



Establishing a shelf life for fresh and refreshed mackerel

*(Scomber scombrus) products, processed and
stored under different commercial conditions*

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Acronyms List

APC	Aerobic Plate Count
BIM	Bord Iascaigh Mhara
cfu	Colony-Forming Unit
FBOs	Food Business Operators
FSAI	Food Safety Authority of Ireland
FSMS	Food Safety Management System
H&G	Headed and Gutted
HORECA	Hotel, Restaurant, Café
mgN	Milligrams of Nitrogen
RSW	Refrigerated Sea Water
SFPA	Sea Fisheries Protection Agency
TVB-N	Total Volatile Base Nitrogen
TVC	Total Viable Count

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Background

In 2021 pelagic species represented 68% of the volume of all fish landings in Ireland and 38% of the value, Mackerel is the highest value wild caught export, worth €73 million in 2021. Typically, over 85% of mackerel is exported annually as a quality frozen commodity to several African, Asian, and European markets. In more recent years, a number of Irish pelagic processors have also processed and sold fresh mackerel domestically and occasionally exported fresh product in whole, headed and gutted (H&G), and filleted formats. Fresh mackerel tends to command a premium over frozen, and customers are increasingly seeking consistent year-round supply, particularly for fillets. To satisfy these growing demands, some processors are importing fresh mackerel. In addition, nationally, customers are increasingly requesting frozen product from pelagic processors for subsequent tempering and processing for the retail market. It has been suggested that up to forty percent of mackerel fillets sold in retail are refreshed (frozen-defrosted).

Council Directive 2000/13/EC defines the date of minimum durability of a foodstuff as being the date until which a foodstuff retains its specific properties when properly stored. Regulation 852/2004/EC states that processors as Food Business Operators (FBOs) have primary responsibility for ensuring the food safety of their products. As market opportunities develop for fresh and refreshed product, processors are increasingly being asked by their customers to provide associated accurate shelf-life data. In addition, the Sea Fisheries Protection Agency (SFPA) has been requesting that regular shelf-life testing be carried out by FBOs on samples of fresh and refreshed products to comply with their Food Safety Management Systems (FSMS). The SFPA has also recommended that definitive shelf-life studies be carried out to further meet food safety requirements. If accurate shelf-life results are produced, there is also the potential for a reduction in the frequency of costly food safety testing of samples, which would be of benefit to FBOs.

In 2020 a number of Irish processors approached BIM seeking support to set up trials to determine shelf-lives for a variety of fresh and refreshed mackerel product formats. This study describes the relevant trials conducted.

Aims and Objectives

To determine shelf lives for fresh and refreshed mackerel formats stored under normal commercial chilled conditions.

Objectives

To achieve this the following objectives were set out:

- To source fresh mackerel from both the summer inshore hook and line fishery and the winter RSW fishery;
- To ensure fish samples sourced are fully traceable with known time temperature history tracked from the vessel through to processing and storage;
- To process mackerel into various product formats and store them under chilled commercial conditions and to conduct shelf-life testing for a minimum of nine days;
- To replicate the chilled shelf-life studies on the same batches of refreshed mackerel (both summer and winter) and to assess the impact of freezing and tempering on subsequent shelf-life;
- To use sensory assessment protocols and accredited laboratories to generate the necessary quality and food safety data;
- To analyse the data and produce a technical report for FBOs and the SFPA.

Methodology

Sourcing mackerel samples

To ensure shelf-life results are suitably representative, mackerel samples were sourced from the summer and winter mackerel fisheries. A brief description of the fisheries and sourcing details are provided.

Summer mackerel fishery

The summer mackerel fishery takes place between May and August each year with up to 60 inshore vessels generally fishing off the north Mayo coast using hook and line systems. The small-volume day vessels typically store mackerel under ice in insulated bins. The fish are generally of good extrinsic quality; however mackerel are typically lower fat (8-12%) and occasionally have feed in the gut which can impair intrinsic quality.

A 500kg sample of mackerel from the MFV Treasa Mairead (WT404) was collected on 16th May 2021 and transported by road in slush ice from North Mayo to Island Seafoods Ltd, a pelagic processing plant located in Killybegs. On arrival at the plant the fish were placed in a 1000L bin of iced seawater. A log tag (TRIX-8 temperature logger) was placed in the sample fish bin immediately after the fish were caught and temperature was logged for the subsequent carriage to Killybegs (see figure1).



Figure 1: Log Tags (TRIX-8 temperature logger) used during trials

Winter mackerel fishery

Over thirty vessels, comprising of larger Refrigerated Sea Water (RSW) vessels and polyvalent tank boats, target mackerel between October and January each year. As mackerel are highly migratory, these vessels pursue and catch the fish from north of Scotland through to off the southwest coast of Ireland, between October and January each year. The fish are typically high fat (>20%) and have no notable feed in the gut, and therefore are of good intrinsic quality. In addition, despite being a volume-based fishery, the vessels are highly specialised and can efficiently catch >500MT in a haul and gently pump directly from the net in the water into refrigerated sea water tanks, for subsequent chilled storage until discharge by pumping when the vessel lands to processors. A 910kg sample of mackerel was sourced from the MFV Cataleya when it landed in Killybegs on the 29th of October 2021. Fish were discharged into a commercial 25MT tanker at Killybegs pier and transported by road in RSW to a local pelagic processing plant (Ward Fish Ltd) and subsequently transported to Island Seafoods Ltd to set up and conduct the shelf-life trials. A log tag (TRIX-8 temperature logger) temperature logger was placed in the sample fish bin immediately after the fish were caught and temperature was logged for the subsequent carriage to Killybegs (see figure 2). The temperature of fish on arrival at the plant was further checked by probing a sample of 5 fish.



Figure 2: Vessel being discharged into tanker at pier

Set up of shelf-life trials

Sample processing and storage

All trials were conducted at Island Seafoods Ltd. The same protocol was followed for both the summer and winter caught trials. Prior to the trials, half of both winter and summer caught mackerel batches were placed in 20kg waxed

cartons and blast frozen for circa twenty hours to a temperature of -28°C. These frozen samples were held in frozen storage for subsequent trials (described below).



Figure 3: Fish held in a commercial chill during shelf-life trials at Island Seafoods

For the fresh shelf-life trials, both summer and winter mackerel samples were processed into the following formats and stored under normal commercial conditions (-1° C to 0° C):

- Whole mackerel (100kg) in 500kg container containing slush ice (300 litres 3% salt-in-water solution & 15kg ice);
- Whole mackerel (15kg) in ice (5kg) in 20kg poly boxes;
- H&G mackerel (100kg) in 500kg fish bin containing slush ice (300 litres 3% salt-in-water solution & 15kg ice);
- Mackerel fillets (15kg) in ice (5kg) in 20kg polystyrene boxes.



Figure 4: Whole mackerel sample assessed during shelf-life trial at Island Seafoods



Figure 5: H&G mackerel sample assessed during shelf-life trial at Island Seafoods



Figure 6: Mackerel fillet samples assessed during shelf-life trial at Island Seafoods

For the refreshed shelf life trials, the 20kg mackerel batches were thawed in a temperature controlled immersion unit (Optimar DF12-LB-1000/2000) and the shelf-life trials were replicated for both the winter and summer caught fish.

When the fish were sufficiently thawed, they were processed into the relevant formats and storage conditions for the trials. Table 1 outlines the dates when the fresh and refreshed trials were commenced

	Start Date	End Date
Fresh Summer Mackerel	17/05/21	28/05/21
Refreshed Summer Mackerel	29/06/21	29/06/21
Fresh Winter Mackerel	29/10/21	08/11/21
Refreshed Winter Mackerel	07/12/21	15/12/21

Table 1: Dates of fresh and refreshed trials carried out in summer and winter

Assessment of samples

During the shelf-life trials regular sampling was conducted to record fish core temperatures, assess sensory quality, and collect samples for food safety testing. A local accredited laboratory (Aqualab) was used to carry out the relevant food safety tests.

Recording core temperatures

A temperature probe (ED Thermo Jack) was used to record individual fish temperatures during the trials. During each sampling occasion temperatures were recorded from a total of 5 fish by inserting the probe into the flesh of the fish.



Figure 7: Recording temperature of fish using a temperature probe (ED Thermo Jack)

Sensory assessment

Sensory assessments were conducted during each sampling occasion. BIM's species-specific pelagic quality scoring system for mackerel was used (Appendix III) and the Torry freshness scoring system (fresh formats only) was also used to assess samples (Appendix IV). The BIM quality index scoring system was adapted based on the formats being assessed and whether the product was fresh or refreshed. For the headed & gutted and fillet presentations, it was not possible to score the eyes, gill colour, or gill odour and therefore these attributes were removed from the assessment and the total scores were reduced by 15. In the frozen presentation, the maximum score was reduced by 5 as the eye attribute was eliminated from the assessment. The Torry Freshness Scoring System for raw mackerel was used in conjunction with the BIM scoring system for the fresh formats. The Torry scoring system was deemed unsuitable for refreshed formats as it was developed for fresh fish assessments only. In addition, the Torry scoring system could only be used on whole fish as it could not be readily adapted for other formats.



Figure 8: Sensory assessment in progress

Chemical and Microbiological Testing

Samples were collected during each sampling occasion and the following chemical and microbiological tests were conducted by the accredited laboratory:

- Salmonella spp.
- Histamine
- Total Volatile Base Nitrogen
- Fat Content
- TVC @ 30°C
- Staphylococcus aureus
- Enterobacteriaceae
- E. coli
- Pseudomonas spp.
- Listeria monocytogenes



Figure 9: Line caught fish after arriving in Killybegs stored in iced sea water

Results

Sensory results

Summer Fresh

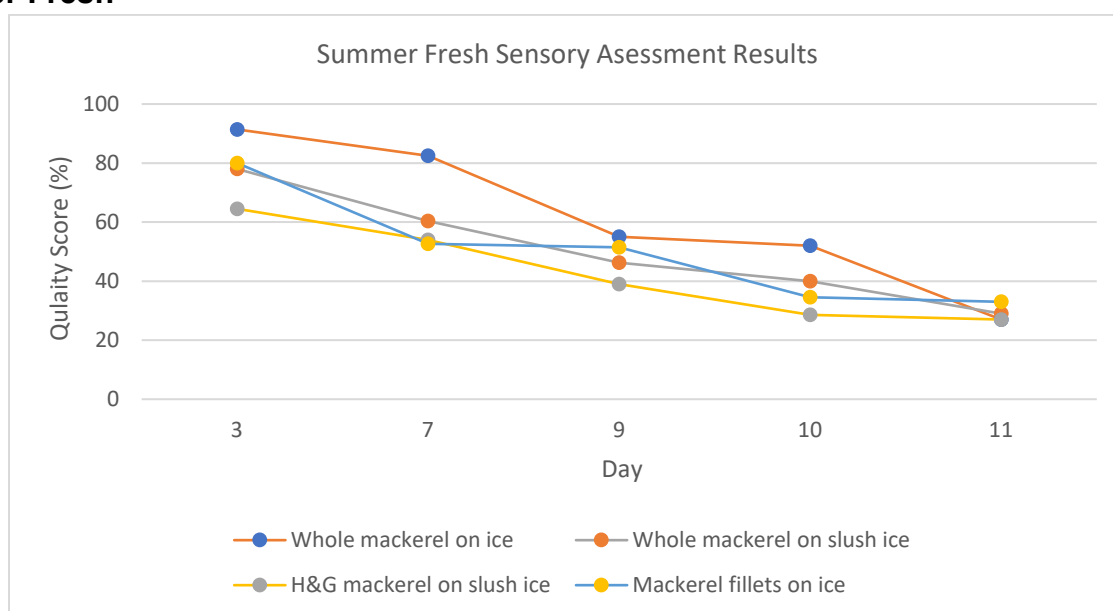


Figure 10: Sensory assessment results for summer fresh whole mackerel stored on ice, fresh whole mackerel stored on slush ice, fresh H&G mackerel stored on slush ice, and fresh mackerel fillets stored on ice

Sensory assessment of summer fresh mackerel commenced on day 3 of the trials and revealed that all formats and

storage conditions scored high or very high, with whole mackerel on ice scoring highest (very high: 91.4%), whereas H&G on slush ice scored lowest (medium: 64.5%). All formats deteriorated over time but remained acceptable (medium quality) up to day 9, and whole mackerel on ice ranked highest (55%) and H&G ranked lowest (39%). By day 11 all formats and storage conditions were of low quality (<33%) with minimal differences in the attributed scores.

