X	0.1	0.4	0.4	0.2	81.3	81.5	81.2	80.9	1.2	1.2	1.1	1.2 *	2.88	2.90	2.73	2.84
	V	0.8	0.6	0.5	0.7	80.7	83.4	83.3	81.3	1.17	1.16	1.01	1.18	2.98	2.67	2.70	2.91
	L	0.6	0.6	0.6	0.7	80.3	83.4	80.0	81.4	1.12	1.06	1.04	1.05	2.99	2.63	2.83	2.74
	M	0.2	0.2	0.1	0.2	81.5	80.7	81.7	82.5	1.17	1.13	1.13	1.07	2.90	2.97	2.84	2.72
	T	0.6	0.6	0.6	0.5	81.0	81.1	80.6	81.1	1.16	1.09	1.14	1.20	2.80	2.66	2.93	2.72
Hand filleted fillet	X	0.3	0.2	0.3	0.2	81.4	81.3	81.8	81.4	1.2	1.2	1.2	1.2*	2.91	2.96	2.77	2.80
ingredient	V	0.7	0.7	0.8	0.7	81.9	82.2	81.7	81.7	1.16	1.08	1.10	1.10	2.87	2.79	2.89	2.76
	L	0.5	0.4	0.4	0.6	78.9	80.3	81.4	80.0	1.13	1.03	1.05	1.13	3.16	3.14	2.69	2.98
	M	0.2	0.3	0.3	0.4	82.2	81.0	81.9	80.4	1.13	1.13	1.16	1.17	2.78	2.92	2.86	3.09
	T	0.7	0.6	0.6	0.5	80.3	80.7	80.4	81.4	1.15	1.14	1.15	1.13	2.83	2.94	2.83	2.68
Hand filleted mince	X	0.2	0.4	0.4	0.6	81.7	81.5	81.2	81.7	1.2	1.2	1.1	1.1*	2.81	2.76	2.85	2.76
ingredient	V	0.8	0.4	0.8	0.9	82.4	82.4	82.6	82.5	1.12	1.13	1.07	1.11	2.74	2.60	2.80	2.81
	L	0.7	0.4	0.6	0.8	80.9	82.1	81.5	80.8	1.14	0.89	1.12	1.07	2.64	2.75	2.90	2.93
	M	0.2	0.2	0.2	0.3	82.7	82.6	82.5	82.4	1.14	1.16	1.17	1.15	2.67	2.67	2.70	2.73
	T	0.6	0.7	0.6	0.7	81.4	81.0	81.5	80.9	1.14	1.16	1.15	1.14	2.79	2.82	2.57	2.93
Commercial fillet	X	0.3	0.4	0.4	0.1	83.2	82.0	81.7	81.9	1.1	1.1	1.1	1.1*	2.73	2.74	2.94	2.67
block	V	0.8	0.8	0.7	0.8	81.3	82.1	81.3	81.7	1.13	1.11	1.10	1.13	2.81	2.81	2.70	2.69
	L	0.6	0.5	0.5	0.6	82.0	81.0	80.2	81.1	1.01	1.13	1.04	1.08	2.56	2.65	2.99	2.89
	M	0.2	0.2	0.2	0.2	82.1	82.1	81.5	82.5	1.09	1.10	1.14	1.13	2.79	2.79	2.89	2.80
	T	0.5	0.9	0.5	0.5	82.2	80.9	80.5	80.9	1.11	1.13	1.13	1.13	2.74	2.84	3.02	2.71
Commercial mince	X	0.6	0.1	0.3	0.4	81.8	82.4	81.8	82.6	1.1	1.1	1.0	1.1*	2.72	2.82	2.80	2.79
block	V	0.7	1.0	0.5	0.7	82.3	81.8	82.2	81.9	1.09	1.11	1.14	1.14	2.71	2.72	2.63	2.74
	L	0.6	0.5	0.7	0.7	81.0	80.9	79.3	80.8	1.09	0.97	1.12	0.95	2.65	2.71	3.35	3.05
	M	0.2	0.2	0.2	0.2	82.0	81.9	82.1	82.5	1.11	1.13	1.12	1.14	2.82	2.79	2.79	2.75
	T	0.6	0.6	0.6	0.6	80.6	80.6	81.7	80.8	1.14	1.14	1.14	1.13	2.68	2.66	2.67	2.67

