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Overview of Seafood Research at Ashtown Food Research Centre (1990-2007)

Ashtown Food Research Centre

RESEARCH & TRAINING FOR THE FOOD INDUSTRY

RESEARCH REPORT NO 93

OVERVIEW OF SEAFOOD RESEARCH AT ASHTOWN FOOD RESEARCH CENTRE (1990-2007)

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SUMMARY

In recent years, the Irish seafood industry has faced stringent quotas and dwindling fish stocks. The introduction of fish farming added a new dimension but falling prices also created difficulties for this sector. However, the recent report of the Seafood Industry Strategy Group on 'Steering a New Course' and the Sea Change Programme of the Marine Institute will add new impetus to the industry. The current report summarises R&D on seafood conducted at Ashtown Food Research Centre (AFRC) in the period 1990-2007 and represents a major portion of seafood R&D conducted nationally during that period. Surveys on fish preferences indicated that the quality of fish in supermarket wet fish counters was considered 'good' by 76% of interviewees while only 0.3% said 'poor'. A visual panel of 386 consumers held in the departure lounge of Dublin airport indicated a preference (43%) for smoked salmon which had a light pink colour. The percentages choosing other samples were 21% (deep orange), 21% (kipper-like) and 15% (orange-pink). Three trials were conducted related to monitoring of fish quality. Condition factor of salmon is easily measured and is a good index of salmon quality and has major application at retail level. A range of procedures was compared for measuring the fat content of herrings with emphasis on low cost rapid procedures. A near infrared procedure was found to have application in salmon especially in situations where only approximations of oil and moisture content are required. Trials relating to product development included added-value herring products, fish products with oat fractions, the use of fish surimi in gluten-free breads and the stability of omega-3 polyunsaturated fatty acids in heat-processed fatty fish. Trials on the cold chain addressed the effects of temperature fluctuations below freezing point on product quality, the use of very low temperatures and the storage conditions for frozen fish mince. Freeze-chilling was found to be an acceptable technology for extending the shelf-life of fresh pre-packed fish fillets. Extensive testing was conducted on new fish species and many were found to be suitable for sale as both fresh fillets and processed products. More recent work addressed the area of fish as a functional food. In this context, the taurine content of different fish species

both fresh and processed was measured and gluten-free ready-meals (salmon lasagne and salmon 'Rigati') containing nutraceuticals were formulated. There is ongoing emphasis on the dissemination and technology transfer of the findings to the seafood sector and other end-users. The R&D was funded or facilitated by the EU (both Framework and Structural Funds), by student placement via LEONARDO and other programmes and by a number of Irish State Agencies.

INTRODUCTION

Ireland is an island nation and as such should have a highly developed and extensive seafood industry. Historically, this has not been the case due to a number of factors including a small fleet size (and also small trawlers) which in turn led to low catch volumes and, therefore, lower fish quotas than might be expected for a nation with so many rich fishing grounds in its vicinity. In more recent years, the industry has faced even more stringent quotas and dwindling fish stocks. The introduction of fish farming added a new dimension to the Irish industry but falling prices have created difficulties for this sector. However, times are now changing for the better and the report of the Seafood Industry Strategy Group [Cawley (Chairman), 2006] on 'Steering a New Course' has been published recently and there is major national will and a strong determination to implement its findings. The report includes key recommendations on market development, market-led innovation, processing sector restructuring and development. In parallel, the Marine Institute has introduced its Sea Change Programme (2006) which is a Marine Knowledge, Research and Innovation Strategy for Ireland (2007-2013). Some aspects of this are already coming on-stream with the announcement of a new joint research initiative on marine nutraceuticals/functional foods by the Marine Institute and the Department of Agriculture, Fisheries and Food in late 2007. A Seafood Innovation Link was established in 2006 between AFRC and Bord Iascaigh Mhara (BIM) to strengthen critical mass within seafood R&D and to provide the industry with a specialist market-focused source of seafood innovation aimed at achieving commercial success. These measures have come

on-stream at a time when there is unprecedented worldwide demand for seafood and the health benefits from consuming seafood are being increasingly recognised by consumers. This was highlighted and made extensive headlines at the World Seafood Congress held in Dublin in September 2007.