Summer Refreshed

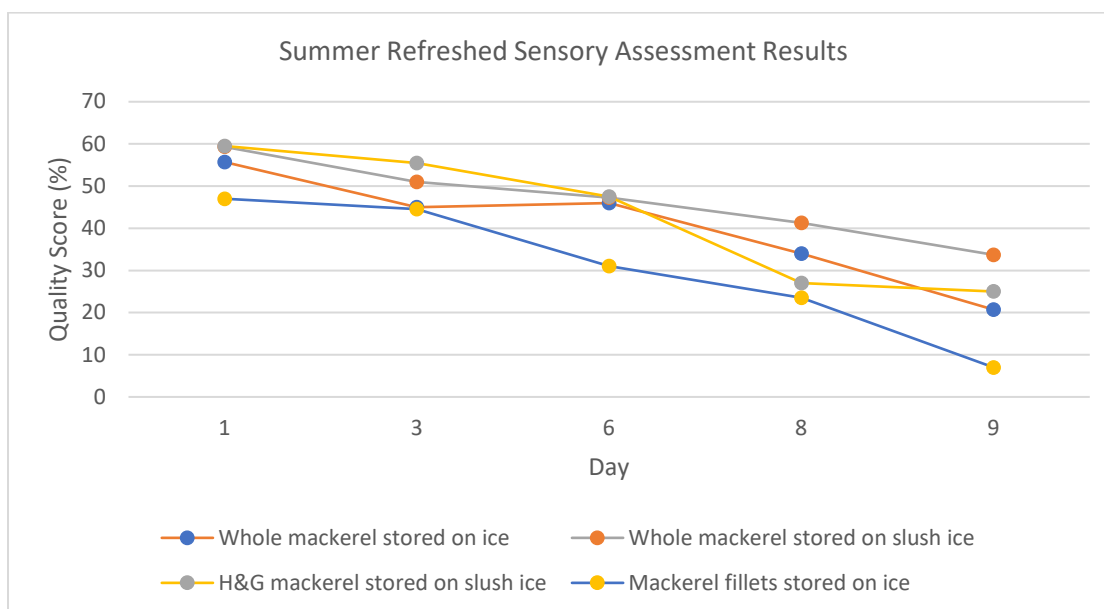


Figure 11: Sensory assessment results for summer refreshed whole mackerel stored on ice, refreshed whole mackerel stored on slush ice, refreshed H&G mackerel stored on slush ice, and refreshed mackerel fillets stored on ice

All refreshed samples were of a medium grade on day 1 of the sensory assessments. The ranking of different formats and storage conditions differed from the Summer Fresh, with H&G on slush ice and whole mackerel on slush ice both scoring highest (59.5%). By day 6 all formats and storage conditions remained medium quality, except for mackerel fillets on ice, were assessed as low quality (31%). By day 8 all formats and storage conditions were of low quality, apart from whole mackerel on slush ice, which attained a medium score (33.7%).

Feed was evident in the gut of some of the summer caught mackerel samples and this had contributed to quality loss over time. During feeding periods, the digestive tract contains elevated bacterial levels that produce additional digestive enzymes capable of causing accelerated post-mortem autolysis.

Winter Fresh

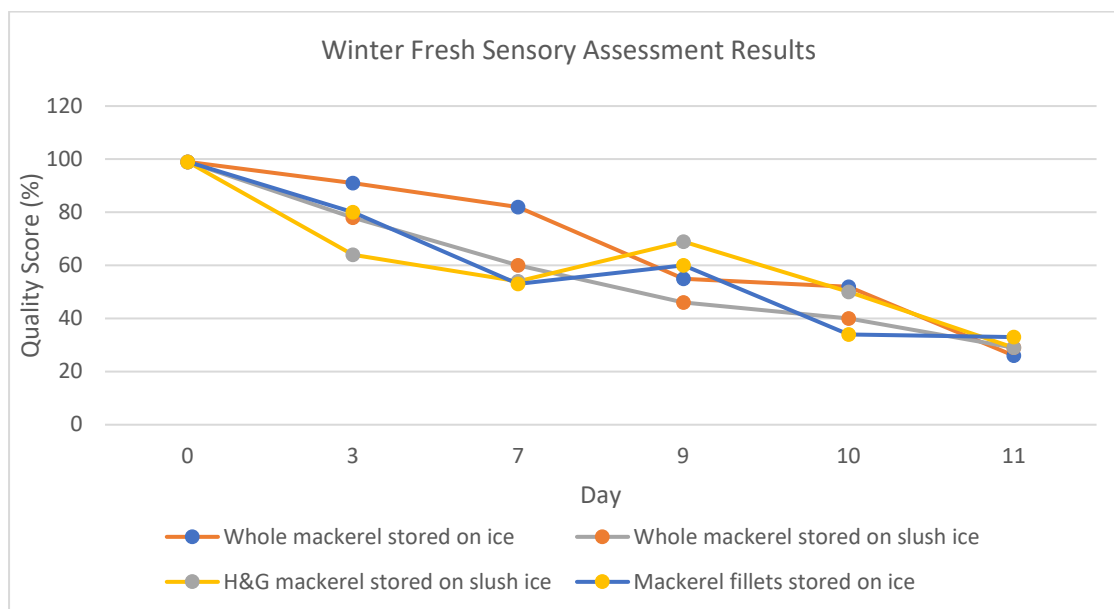


Figure 12: Sensory assessment results for winter fresh whole mackerel stored on ice, fresh whole mackerel stored on slush ice, fresh H&G mackerel stored on slush ice, and fresh mackerel fillets stored on ice

Sensory assessment was carried out on day 0 and all formats in all storage conditions ranked very high (99%). By day 7, whole on ice maintained relatively high quality (82%), whereas the remaining formats and storage conditions dropped to medium quality (<60%). Nonetheless, all formats and storage conditions maintained medium quality until day 9, with H&G on slush ice attaining the highest score (69%). Whole mackerel on ice and H&G on slush ice maintained a medium quality score (50%) at day 10.

Winter Refreshed

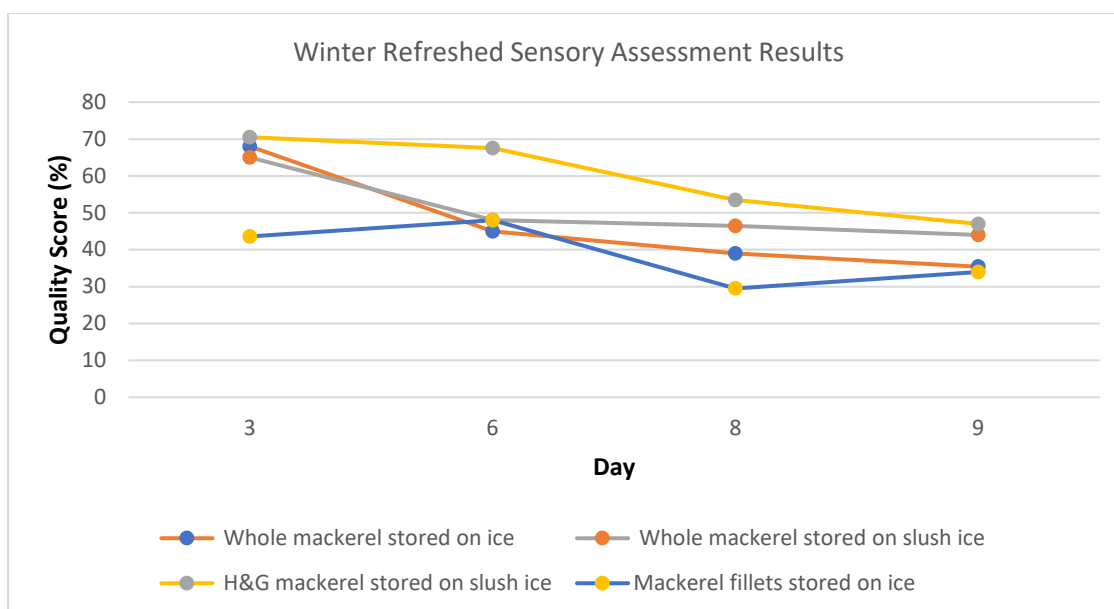


Figure 13: Sensory assessment results for winter refreshed whole mackerel stored on ice, refreshed whole mackerel stored on slush ice, refreshed H&G mackerel stored on slush ice, and refreshed mackerel fillets stored

on ice

Sensory assessments were carried out from day 3 and revealed that all formats and storage conditions scored high (>65%), apart from fillets on ice, which attained a medium score (43.6%). By day 8 all formats and storage conditions attained a medium score (>39%), apart from fillets on ice, which attained a low score (29.5%). H&G on slush ice and whole mackerel on slush ice maintained a medium score (>44%) at day 9.

Chemical and Microbiological Results

Chemical and microbiological tests were conducted to coincide with the sensory assessments. Where possible threshold levels for each test conducted have been indicated in the various charts and tables and the associated sources are provided in Appendix (VI). It is worth noting that no permissible levels for TVB-N are set for pelagic species, however the industry 'norm' is 35mgN/100g.

Summer Fresh

Analysis of fat content verified that mackerel is of low fat during the summer months, ranging between 1.62% for fillets on ice to 3.8% for whole on ice and whole on slush ice samples.