* Missing data

Table A-5. Proximate Analysis Results - Imported Blocks

			% Fat					% Moisture					% Ash					% Nitrogen				
			Lab Code																			
Sample	Treatment	Type	X	V	L	M	T	X	V	L	M	T	X	V	L	M	T	X	V	L	M	T
Denmark (Barents Sea)	Double Frozen	Fillet block	0.4	0.6	0.67	0.2	0.5	81.9	82.6	81.2	82.4	82.2	1.3	1.32	1.22	1.35	1.36	2.74	2.61	2.92	2.66	2.81
Poland (Baltic Sea)*	Single Frozen	Fillet block	0.3	0.8	0.64	0.2	0.5	83.2	83	81.5	82.6	82.6	1.3	1.24	1.05	1.25	1.26	2.19	2.69	2.64	2.63	2.49
Poland (Baltic Sea)	Single Frozen	Fillet block	0.2	0.5	0.65	0.2	0.4	83.3	82.5	82.5	83.2	82.1	1.1	1.1	1.04	1.14	1.10	2.45	2.7	2.53	2.61	2.60
Poland (Barents Sea)	Double Frozen	Mince block	0.3	0.7	0.74	0.2	0.7	83.2	81.6	82.2	82.9	82.5	1.1	1.1	1.03	1.08	1.08	2.62	2.72	2.73	2.56	2.77
Poland (Baltic Sea)	Single Frozen	Fillet block	0.4	0.5	0.73	0.2	0.4	84.0	82.6	85.3	83.4	82.9	1.2	1.16	1.09	1.18	1.18	2.36	2.55	2.30	2.57	2.30
Iceland (Icelandic Waters)	Single Frozen	Fillet block	0.7	0.6	0.60	0.2	0.4	81.9	81.1	81.4	82.7	81.7	1.0	1.01	0.98	1.00	1.00	2.57	2.89	2.73	2.77	2.67
Iceland (Icelandic Waters)	Single Frozen	Mince block	0.6	0.5	0.31	0.2	0.5	83.9	83.4	83.0	83.4	82.3	1.0	1.06	1.00	1.01	1.00	2.46	2.71	2.56	2.48	2.37
Iceland (Icelandic Waters) * +	Single Frozen	Mince block	0.0	0.6	0.52	0.2	0.4	87.2	85.1	85.1	86.5	86.0	1.2	1.14	1.09	1.19	1.14	2.24	2.03	2.23	1.93	2.05
Iceland (Icelandic Waters)	Single Frozen	Mince block	0.0	0.6	0.62	0.2	0.6	81.9	80.6	81.7	81.7	80.2	1.0	0.89	0.89	0.94	0.90	2.68	2.96	2.54	2.75	2.95
Norway (Norwegian)	Single Frozen	Fillet block	0.3	0.7	0.54	0.3	0.6	81.6	79.5	80.1	79.7	79.6	1.1	1.1	0.96	1.01	1.08	2.89	3.09	3.21	3.17	3.05
Norway (Norwegian) *	Single Frozen	Mince block	0.4	0.7	0.77	0.2	0.6	81.4	81.8	79.5	81.5	79.5	1.1	1.07	1.02	1.00	1.04	2.41	2.98	3.03	2.75	2.89
Norway (Norwegian) *	Single Frozen	Mince block	0.4	0.7	0.74	0.2	0.6	82.4	82.9	83.9	83.1	82.1	1.4	1.26	1.27	1.36	1.31	2.39	2.38	2.37	2.45	2.41
Norway (Norwegian)	Single Frozen	Fillet block	0.5	0.9	0.76	0.2	0.6	83.0	82.2	81.0	82.3	81.2	1.1	1.12	0.96	1.14	1.08	2.61	2.74	2.74	2.69	2.53
China (Barents Sea)	Double Frozen	Fillet block	0.2	0.9	0.76	0.2	0.7	82.1	82.1	81.1	81.3	80.9	0.9	0.94	0.88	0.98	0.96	2.64	2.81	2.96	2.98	2.55
China (Bering Sea)	Double Frozen	Fillet block	0.3	0.8	0.65	0.3	0.7	80.8	80.3	79.5	81.2	79.0	0.8	0.92	0.80	0.88	0.89	2.73	3.17	2.81	2.99	3.01
Russia (Barents Sea)	Double Frozen	Fillet block	0.3	0.7	0.58	0.2	0.5	81.8	82.2	82.2	82.3	81.8	1.0	0.97	0.90	0.97	1.02	2.65	2.88	2.91	2.82	2.77
Lithuania (Baltic)	Double Frozen	Fillet block	0.0	0.5	0.61	0.3	0.5	81.6	82.4	80.6	82.3	81.8	1.0	0.99	1.00	1.01	1.07	2.75	2.61	2.80	2.69	2.87

* Samples suspected of having abnormal moisture and ash values
\+ Not included in statistical analysis