PROJECTS AND OUTCOMES

The current report documents R&D on seafood conducted at Ashtown Food Research Centre (AFRC) in the period 1990-2007 *i.e.* prior to the Cawley Report (2006) and Sea Change (2006) initiatives and represents a major portion of seafood R&D conducted nationally during that period. It was conducted in times of low levels of national funding for seafood R&D. The research was funded or facilitated by the EU, both Framework and Structural Funds, and also by student placement via LEONARDO and other programmes, the Marine Institute, Bord Iascaigh Mhara (BIM), Enterprise Ireland and by the seafood industry. A wide range of topics was investigated with emphasis on the quality and processability of underutilised fish species and on marine functional foods.

CONSUMER SURVEY ON FISH PREFERENCE

It is always important to assess consumer preferences for foods and food products and hence this study on fish. A survey of 800 female consumers in four Dublin supermarkets (200 in each) indicated that cod, salmon and plaice were the preferred species (Fernandez-Celemin and Gormley, 1995; Fernandez-Celemin *et al.*, 1995) (Table 1). There were a number of preference differences related to social class which are listed in Table 1. Twenty-four percent of interviewees bought fish several times per week, 40% once per week and the remainder less frequently. The quality of fish in supermarket wet fish counters was considered 'good' by 76% of interviewees while only 0.3% said 'poor'. These data were based on a limited sample size and may or may not reflect the overall position in Dublin or indeed nationally.

Table 1: Preference (%)[a] by 800 consumers for different types of fish

Fish type	Social class			Overall
	A	B	C	
Cod	18.9	24.6	21.0	21.5
Salmon	18.0	12.0	12.5	14.5
Plaice	9.6	8.3	13.1	9.9
Haddock	3.4	6.6	3.4	4.6
Ray	1.2	6.6	5.7	4.3
Monkfish	6.5	2.3	1.7	3.9
Shellfish	5.6	3.0	1.1	3.6
Smoked fish	1.9	3.0	5.7	3.1
Trout	4.3	2.7	0.6	2.9
Sole	4.3	1.3	2.3	2.8
Other[b]	26.3	29.6	32.9	28.9

[a]Underlined values are statistically different in relation to social class

[b]Includes many other species, canned and frozen fish and also 'no preference'

CONSUMER PREFERENCE FOR SMOKED SALMON

Smoked salmon is now a commodity product and sales depend on a number of factors including colour. A visual panel of 386 consumers held in the departure lounge at Dublin airport indicated a preference (43%) for smoked salmon which had a light pink colour (Gormley, 1992). The percentage choosing the other samples were 21% (deep orange), 21% (kipper-like) and 15% (orange-pink). The effect was independent of the nationality and sex of the panellists but frequent purchasers of smoked salmon preferred a more orange product.

CONDITION FACTOR FOR SALMON

In recent years, most salmon is farmed and supplies of wild salmon are declining steadily. Much of today's sales are of fresh product from wet fish counters in retail outlets. In this context, condition factor (CF) is a useful index to relate the length of a salmon to its weight and so to determine the condition of the fish. Three equations were developed:

1. CF = [fish weight (g) x 100] ÷ [fish length (cm)]^3
2. CF (farmed) (+gut) = -0.022 + 1.1184 CF (-gut)
3. CF (wild) (+gut) = -0.0471 + 1.1219 (-gut)

The first equation is to calculate the CF; the second to compare the gut-in and gut-out CF for farmed salmon; the third to compare the gut-in and gut-out CF for wild salmon. Tests on 882 salmon (587 farmed and 295 wild) indicated that CF is a useful and easily-measured quality index for salmon, especially when combined with data for skin colour and fat content (Schallich and Gormley, 1996a). Wild salmon were better conditioned than farmed and CF values of >0.90 are desirable for gutted salmon (wild and farmed) and >0.96 and >0.98 for gut-in wild and farmed fish respectively. Wild salmon had a slightly lower mean fat content than farmed (12.3 *vs* 12.5%$^{w}/_{w}$) but showed more variation in fat content. Taste panels were unable to detect a statistically significant flavour difference between farmed and wild salmon (Schallich and Gormley, 1996b).