In general, for each of the tests, there were no acceptable threshold levels breached up until day 9. At day 9 a TVB-N level of 33.22mgN/100g was evident for fillets on ice and this level increased further to 40.11mgN/100g by day 11. Likewise, samples of fillets on ice had a notable histamine level of 104.84 mg/100g on day 11, which and this elevated to 436.64g/100g by day 11. Elevated pseudomonas levels were detected by day 11 on samples of whole on ice (1.3×10^7 mg/100g) and whole on slush ice (5.5×10^6 mg/100g).

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice
0	3.8	3.8	3.19	1.62

Table 2: Fat content (%) for fresh summer whole mackerel stored on ice & slush ice, headed & gutted (H&G) mackerel and mackerel fillets sampled at beginning of shelf-life trials

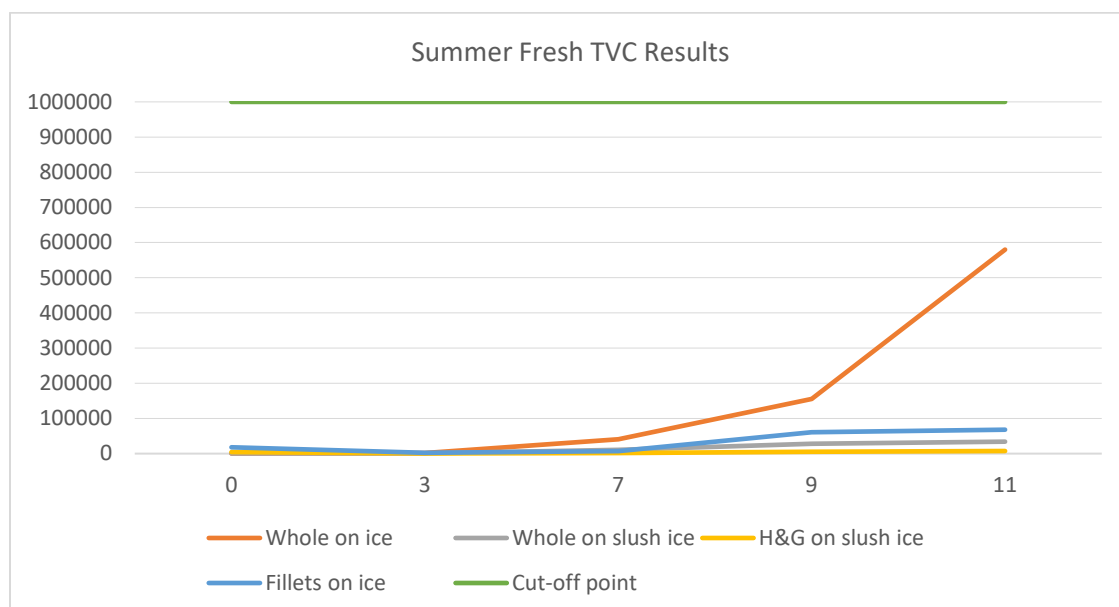


Figure 14: Total Viable Count results (TVCs cfu/g) for fresh summer whole mackerel stored on ice & slush ice, headed & gutted (H&G) mackerel and mackerel fillets sampled during shelf-life trials

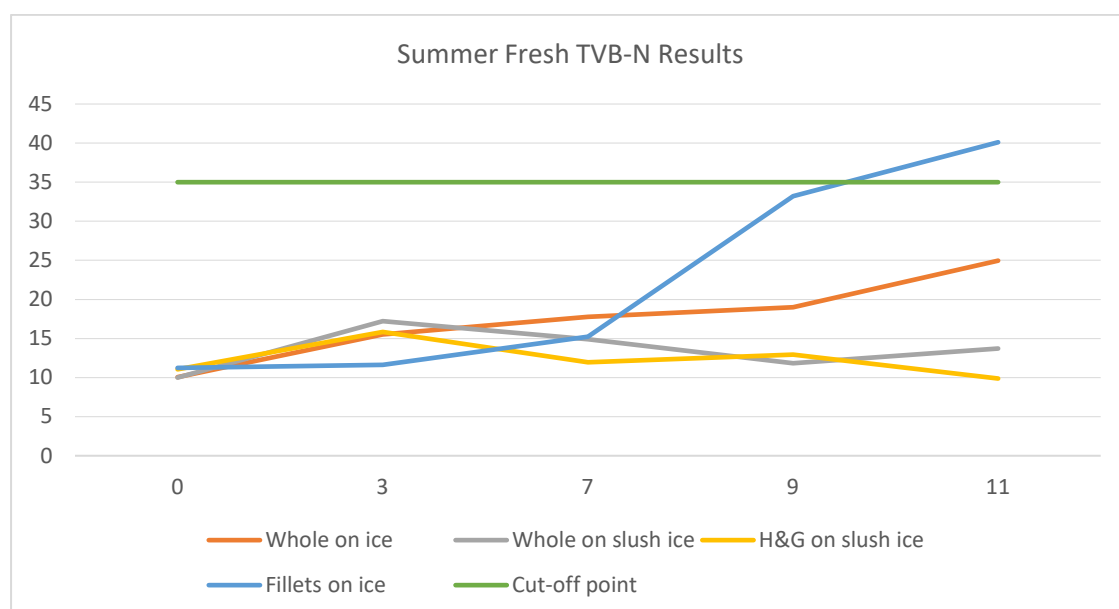


Figure 15: Total Volatile Base Nitrogen results (mgN/100g) for fresh summer whole mackerel stored on ice & slush ice, headed & gutted (H&G) mackerel and mackerel fillets sampled during shelf-life trials. Note: No permissible levels for TVB-N are set for pelagic species (Appendix VI), however a guideline figure of 35 mgN/100g is typically used by industry

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	<2.5	<2.5	<2.5	<2.5	200
3	<2.5	<2.5	<2.5	<2.5	200
7	<2.5	<2.5	<2.5	<2.5	200
9	7.03	2.65	<2.5	104.84	200
11	6.69	27	<2.5	436.64	200

Table 3: Histamine results (mg/100g) for fresh summer whole mackerel stored on ice & slush ice, headed & gutted (H&G) mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	<10	<10	<10	<10	N/A
3	<10	<10	<10	<10	N/A
7	<10	<10	<10	<10	N/A
9	<10	30	<10	<10	N/A
11	<10	230	<10	<10	N/A

Table 4: Enterobacteriaceae results (cfu/g) for fresh summer whole mackerel stored on ice & slush ice, headed & gutted (H&G) mackerel and mackerel fillets sampled during shelf-life trials.

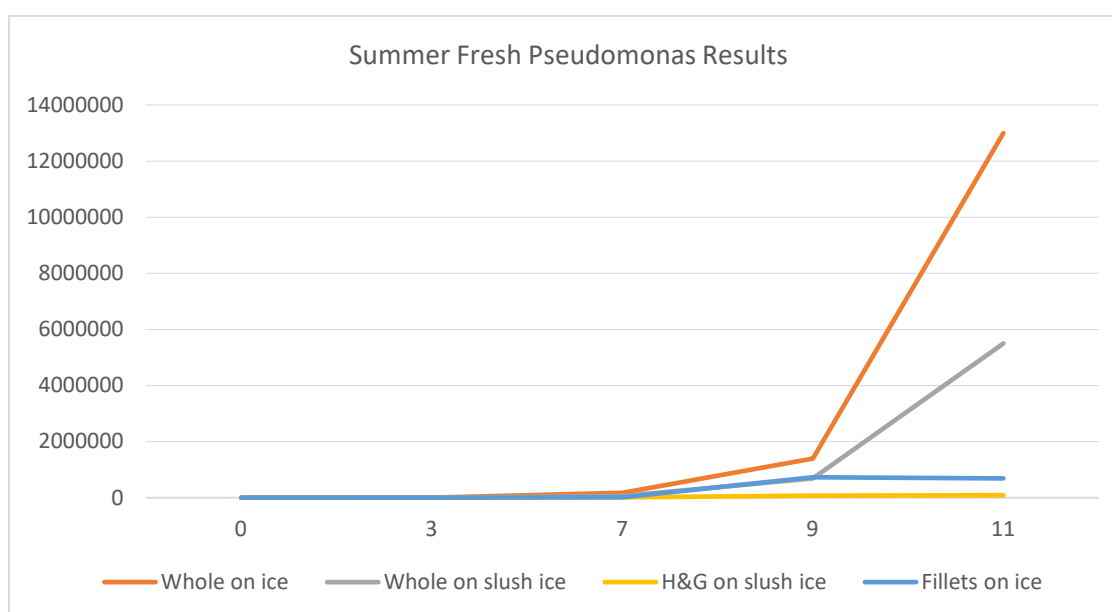


Figure 16: Pseudomonas results (cfu/g) for fresh summer whole mackerel stored on ice & slush ice, headed & gutted (H&G) mackerel and mackerel fillets sampled during shelf-life trials. Note: While there is no legislative limit imposed for Pseudomonas spp. a level of 10^7 cfu/g is considered the maximum acceptable level (Appendix VI)

Summer Refreshed

Fat contents in general were higher on the refreshed samples, ranging from 4.33% to 6.51% for H&G on slush ice and whole on slush ice respectively.

Although elevated histamine levels were not detected throughout the trial, elevated Enterobacteriaceae levels were detected on day 6 (290cfu/g) for whole fish on slush ice.

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice
0	6.01	6.51	4.33	5.23

Table 5: Fat content (%) for refreshed summer whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled at beginning (day 0) of shelf-life trials

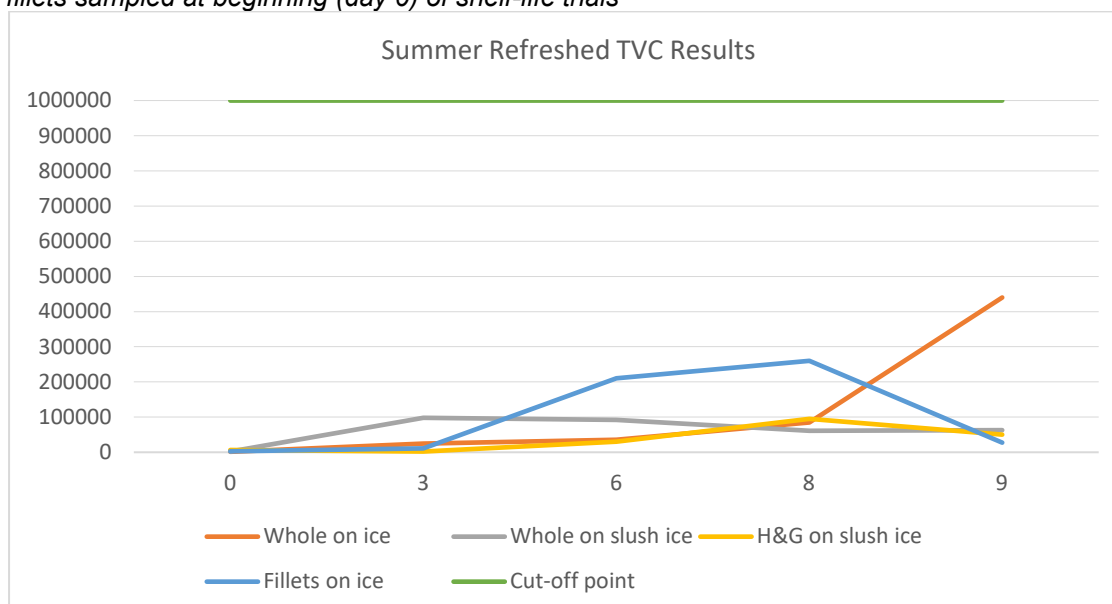


Figure 17: Total Viable Count results (TVCs cfu/g) for refreshed summer whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

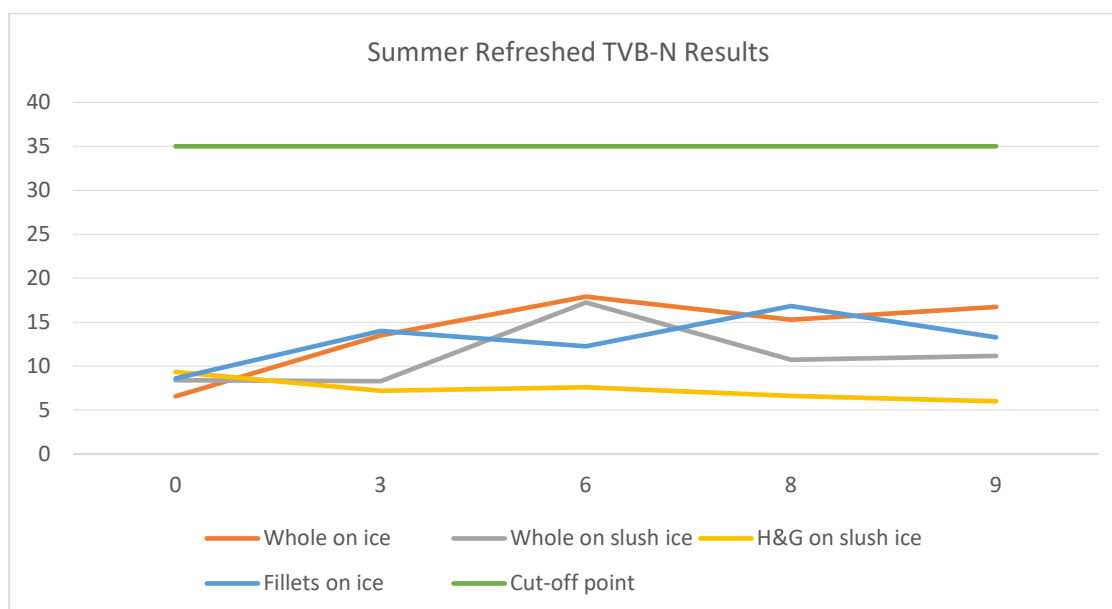


Figure 18: Total Volatile Base Nitrogen results (mgN/100g) for refreshed summer whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials. Note: No permissible levels for TVB-N are set for pelagic species (Appendix VI), however a guideline figure of 35 mgN/100g is typically used by industry

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	<2.5	<2.5	<2.5	<2.5	200
3	<2.5	<2.5	<2.5	<2.5	200
6	<2.5	<2.5	<2.5	<2.5	200
8	<2.5	<2.5	<2.5	<2.5	200

9	<2.5	<2.5	<2.5	<2.5	200
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Table 6: Histamine results (mg/100g) for refreshed summer whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	<10	<10	<10	<10	N/A
3	<10	<10	<10	<10	N/A
6	10	290	<10	80	N/A
8	<10	<10	<10	<10	N/A
9	<10	<10	<10	<10	N/A

Table 7: Enterobacteriaceae results (cfu/g) for refreshed summer whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

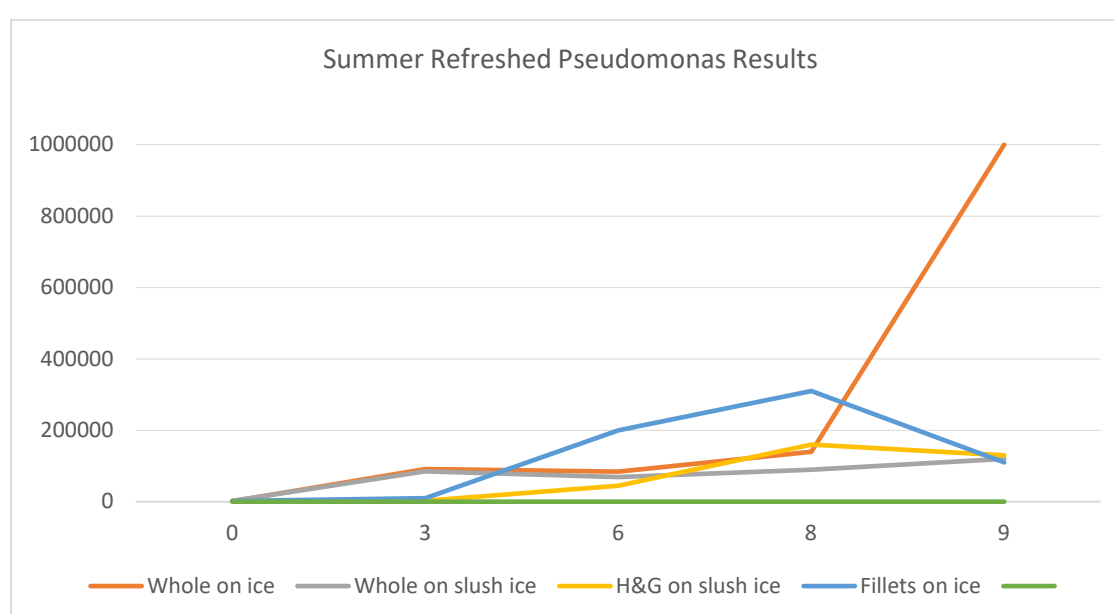


Figure 19: Pseudomonas results (cfu/g) for refreshed summer whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials. Note: While there is no legislative limit imposed for Pseudomonas spp. a level of 10^7 cfu/g is considered the maximum acceptable level (Appendix VI)

Winter Fresh

Fat content was only derived for whole on ice samples and revealed an elevated 24.31%.

As with the summer samples, there were few discernible trends notable throughout the trials on winter fresh samples. By day 10 TVC levels of 1×10^6 cfu/g were detected for fillets on ice and H&G on slush ice. Other tests did not reveal elevated chemical or microbiological levels on day 7. By day 10 an elevated Pseudomonas figure of 1.65×10^6 cfu/g was detected for fillets on ice samples.

Sampling day	Whole on slush ice
0	24.31

Table 8: Fat content (%) for fresh winter whole mackerel stored on slush ice sampled at beginning (day 0) of shelf-life trials

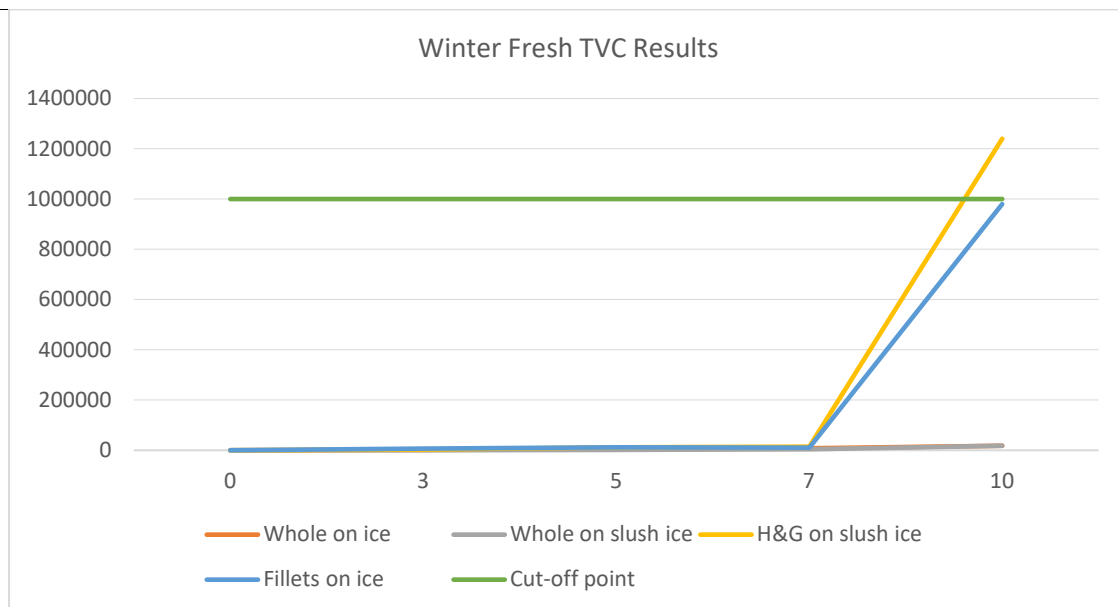


Figure 20: Total Viable Count results (TVCs cfu/g) for fresh winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

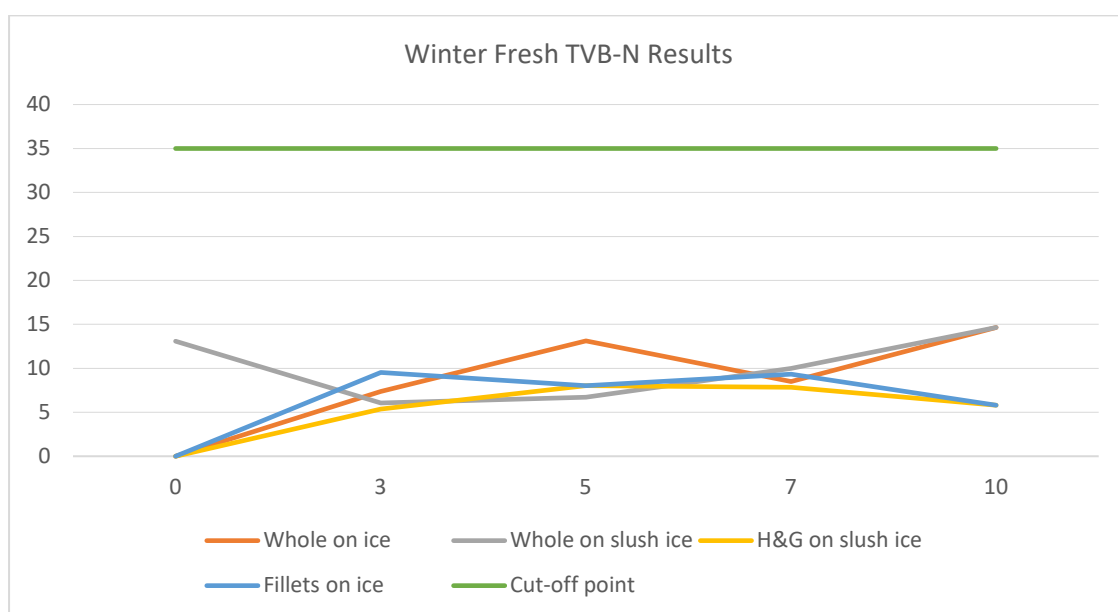


Figure 21: Total Volatile Base Nitrogen results (mgN/100g) for fresh winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials. Note: No permissible levels for TVB-N are set for pelagic species (Appendix VI), however a guideline figure of 35 mgN/100g is typically used by industry