NON-INVASIVE AND NON-DESTRUCTIVE TESTING OF FARMED SALMON

Non-invasive testing of foods is highly desirable as the units tested are not destroyed and so are still available for sale. Near-infrared (NIR) spectroscopy has been applied (by placing a fibre-optic probe on the side of the salmon) to the measurement of oil and moisture in farmed salmon. Six selected measuring points were used on the dorsal and ventral surfaces of each fish side and 294 sample sites were used overall. The best dorsal calibration produced

a standard error of prediction for oil and moisture of 2.0 and 1.45% respectively; corresponding figures for the best ventral calibrations were 2.4 and 1.9%. These results suggest that the NIR procedure has application in situations where only approximations of oil and moisture content are required (Downey, 1996).

MEASURING THE FAT CONTENT OF HERRING

Fat content is always an issue in the bulk sale of herrings and so it is important to have a test that is robust, fast and accurate. A Task Force in Ireland on the 'Management and Marketing of Herring' requested the development of a measuring system for the fat content of herring which could be used throughout the industry. This prompted a study at Ashtown Food Research Centre in association with Bord Iascaigh Mhara and the Marine Institute which compared the standard Soxhlet method to four other tests namely near infrared, microwave test, fexIKA method and the Torry Meter. The main findings were: (i) comparisons between the Soxhlet and the other test procedures for estimating the fat content of herrings showed that the near infrared (NIR) method gave the best prediction of Soxhlet (standard method) results. The microwave test performed next best. (ii) The Torry meter fulfils the requirement of industry for a rapid procedure as do the NIR and microwave methods. The Soxhlet and fexIKA use solvent extraction and are relatively slow procedures. (iii) The microwave method is a low cost procedure; the Torry meter is cheap on a sample basis but the NIR test is expensive due to the cost of the instrument. The Torry and NIR procedures require minimal operator skills while the microwave method needs an attentive operator and is open to inter-operator differences. (iv) Torry fat meter readings were unaffected by filleting but were influenced considerably by factors affecting the water content of herring such as icing (increases water content) or desiccation (Vogt *et al.*, 2002).

There are many processed herring products on the market and competition is keen. Therefore, products need to have something extra to succeed and this was the goal of this trial. A range of preservative-free, added-value, chilled herring products were developed with excellent sensory properties and with a commercial, high-quality shelf-life. The preparation of a special mayonnaise which was milder, creamier and less acidic than conventional mayonnaise was a key factor in the development of the products. Products with gourmet sauces and packed in glass jars were aimed at the continental European market, especially the German market, while the shorter-shelf-life salad product was aimed at the Irish and UK markets (Ross *et al.*, 1993). The composition of the marinating solutions is given in Table 2 and some test values in Table 3. The so-called Matjes Reif product was very tender (low shear value) and had a low level of acid relative to the other two products.

Table 2: Composition of herring marinating solutions

	%			
Solution	Salt	Acetic acid	Water	Matjes Reif [a]
1	14	7.0	79.0	0
2	11	5.5	83.5	0
3	12	0	85.5	2.5

[a]Matjes Reif solution supplied by Reinert Gruppe, Germany

Table 3: Tests on marinated herring—typical values

Marinating solution	Shear value (kN)	Salt (% w/w)	Acetic acid (%)	pH	Colour (L/b)[a]
1	2.6	6.6	3.0	3.9	7.7
2	2.0	5.1	2.8	4.1	7.6
3	0.5	7.2	<0.5	5.1	6.2

[a]Hunter colour meter [white/yellow (L/b)] ratio

OAT-ENRICHED FISH PRODUCTS

Oats are a traditional food with a good health image, some of which is attributed to their ß-glucan content. Oats are often fractionated by millers to oat flour and oat bran with the former particularly rich in ß-glucan and sold as such to consumers. Oat flour is, therefore, a by-product of the fractionation and its utility as an extender of fish protein was evaluated in this study. Oat flour, oat bran and whole oats were used as extenders in frozen minced nuggets of cod and salmon, and inclusions of circa 5% (based on fish weight) were the upper limit for acceptability (Table 4). Most emphasis was on the use of oat flour. The inclusion of oat fractions decreased the moisture content of gels and nuggets made from the minces and also decreased the whiteness of cod gels and nuggets, and the redness of salmon gels and nuggets. The oat fractions enhanced water binding and raised the compressive strength, puncture force and elasticity index of gels from cod and salmon which suggests a synergistic effect between the oat and fish constituents (Braren and Gormley, 1998).