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	-	<2.5	-	-	200

3	<2.5	<2.5	<2.5	<2.5	200
5	<2.5	<2.5	<2.5	<2.5	200
7	<2.5	<2.5	<2.5	<2.5	200
10	<2.5	<2.5	<2.5	<2.5	200

Table 9: Histamine results (mg/100g) for fresh winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	-	<10	-	-	N/A
3	<10	<10	<10	<10	N/A
5	<10	-	<10	<10	N/A
7	<10	<10	<10	<10	N/A
10	<10	<10	<10	540	N/A

Table 10: Enterobacteriaceae results (cfu/g) for fresh winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

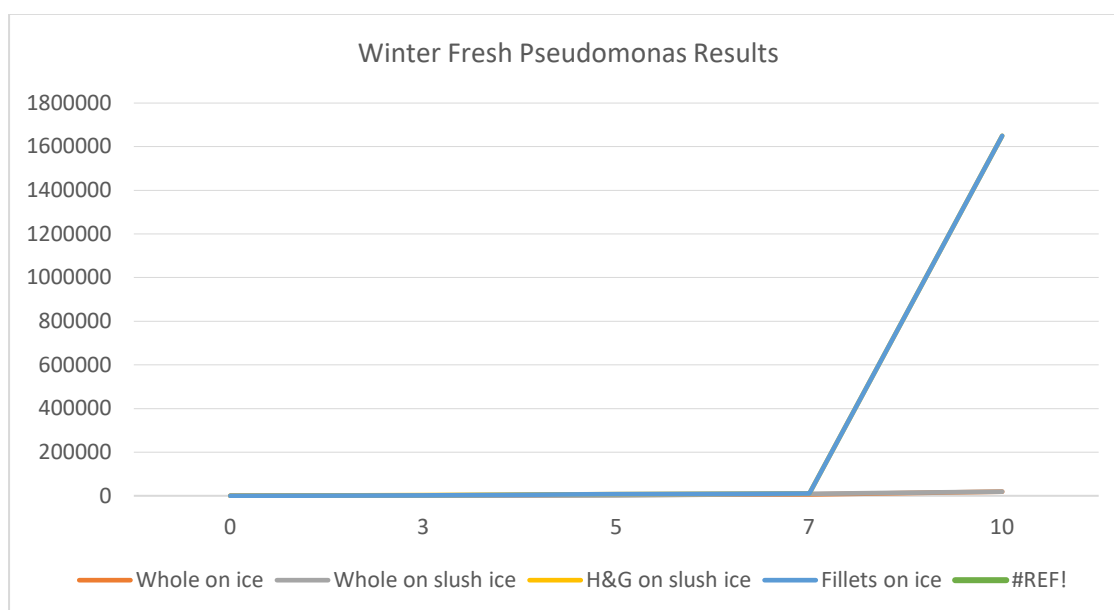


Figure 22: Pseudomonas results (cfu/g) for fresh winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials. Note: While there is no legislative limit imposed for Pseudomonas spp. a level of 10^7 cfu/g is considered the maximum acceptable level (Appendix VI)

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
10	Not Detected in 25g	Not Detected in 25g	Not Detected in 25g	Not Detected in 25g	N/A

Table 11: Listeria monocytogenes results (cfu/g) fresh winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	-	<10	-	-	N/A
10	<10	<10	<10	<10	N/A

Table 12: *E.coli* results (cfu/g) for fresh winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	-	<10	-	-	N/A
10	<10	<10	<10	<10	N/A

Table 13: Coag+ staphylococci (incl. *S. aureus*) results (cfu/g) for fresh winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	-	Not Detected in 25g	-	-	N/A
10	Not Detected in 25g	Not Detected in 25g	Not Detected in 25g	Not Detected in 25g	N/A

Table 14: *Salmonella* results (cfu/g) for fresh winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Winter Refreshed

Fat content was only derived for whole on ice samples and revealed an elevated level of 23.11%.

There were no threshold levels breached. *Pseudomonas* levels were elevated on day 8 for whole on slush ice (55,000cfu/g) and fillets on ice (72,000cfu/g), and by day 9 all formats had elevated levels, ranging from 61,000cfu/g for H&G on slush ice to 83,000cfu/g for both fillets on ice and whole on slush ice.

Sampling day	Whole on slush ice
0	23.11

Table 15: Fat content (%) for refreshed winter whole mackerel stored on ice at beginning (day 0) of shelf-life trials

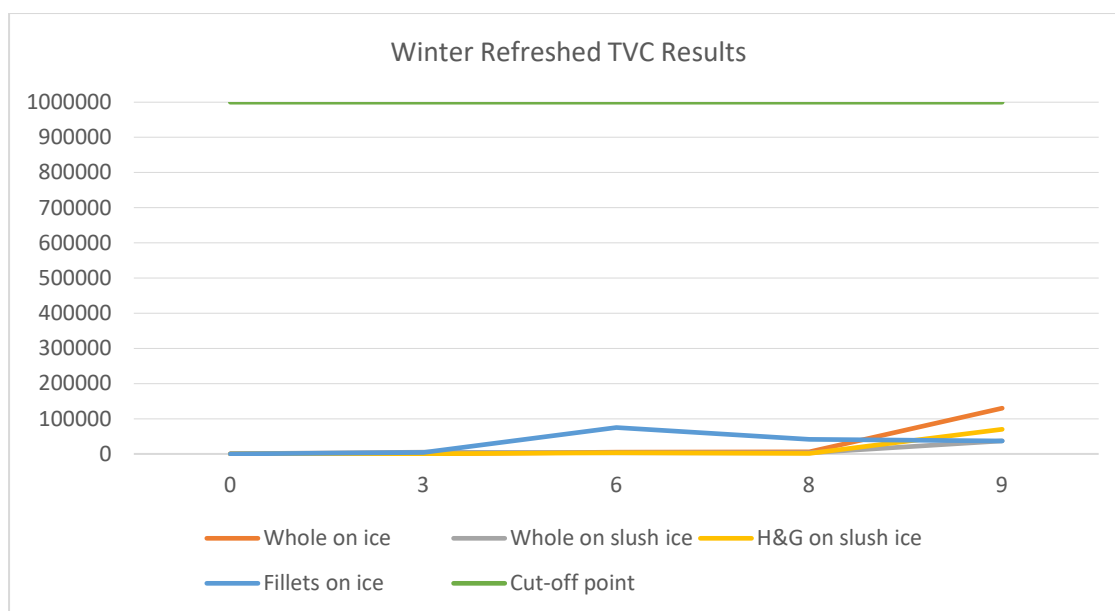


Figure 23: Total Viable Count results (TVCs cfu/g) for refreshed winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

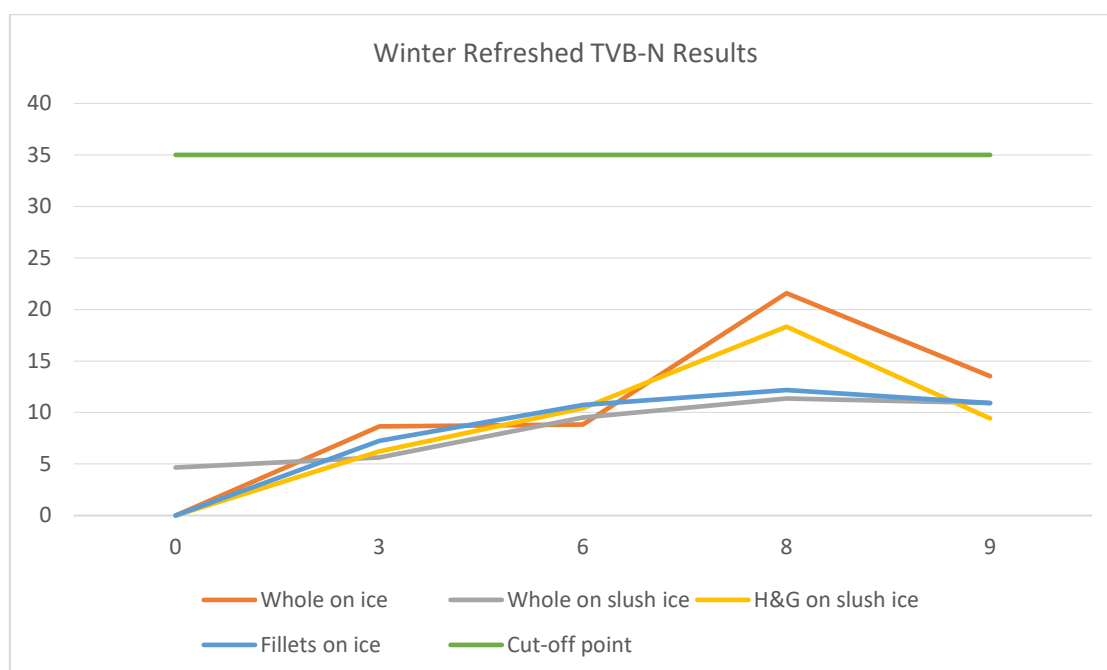


Figure 24: Total Volatile Base Nitrogen results (mgN/100g) for refreshed winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials. Note: No permissible levels for TVB-N are set for pelagic species (Appendix VI), however a guideline figure of 35 mgN/100g is typically used by industry

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	-	-	-	-	200
3	-	<2.5	<2.5	<2.5	200
6	-	<2.5	<2.5	<2.5	200
8	-	<2.5	<2.5	<2.5	200
9	<2.5	<2.5	<2.5	<2.5	200

Table 16: Histamine results (mg/100g) for refreshed winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	-	-	-	-	N/A
3	<10	<10	<10	<10	N/A
6	<10	<10	<10	<10	N/A
8	<10	<10	<10	<10	N/A
9	<10	<10	<10	<10	N/A

Table 17: Enterobacteriaceae results (cfu/g) for refreshed winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

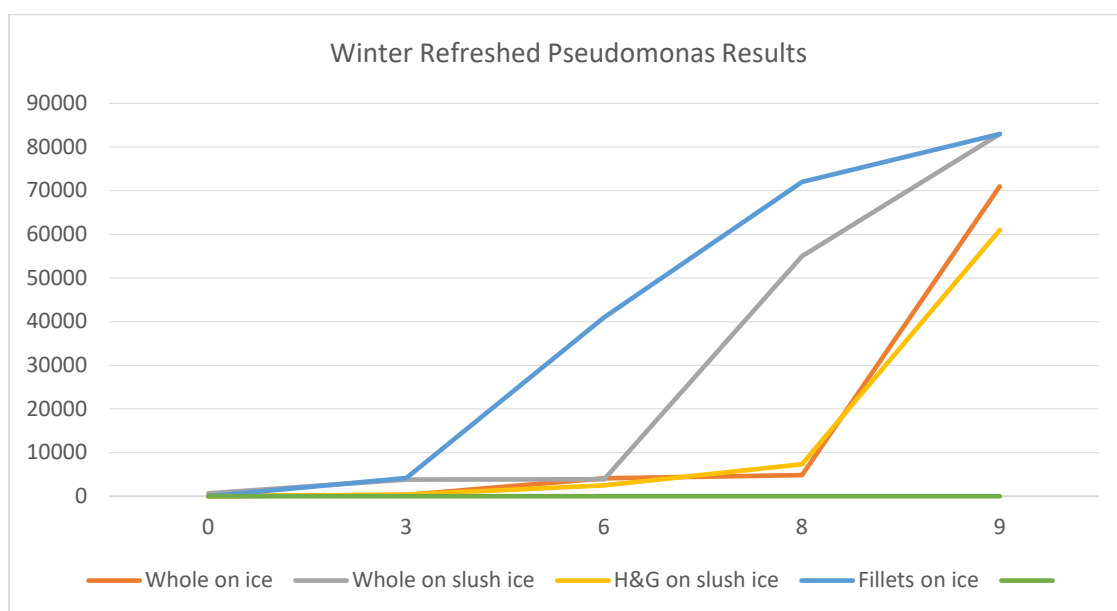


Figure 25: Pseudomonas results (cfu/g) for refreshed winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials. Note: While there is no legislative limit imposed for Pseudomonas spp. a level of 10^7 cfu/g is considered the maximum acceptable level (Appendix VI)

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
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0	-	Not Detected in 25g	-	-	N/A
9	Not Detected in 25g	Not Detected in 25g	Not Detected in 25g	Not Detected in 25g	N/A

Table 18: *Listeria monocytogenes* results (cfu/g) refreshed winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	-	<10	-	-	N/A
9	<10	<10	<10	<10	N/A

Table 19: *E.coli* results (cfu/g) for refreshed winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	-	<10	-	-	N/A
9	<10	<10	<10	<10	N/A

Table 20: Coag+ staphylococci (incl. *S. aureus*) results (cfu/g) for refreshed winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	-	Not Detected in 25g	-	-	N/A
9	Not Detected in 25g	Not Detected in 25g	Not Detected in 25g	Not Detected in 25g	N/A

Table 21: *Salmonella* results (cfu/g) for refreshed winter whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Conclusions and Recommendations

Sensory assessment uses physical characteristics to determine a score indicating the freshness quality of seafood. With minimum training it provides a reasonably user-friendly and reliable method to categorize the quality of fish. The quality assessment methods that were adapted for the various formats and refreshed products in this study appeared to perform well and provide a coherent appraisal of quality loss over time. Results from the sensory trials conducted revealed that medium quality scores were generally maintained in both summer and winter fresh samples up to day nine, with winter fish generally performing better due to the fact the summer mackerel had feed content in the gut. This can lead to more rapid deterioration of the gut cavity due to increased post-mortem enzymatic activity. It was clear that the impact of freezing and defrosting was a larger determinant on sensory quality loss, with medium quality only being maintained up to day six on refreshed summer and winter samples.

The large number of microbiological and chemical laboratory tests that were conducted during the trials by an accredited laboratory also provided clear temporal trends. For the fresh samples analysed, in general laboratory results showed that no threshold levels were breached for each of the tests until an advanced stage of the trials (c. day nine and beyond) when sensory attributes for the various batches showed significant quality deterioration. For refreshed samples, laboratory tests verified the more rapid temporal sensory quality deterioration, with elevated levels evident typically from day 8, but on occasion day 6.

From the trial results a seven-day shelf-life is achievable for the fresh summer and winter mackerel formats stored under commercial chilled conditions (-1°C to 0°C). A five-day shelf-life is achievable for refreshed summer and winter mackerel formats stored under commercial chilled conditions (-1°C to 0°C). It is likely that an increase in shelf-life could be achieved. Firstly, the samples batches were being physically disturbed by the daily sampling routine, which would impact on quality. Under normal commercial storage conditions, this level of daily disturbance would not occur. Secondly, ice and slush ice were not changed for the duration of the trials in the various test batches, which could have impaired quality over time. Processors will often top-up or replace ice/slush ice when products are in storage for more than twenty-four hours. The tempering and defrosting unit used for the trials allowed for defrosting to be conducted in a controlled environment. However, this was a test unit, and it was acknowledged that further improvements could be made in the tempering process cycle to further improve quality for refreshed product.

It is also important to note that overall product shelf-life can be impacted by upstream and downstream supply chain practices. Upstream, vessels and associated logistics supplying raw material to processors must operate to best practice, which includes appropriate chill chain management (852/2004/EC). Likewise, downstream, food business operators selling to secondary processors, HORECA (Hotels, restaurants, café), and retailers should take account of their refrigeration and storage temperatures when setting and validating food shelf-life. See FSAI Guidance Note No. 18. https://www.fsai.ie/publications_GN18_shelf-life/.

This study provides a robust baseline that shows that pelagic processors can attain a reasonable shelf- life for mackerel if they follow best manufacturing practice. In general mackerel is not held under chilled conditions for extended periods at pelagic processing plants. Fish are usually frozen either graded whole, filleted, head and gutted and then promptly frozen, typically within forty-eight hours. Customers of pelagic processors are often processors themselves that produce retail packs of mackerel fillets, and these fillets are often skin-packed under modified atmosphere and thus can attain a good shelf-life. Testing skin-packed fillets was outside the scope this study. It is worth noting that these processors who produce these packs have typically carried out robust in-house trials. To ensure compliance, it is the responsibility of each pelagic fish processor, as FBOs, to ensure that they maintain minimum standards with regard to handling and hygiene (852/2004/EC). To allow industry to use this study it is suggested that processors use it when designing and reviewing their FSMSs and ensure they continue to sample regularly to ensure they can demonstrate compliance. BIM also provides training on quality and food safety for fishing crew and processors, and it is the responsibility of processors to ensure that their staff are appropriately trained to meet all relevant legislation (852/2004/EC). All processors, as FBOs, are also required to have up to date FSMSs and these are regularly checked by SFPA officers to ensure compliance.

Appendix I: Sensory assessment tables

Summer fresh:

Day	Average score	Quality score %	Quality grade	Average Torry score	Comments
0	34.7	99.1	Very high	9.8	
1	34	97	Very high	9.5	
3	32	91.4	Very high	8.4	
7	28.3	82.5	High	7.98	
9	19.4	55	Medium	6.6	Burst bellies in 3/10 fish assessed
10	18.2	52	Medium	5.2	Burst bellies in 7/10 fish assessed
11	9.6	27	Low	3.5	

Table 22: Sensory assessment results for fresh whole mackerel stored on ice

Day	Average score	Quality score %	Quality grade	Average Torry score	Comments
3	27.5	78	High	7.9	

7	21.1	60.3	Medium	5.1	
9	16.2	46.2	Medium	4.8	
10	14.1	40	Low		Burst bellies in 8/10 fish assessed
11	10.2	29	Low	3.65	

Table 23: Sensory assessment results for fresh whole mackerel stored on slush ice

Day	Average score	Quality score %	Quality grade	Comments
3	12.9	64.5	High	
7	18.8	54	Medium	
9	13.8	39	Low	
10	10	28.6	Low	Sour smell from body cavity; rancid smell
11	10.2	27	Low	

Table 24: Sensory assessment results for fresh H&G mackerel stored on slush ice

Day	Average score	Quality score %	Quality grade	Comments
3	16	80	High	
7	18.4	52.6	Medium	
9	10.3	51.5	Medium	Fillets smell sour
10	6.9	34.5	Low	Sour smell from fillets
11	6.7	33	Low	Strong sour smell; slime on all fillets

Table 25: Sensory assessment results for fresh mackerel fillets stored on ice

Summer refreshed:

Day	Average score	Quality score %	Quality grade	Comments
1	16.7	55.7	Medium	Burst bellies in 2/10 fish; fish were bruised looking compared to whole fish in slush ice
3	13.5	45	Medium	
6	13.8	46	Medium	
8	10.2	34	Low	Mackerel were very soft; skin badly discoloured
9	6.2	20.7	Very low	Fish had rancid smell and were very soft; not fit for human consumption

Table 26: Sensory assessment results for refreshed whole mackerel stored on ice

Day	Average score	Quality score %	Quality grade	Comments
1	17.8	59.3	Medium	
3	15.3	51	Medium	Burst bellies in 3/10 fish; eyes damaged during thawing

6	14.2	47.3	Medium	Eyes were red; gills in poor condition; rancid smell from flesh; not fit for human consumption
8	12.4	41.3	Medium	Burst bellies in 6/10 fish; soft texture although not as bad as whole fish stored on ice; not fit for human consumption
9	10.1	33.7	Low	Very soft texture; sour smell from flesh when filleted

Table 27: Sensory assessment results for refreshed whole mackerel stored on slush ice

Day	Average score	Quality score %	Quality grade	Comments
1	11.9	59.5	Medium	Bones protruding from inner flesh
3	11.1	55.5	Medium	Bones protruding in inner flesh in 2/10 fish assessed
6	9.5	47.5	Medium	This is still the best presentation
8	8.1	27%	Low	
9	5	25	Low	Soft texture; rancid smell from flesh; best of the formats but 3/10 fish assessed displayed protruding bones from inner flesh

Table 28: Sensory assessment results for refreshed H&G mackerel stored on slush ice

Day	Average score	Quality score %	Quality grade	Comments
1	9.4	47	Medium	Fillets were of poor quality and displayed significant gaping; Fish were difficult to fillet due to feed in stomachs; some wrinkling of skin on fillet
3	8.9	44.5	Medium	Sour smell in 2/10 fillets assessed; considerable gaping, loss of texture and wrinkling of skin
6	6.2	31	Low	Fillets in very poor condition; sour smell from fillets; soft texture, 2/10 assessed were disintegrating; skin wrinkled in 7/10 fillets assessed
8	4.7	23.5	Low	Significant gaping; very soft texture with wrinkled skin; sour smell; not fit for human consumption
9	1.4	7	Very low	Sour smell; gaping; loss of fillet shape; wrinkling of skin

Table 29: Sensory assessment results for refreshed mackerel fillets stored on ice

Winter fresh:

Day	Quality score %	Quality grade	Average Torry score	Comments
0	99	Very high	9.825	
1		Very high	9.7	Fish in very good condition
3	91	Very high	8.4	Excellent quality
7	82	High	7.9	No bellies burst but beginning to deteriorate
9	55	Medium	6.75	Burst bellies in 30% of fish assessed Sour smell
10	52	Medium		Fish soft 70% bellies burst