FISH SURIMI IN GLUTEN-FREE BREAD

The absence of gluten creates major problems for bakers and conventional breads generally have a better structure than gluten-free breads The search for alternative proteins with properties mimicking those of gluten continues and it is in this context that fish surimi was tested. A control gluten-free bread formulation based on rice and potato starch was supplemented with fish surimi (as a potential structure enhancer) at a 10% inclusion level (of starch weight). Frozen surimis from mackerel, blue whiting, red gurnard and pollock were evaluated. The inclusion of surimi darkened crust colour, and softened

Table 4: Taste panel preference scores[a] (rank sums)[b] for cod nuggets with oat fractions

	Panel		
	1	2	3
Oat fraction inclusion[c] (%)	Oat flour	Oat bran	Whole oats
0	11	15	13
2.5	19	21	14
5	30	25	29
10	32	35	30
15	43	39	34
No. of tasters	9	9	8

[a]Samples ranked 1st (most preferred) to 5th
[b]Sums for 8 or 9 tasters; low sums indicate the preferred samples
[c]Relative to weight of fish mince

the crust and crumb except for bread with red gurnard surimi which had a much firmer crust and crumb, and the smallest loaf volume. There were inverse relationships between loaf volume x crust/crumb firmness and positive relationships between crust/crumb firmness x number of gas cells cm^{-2}. The breads with surimi had an attractive appearance. Paired comparison taste

panel tests for acceptability indicated no difference between the control and the surimi breads, with the exception of bread with blue whiting surimi which was preferred ($P<0.05$) to the control (Gormley *et al.*, 2003).

POLYUNSATURATES IN SALMON

The so-called omega-3 polyunsaturates (PUFAs) have a good health image and have been shown to have anti-thrombotic and other beneficial effects in humans. Salmon are a good dietary source. Tests have shown no differences between wild and farmed salmon as sources of omega-3 PUFAs with both types supplying about 1g per 100g fish consumed. However, the ratio of omega-3 to omega-6 PUFAs was on average 6-fold higher in the flesh oil of wild salmon than in farmed due to the use of lineoleic (an omega-6 PUFA) rich vegetable oil in the diet of the latter (Cronin *et al.*, 1991).

COLD CHAIN STUDIES

The cold chain is of paramount importance for maintaining the quality of both frozen and chilled consumer food products and tests were conducted on cold chain performance (Gormley, 1990; 1996a). These included the effects of temperature fluctuations below freezing point followed by storage for 8 months at a steady -30°C (termed fluctuating regime) on the quality of raw salmon fillets and smoked mackerel fillets. Duplicate samples were stored at a steady -60°C for 8 months (termed superfreezing) and at a steady -30°C (termed control) for comparison (Gormley *et al.*, 1999; Gormley and Walshe, 2000). Superfreezing gave the lowest level of rancidity in both fish types and the fluctuating regime the highest. Sensory tests (for preference) on both microwaved salmon and smoked mackerel showed no statistically significant difference between samples from the superfreezing, fluctuating or control regimes. These results highlight the importance of minimising fluctuating cold storage temperatures for sensitive products, such as smoked mackerel, and also the potential benefits of superfreezing (Gormley *et al.*, 2000). However, the benefits of superfreezing must be balanced against the cost.