				Rancid smell
11	26	Low	3.8	Fish very soft and rancid 80% of bellies burst

Table 30: Sensory assessment results for fresh whole mackerel stored on ice

Day	Quality score %	Quality grade	Average Torry score	Comments
0	99	Very high	9.825	Fish in excellent condition
1		Very high	9.525	Fish in good condition slightly bleached from fresh water
3	78	High	7.9	More bleaching due to fresh water
7	60	Medium	5	Bellies burst in 10% of fish Gills sour smell
9	46	Medium	4.75	Definitely not edible. Bellies burst in 50%
10	40	Low		Fish Rancid 80% bellies burst
11	29	Low	3.4	Fish very soft and rancid >80% of bellies burst

Table 31: Sensory assessment results for fresh whole mackerel stored on slush ice

Day	Quality score %	Quality grade	Average Torry score	Comments
0	99	Very high	9.825	
3	64	High	7.9	These are keeping very well
7	54	Medium	5	This format has kept best and are still quite firm
9	69	Medium		Still the best quality of all the forms
10	50	Medium		Fish still reasonably solid but rancid smell
11	29	Low		Flesh firm but rancid

Table 32: Sensory assessment results for fresh H&G mackerel stored on slush ice

Day	Quality score %	Quality grade	Average Torry score	Comments
0	99	Very high	9.825	
3	80	High		Very good quality with excellent skin colour
7	53	Medium		Fillets showing some signs of bleaching and smell sour
9	60	Medium		Flesh soft and sour/ rancid smell
10	34	Low		Fillets very soft and rancid
11	33	Low		Fillets very soft rancid and red

Table 33: Sensory assessment results for fresh mackerel fillets stored on ice

Winter Mackerel from the MFV Cataleya

Day	Quality score %	Quality grade	Average Torry score	Comments
0	99	Very high		Excellent quality fish -1°C on landing
3	88.3	Very high	9.4	Very good quality
5	79	High	8	

7	73.4	High	7.2	
10	49	Medium	5.7	Fish very soft and rancid smell

Table 34: Sensory assessment results for fresh whole mackerel stored on ice

Day	Quality score %	Quality grade	Average Torry score	Comments
3	75	High	8.5	Excellent quality
5	73	High	7.3	
7	63.1	Medium	6.7	Fish beginning to smell slightly rancid
10	43	Medium	4.8	Rancid smell

Table 35: Sensory assessment results for fresh whole mackerel stored on slush ice

Day	Quality score %	Quality grade	Average Torry score	Comments
3	80	High		High quality fish
5	67.5	High		Slight rancid smell reddening of fillet
7	52	Medium		Rancid smell from fish Bones separating from flesh
10	25.5	Low	5.7	Very soft flesh Rancid smell Pale grey colour flesh

Table 36: Sensory assessment results for fresh mackerel fillets stored on ice

Day	Quality score %	Quality grade	Comments
3	79.6	High	High quality fish
5	70	High	Bone separating in 20% of fish
7	44	Medium	
cata10	42.5	Medium	Fish soft breaking away from bone Rancid smell

Table 37: Sensory assessment results for fresh H&G mackerel stored on slush ice

Winter refreshed:

Day	Quality score %	Quality grade	Comments
3	68	High	
6	45	Medium	Soft bruising and blood stained
8	39	Low	Fish soft and bruised
9	35.4	Low	Rancid smell

Table 38: Sensory assessment results for refreshed whole mackerel stored on ice

Day	Quality score %	Quality grade	Comments
3	65	High	
6	48	Medium	Fish soft
8	46.5	Medium	Fish beginning to smell rancid
9	44	Medium	Fish smelling rancid

Table 39: Sensory assessment results for refreshed whole mackerel stored on slush ice

Day	Quality score %	Quality grade	Comments
3	43.6	Medium	Fillets gaping
6	48	Medium	Loosing texture Gaping badly
8	29.5	Low	Fillets smelling badly
9	34	Low	Fillets very soft

Table 40: Sensory assessment results for refreshed mackerel fillets stored on ice

Day	Quality score %	Quality grade	Comments
3	70.5	High	
6	67.5	High	Fish reasonably firm
8	53.5	Medium	Flesh going away from bones
9	47	Medium	Fish very soft and coming away from the bone

Table 41: Sensory assessment results for refreshed H&G mackerel stored on slush ice

Appendix II: Sensory Analysis Photos



Figure 26: Summer mackerel lined up for sensory assessment



Figure 27: Summer mackerel lined up for sensory assessment



Figure 28: Summer mackerel lined up for sensory assessment



Figure 29: Summer mackerel during sensory assessment



Figure 30: Winter mackerel during sensory assessment

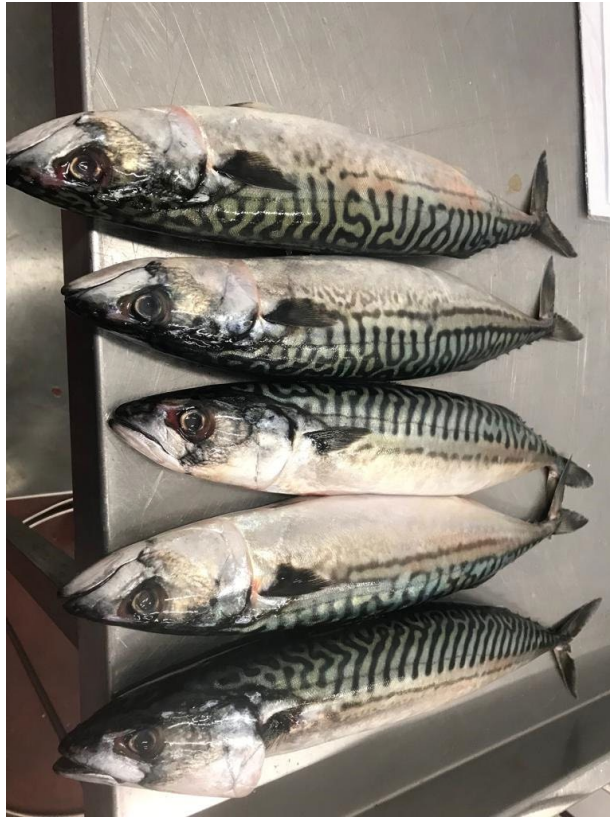


Figure 31: Winter mackerel lined up for sensory assessment



Figure 32: Winter mackerel during sensory assessment

Appendix III: Mackerel quality assessment sheet

Date		Location	
Time		Equipment	
Species		Fish format	(Whole, fillet or H&G)
Product format	(block frozen or IQF)	Assessed by	

Batch number & grade	
Agreed thawing temp	
Time to thaw to agreed temp	
Specify method/settings:	(temperature, throughput, speed etc)

	1. Very high	2.High	3.Medium	4.Low	5.Very low
Eye- Results for 10 fish					
Body colours- Results for 10 fish					
Iridescence- Results for 10 fish					
Flesh texture- Results for 10 fish					
Rigor- Results for 10 fish					
Gill odour- Results for 10 fish					
Gill colour- Results for 10 fish					
COLUMN TOTALS					
Coefficient	x5=	x4=	x3=	x2=	x1=
Average Score: (column 1 + 2 + 3 + 4 + 5) / 10 fish =					
Quality score: Average score/35 x 100 =					
Quality Grade	Very high	High	Medium	Low	Very Low
	>80%	80% - 61%	60% - 41%	40% - 21	<21%

Freshness Attributes

	Very high	High	Medium	Low	Very low
Eye	Eye clear, black, stands out from head, surface of eye convex. Area in front of eye clear and bright.	Eye beginning to cloud (30% cloudy). Surface of eye slightly convex or flat. Area in front of eye dull.	Eye about 50% cloudy. Surface of eye slightly flat or slightly concave, slightly wrinkled. Area in front of eye dull and rosy.	Eye opaque. Surface of eye concave, wrinkled. Area in front of eye rosy	Eye opaque. Brown, and dissolving. Sunken, badly wrinkled. Area in front of eye bloody.

Body colours	Bright and vivid	Slight dulling and fading.	Body colours dull and faded.	Body colours very dull and faded.	Body greying, colours not visible.
Iridescence	Pearly white belly, iridescence all over.	Belly white, iridescence reduced slightly	Belly white, patchy iridescence.	Belly white but with some golden patches, iridescence patchy or absent.	Belly with golden hue, no iridescence.
Flesh texture	Flesh firm and elastic (springs back quickly into shape when pressed with thumb).	Flesh firm and slightly elastic (springs back into shape but not as quickly).	Flesh softening (doesn't spring back fully on pressing, small thumb print remaining).	Flesh soft (doesn't spring back at all on pressing, thumb print remaining).	Flesh very soft (doesn't spring back at all with flesh easily extruded through skin).
Rigor	Fish pre-rigor or in rigor, rigid.	Fish out of rigor, still quite rigid.	Fish out of rigor, not stiff but not limp.	Fish out of rigor, going limp.	Fish out of rigor, limp.
Gill odour	Fresh, sea water odour.	Neutral or no odour.	Slight metallic or musty odour	Strong metallic or musty odour.	Pronounced 'off' odour.
Gill colour	Gills dark red, bright, mucus clear.	Gills red with slight bleaching, mucus clear.	Gills red with pronounced bleaching (up to 30%), Mucus slightly opaque.	Gills with large amount of bleaching (50%+), mucus opaque or slightly cloudy	Gills brown and putrid, mucus opaque, cloudy
	Very high	High	Medium	Low	Very low

Appendix IV: Torry Freshness Scoring System for Raw Mackerel

Torry Raw Mackerel Score Sheet

Sample Code	Attribute				Average Score
	Skin & Body	Eyes	Gills - Appearance	Gills - Odour	