FREEZE-CHILLING OF FISH

Freeze-chilling is being used increasingly in the food industry for logistic and production reasons. It enables chilled products to reach more distant markets. Freeze-chilling involves freezing and frozen storage followed by thawing and chilled storage. Part 1 of an extensive study indicated that freeze-chilling was a suitable technology for pre-packed whiting, mackerel and salmon portions and confers logistic and shelf-life benefits during distribution and retailing (Fagan *et al.*, 2003a,b). In part 2, MAP packs performed well during freeze-chilling but the packs with 100% CO_2 showed slight implosion after 5 days storage at 3-4^{0}C (Fagan *et al.*, 2004). The combination of MAP with freeze-chilling gave shelf-lives of 5 days (whiting and mackerel) and 7 days (salmon) which is 1-2 days longer than freeze-chilled portions packaged in air. The test packs conformed with EC and National Guidelines in that TVBN (total volatile base nitrogen) values were below 35 mg N/100g (Council Regulation No. 95/149/EC) and TVCs (total viable counts) less than $\log_{10}6$ cfu/g (one million viable cells per gram) with the exception of salmon packed in air (Table 5). A CO_2 atmosphere resulted in the lowest TVCs in all three species. Successful tests have also been conducted on the freeze-chilling of steamed salmon portions (O'Leary et *al.*, 2000).

Table 5: Effect of modified atmosphere packaging with freeze-chilling on the total viable count values ($\log_{10}$cfu/g) of raw fish fillets[a]

	Gaseous atmosphere					
Species	Air	30/40/30[b]	60/40[c]	CO2[d]	F-test	LSD[e]
Whiting	4.81	4.48	NT[f]	4.34	P<0.001	0.20
Mackerel	4.88	NT[f]	4.18	3.99	P<0.001	0.16
Salmon	6.23	NT[f]	5.04	4.53	P<0.001	0.32

[a]Data averaged over test days 0, 3 and 7 (samples held at 2-4°C)
[b]30%O_2/40%CO_2/30%N_2
[c]60%N_2/40%CO_2
[d]100%CO_2
[e]Least significant difference
[f]Not tested

RETAINING QUALITY IN FROZEN FISH MINCE

Fresh and frozen mince is used as a major ingredient in many frozen fish products *e.g.* fishburgers, fishcakes and other formed products. Freezing fish mince followed by thawing and re-freezing, damages the fish protein and has a deleterious effect on mince quality in terms of water-holding capacity and also its ability to form strong gels. Cryoprotectants help to reduce this damage (Gormley *et al.*, 1992; Glancy *et al.*, 1995; Gormley, 1999). Each of nine dairy ingredients tested exerted a cryoprotective effect (*i.e.* a raised water-holding capacity in the thawed fish tissue) in salmon and spent salmon frozen mince in comparison with control samples (Anese and Gormley, 1995; 1996). In frozen cod and haddock mince, only sodium and calcium caseinate and milk protein isolate exerted a cryoprotective effect while whey protein concentrate gave a reduced water-holding capacity in the thawed fish in comparison with controls.

TESTING UNDERUTILISED AND OTHER FISH SPECIES

As fish stocks dwindle and quotas tighten, the use of underutilised fish species for consumption as fillets/portions and in a range of fish products assumes new importance. For this reason, the evaluation and test processing of underutilised species has been a major topic of research at the AFRC and six separate studies have been conducted.

STUDY 1: The use of Silver Smelt (*Argentinus silus*) in products was investigated in an EU-funded project with BIM, AFRC and IFREMER (France) as partners. Emphasis was on the effects of freezing and thawing on water binding (Gormley *et al.*, 1991; 1993; 1994). The results showed that this bland, white-fleshed fish is useful for a range of products including enrobed nuggets, fingers and fishcakes; it also produces good gels (Gormley *et al.*, 1992; Gormley, 1993; Stoknes *et al.*, 2006).

STUDY 2: Taste panel tests on nine underutilised species indicated that all were liked when tasted as breaded nuggets and all compared favourably with

cod. Greenland halibut and silver smelt were the most outstanding. Both sodium caseinate and whey protein concentrate acted as cryoprotectants when incorporated into the fish minces before freezing, with the former having the larger effect (Maier *et al.*, 1997).

STUDY 3: This was funded under the Marine Research Measure of the Operational Programme for Fisheries which was administered by the Marine Institute. Tests were conducted on 23 underutilised species and taste panellists preferred six of these to cod as fillets, ten as nuggets and eight as fish-cakes. The best species were orange roughy, black scabbard, morid cod and siki shark while the least good were rabbitfish, small-eyed rabbitfish, birdbeak dogfish and flying squid (Brennan and Gormley, 1999a,b).