TORRY Freshness Scoring System for Raw Mackerel

SCORE	APPEARANCE			GILL ODOUR	SCORE
	SKIN AND BODY	EYES	GILLS		
10	Firm body with silky smooth skin. Lateral line and reticulations on upper surface well defined. Body colours iridescent with strong royal blue and turquoise colours on upper surface. Blue and violet on ventral surface with silvery sheen. Passing into rigor or in rigor.	Bulging convex eye with protruding lens. Shiny jet-black pupil with metallic brown iris. Eye-cap water clear	Uniformly dark red with free blood and water-clear slime present	Weak, delicate odours, cloying sweet, sharp, pepper, seaweed, blood	10
9					9
8	Loss of colour definition. Some blood stains apparent. Passing out, or out of rigor	Convex eye lens plane with cornea. Pupil less shiny, iris green/ blue. Slight clouding of eye cap	Dark purple/maroon with paler edge. Congealed blood present with opaque slime	More definite odours as above, also fragrant, fresh grass, fruity, metallic, shellfish	8
7					7
6	Colours of dorsal surface paler, reticulations grey, ventral surface white with golden tinge. Patchy iridescence			Dull muddy odours, musty, mousy, malty, cardboard, linseed oil, cod liver oil, biscuits, blood	6
5	Washed-out colours, definite golden tinge to skin, patchy iridescence. Body soft with red/brown slime oozing from gill covers. Skin wrinkles on flexing	Flattening of eye but still convex. Pupil wrinkled with slight clouding of lens. Iris silvery and starting to wrinkle. Yellowing of eye cap	Loss of colour with red/brown slime	Stale odours as above, also butterscotch, wet cardboard, wet dogs	5
4	Fish limp and floppy with distinct ice marks. Washed-out colours with mottling or golden tinge	Eye-ball plane with eye socket. Cloudy lens with silvery iris showing black specks	Browning of gills, patchy bleaching, increased slime and red/brown slime oozing from gill cover	Mixture of odours from above and below	4
3	Little distinction between upper and lower surfaces. Body very soft. Skin very wrinkled with distinct ice marks	Concave or flattening eye with cloudy pupil	Marked bleaching and browning of gills covered in black slime	Sweet-rotten odours, oil sweet-rotten fruit(grapefruit), old grass cuttings, sickly sour	3

Appendix V: Chemical and microbiological results

Summer fresh

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	360	673	4500	18000	10 ⁶
3	1700	973	436	2300	10 ⁶
7	41000	11000	1800	7300	10 ⁶
9	155000	28000	5600	61000	10 ⁶
11	580000	34000	7400	68000	10 ⁶

Table 42: Total Viable Count results (TVCs cfu/g) for fresh whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	10.06	10	11.04	11.24	35
3	15.52	17.22	15.84	11.64	35
7	17.77	14.9	11.97	15.23	35
9	19	11.85	12.93	33.22	35
11	24.96	13.72	9.88	40.11	35

Table 43: Total Volatile Base Nitrogen results (mgN/100g) for fresh whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials. Note: No permissible levels for TVB-N are set for pelagic species (Appendix VI), however a guideline figure of 35mgN/100g is typically used by industry

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	170	130	3500	8300	10 ⁷
3	1900	3700	1000	3800	10 ⁷
7	170000	61000	12000	19000	10 ⁷
9	1.4 × 10 ⁶	690000	69000	730000	10 ⁷
11	1.3 × 10 ⁷	5.5 × 10 ⁶	90000	690000	10 ⁷

Table 44: Pseudomonas results (cfu/g) for fresh whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Summer Refreshed

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	1400	2100	6400	2800	10 ⁶
3	25000	98000	2100	11000	10 ⁶
6	36000	92000	30000	210000	10 ⁶
8	85000	61000	95000	260000	10 ⁶
9	440000	63000	50000	27000	10 ⁶

Table 45: Total Viable Count results (TVCs cfu/g) for refreshed whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	6.57	8.41	9.34	8.6	35

3	13.48	8.29	7.18	13.99	35
6	17.9	17.24	7.58	12.27	35
8	15.26	10.74	6.61	16.83	35
9	16.73	11.15	6	13.26	35

Table 46: Total Volatile Base Nitrogen results (mgN/100g) for refreshed whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials. Note: No permissible levels for TVB-N are set for pelagic species (Appendix VI), however a guideline figure of 35mgN/100g is typically used by industry

Sampling day	Whole ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	1200	2100	1700	2000	10 ⁷
3	91000	85000	2500	9700	10 ⁷
6	84000	69000	45000	200000	10 ⁷
8	140000	90000	160000	310000	10 ⁷
9	10 ⁶	120000	130000	110000	10 ⁷

Table 47: Pseudomonas results (cfu/g) for refreshed whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Winter Fresh

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0		228.5			10 ⁶
3	1300	473	2900	6100	10 ⁶
5	3700	1500	12000	12000	10 ⁶
7	8500	4500	14000	11000	10 ⁶
10	18000	18000	1.24 × 10 ⁶	980000	10 ⁶

Table 48: Total Viable Count results (TVCs cfu/g) for fresh whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0		13.1			35
3	7.36	6.06	5.37	9.53	35
5	13.135	6.72	8.03	8.03	35
7	8.51	9.99	7.85	9.35	35
10	14.645	14.645	5.81	5.81	35

Table 49: Total Volatile Base Nitrogen results (mgN/100g) for fresh whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials. Note: No permissible levels for TVB-N are set for pelagic species (Appendix VI), however a guideline figure of 35 mgN/100g, as this is typically used by industry

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	
0		60			10^7
3	790	120	2500	1500	10^7
5	4900	1600	7950	7950	10^7
7	6400	8500	11000	11000	10^7
10	19000	19000	1.65×10^6	1.65×10^6	10^7

Table 50: *Pseudomonas* results (cfu/g) for fresh whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Winter Refreshed

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	-	555	-	-	10^6
3	140	5300	591	4500	10^6
6	4700	3500	2900	75000	10^6
8	5800	3400	1100	41000	10^6
9	130000	37000	70000	37000	10^6

Table 51: Total Viable Count results (TVCs cfu/g) for refreshed whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	-	4.66	-	-	35
3	8.65	5.62	6.23	7.25	35
6	8.83	9.53	10.42	10.72	35
8	21.58	11.36	18.33	12.18	35
9	13.54	10.93	9.42	10.93	35

Table 52: Total Volatile Base Nitrogen results (mgN/100g) for refreshed whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials. Note: No permissible levels for TVB-N are set for pelagic species (Appendix VI), however a guideline figure of 35 mgN/100g, as this is typically used by industry

Sampling day	Whole on ice	Whole on slush ice	H&G on slush ice	Fillets on ice	Cut-off point
0	-	660	-	-	10^7
3	300	3800	380	4200	10^7
6	4100	3900	2500	41000	10^7
8	4800	55000	7300	72000	10^7

9	71000	83000	61000	83000	10 ⁷
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Table 53: *Pseudomonas* results (cfu/g) for refreshed whole mackerel stored on ice & slush ice, H&G mackerel and mackerel fillets sampled during shelf-life trials

Appendix VI: References for Limits of TVC, Histamine, TVB-N & *Pseudomonas* spp. Levels

Table 4.1. Sampling plan and recommended microbiological limits for seafood (ICMSF 1986).

Product	Test	Case	Plan Class	n	c	Limit per gram or per cm ²	
						m	M
Fresh and frozen	APC ¹	1	3	5	3	5×10 ⁵	10 ⁷
fish; cold smoked fish	<i>E. coli</i>	4	3	5	3	11	500
Precooked breaded	APC	2	3	5	2	5×10 ⁵	10 ⁷
fish	<i>E. coli</i>	5	3	5	2	11	500
Frozen raw	APC	1	3	5	3	10 ⁶	10 ⁷
crustaceans	<i>E. coli</i>	4	3	5	3	11	500
Frozen cooked	APC	2	3	5	2	5×10 ⁵	10 ⁷
crustaceans	<i>E. coli</i>	5	3	5	2	11	500
	<i>S. aureus</i>	8	2	5	0	10 ³	-
Cooked, chilled,	APC	2	3	5	2	10 ⁵	10 ⁶
and frozen	<i>E. coli</i>	6	3	5	1	11	500
crabmeat	<i>S. aureus</i>	9	2	5	0	10 ³	-
Fresh and frozen	APC	3	2	5	0	5×10 ⁵	-
bivalve molluscs	<i>E. coli</i>	6	2	5	0	16	-

1. APC = Aerobic Plate Count (preferably carried out at 21–25°C on a nutrient rich, non-selective agar.
2. Aerobic Plate Count (APC) or Total Viable Count (TVC) is defined as the number of bacteria (cfu/g) in a food product obtained under optimal conditions of culturing

3. <http://www.fao.org/docrep/003/T1768E/T1768E00.htm#TOC>, Assurance of Seafood Quality, by H. H. Huss, Technological Laboratory, Ministry of Fisheries, Denmark, Food and Agriculture Organization of the United Nations, FAO fisheries technical paper 334, 4. Traditional microbiological quality control

Histamine Tolerance

For fish species of the families: Scombridae, Clupeidae, Engraulidae and Coryphaenidae:

Based on 9 samples, the mean value must not exceed 100 ppm, but 2 samples may exceed 100 ppm but no sample may exceed 200 ppm.

Fish belonging to these families which have undergone enzyme-ripening treatments in brine may have higher levels but not more than twice the above values.

<http://www.inspection.gc.ca/food/fish-and-seafood/exports/by-jurisdiction/european-union/certification-requirements/eng/1308322862954/1308323053859>

TVB-N Levels

Fishery products belonging to the species categories listed shall be regarded as unfit for human consumption where organoleptic assessment has raised doubts as to their freshness and chemical checks reveal that the following TVB-N limits are exceeded:

25 mg of nitrogen/100 g of flesh for *Sebastes* spp., *Helicolenus dactylopterus*, *Sebastichthys capensis*.

30 mg of nitrogen/100 g of flesh for Species belonging to the Pleuronectidae family (with the exception of halibut: *Hippoglossus* spp.).

35 mg of nitrogen/100 g of flesh for *Salmo salar*, species belonging to the Merlucciidae family, species belonging to the Gadidae family.

Blue Whiting are part of the Gadidae family. There is currently no legislation for pelagic fish which are naturally high in TVB-N.

60 mg of nitrogen/100 g of whole fishery products used directly for the preparation of fish oil for human consumption. (Commission Regulation (EC) No 2074/2005 of 5 December 2005)

Russia

The Technical Regulation of CU "On Safety of Food Products" (TR CU 021/2011) lays down sanitary, veterinary and phytosanitary hygienic requirements for food products, including fish and fishery products, in the Russian Federation. Annex 3 to the TR CU 021/2011 lays down hygienic requirements for the food products safety. There are no specific provisions regarding the TVB-N limits for fish or fishery products. However, legislation provides limits for presence of histamine and N-nitrosamines, which are the N-containing pollutants, for fish and fishery products. According to

the Russian legislation, the quantity of histamine which can be found in mackerel, herrings and products of thereof must not exceed 100 mg/kg. The amount of N-nitrosamines (sum of N-nitrosodimethylamine and N-nitrosodiethylamine) for all species of fish and products of thereof shall not exceed 0,003 mg/kg.

China

National Food Standard GB 2733-2005 Hygienic Standard for Fresh and Frozen Marine Products of Animal Origin lays down compositional requirements for marine products of animal origin, including marine fish. According to the Standard, the amount of volatile basic nitrogen (VBN) in marine fish (including mackerel) should be no more than 30 mg / 100 g.

***Pseudomonas* spp.**

Pseudomonas species are a spoilage bacteria and while there is no legislative limit imposed a level of 10^7 cfu/g is considered the maximum acceptable level at any point of shelf life based on guidelines provided by the Institute of Food Science and Technology (IFST (1999). Development and use of microbiological criteria for foods. ISBN 0 905367).

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