STUDY 4: This was conducted in 2001 on steamed fillets of 16 species. They were compared, using taste panels, with steamed cod. No sample was significantly better than cod; however

6-cm line scale with end-points of 0 (unacceptable) and 6 (very acceptable). Corresponding scores for the sugar-based marinades using blue ling were 3.46 (piri piri), 3.26 (chilli + coriander), 3.23 (Chinese), 3.14 (lemon + lime), 2.58 (sweet + sour) and 1.78 (orange). In year 3, the focus was on freeze-chilling and modified atmosphere packaging (MAP). Freeze-chilling confers logistic benefits while MAP often confers additional shelf-life to raw fish fillets. Samples of six species were packed in trays in air and in $30\%O_2/40\%CO_2/30\%N_2$ and were subjected to a freeze-chill regime (chilled component of 2-4ºC for 7 days). The results showed that freeze-chilling combined with MAP is a suitable technology for extending the shelf-life of pre-packaged portions of black scabbard, siki shark, redfish, cardinal fish, roundnose grenadier and blue whiting. The six species received good sensory acceptability scores of 4.54 (cardinal fish), 4.48 (black scabbard), 4.40 (blue whiting), 4.27 (roundnose grenadier), 3.92 (redfish) and 3.34 (siki shark) for

chilled samples at 4ºC on a scale with end-points of 0 (unacceptable) and 6 (very acceptable). The data are means for days 0, 3 and 5. Values for MAP *vs* air for the six species were 4.76 *vs* 4.32 (cardinal fish), 4.90 *vs* 4.01 (black scabbard) 4.60 *vs* 4.20 (blue whiting), 4.33 *vs* 4.21 (roundnose grenadier), 4.01 *vs* 3.73 (redfish) and 2.96 *vs* 3.72 (siki shark). In practical terms this

means a 1 to 3-day extension of shelf-life due to MAP with the exception of siki shark. These findings were supported by total volatile base nitrogen (TVBN), total viable count (TVC) and odour perception data. MAP gave higher drip (both gravity and centrifugal) values than air-packed samples.

However, the gravity drip values were not of a magnitude that required in-pack drip pads with the exception of blue whiting. Roundnose grenadier, siki shark, redfish, black scabbard and cardinal fish had an excellent white flesh; blue whiting had a more translucent appearance (Gormley and Fagan, 2005; Gormley, 2006; Oehlenschläger *et al.*, 2008).

STUDY 6: This took place in 2006 as part of the Seafood Innovation Link programme of AFRC and BIM and involved tests on blue *(Micromesistius poutassou*) and conventional whiting (*Merlangius merlangus*). Added-value breaded products from blue whiting were prepared and received good acceptability scores from taste panels. Tests on conventional whiting involved an appraisal of the effects of various on-board processing techniques on quality. This involved comparisons of gutted fish *vs* fillets stored as chilled *vs* frozen and packed in air *vs* MAP and stored for up to 7 days at 2-4°C. The samples were caught by BIM personnel on board the German deep sea vessel 'Walter Herwig III'. The results indicated that freezing (gutted fish or fillets) on-board at sea delivered the best quality in air or MAP samples during storage at 2-4°C over a 7-day period. MAP gave a 50% shelf-life extension compared to air but required in-pack drip pads (Oehlenschläger *et al.*, 2008).

The overall outcome from the six trials indicated that a number of the species have potential for sale as chilled fillets or as processed products. Their use is based on supply, the size and sustainability of the stock, and on convincing both fishermen and processors that they should catch and process them. It should be noted that many of the data are based on spot samples as it is difficult, logistically, to obtain replicate samples.

FISH AS A FUNCTIONAL FOOD

The functional food and foods-for-health sector is expanding rapidly in developed countries and presents a major opportunity for food and pharmaceutical companies. Fish and fish products have a central position in the functional foods arena as sources of calcium (from fish bones and shells), anti-hypertensive proteins (peptides and protein hydrolysates), antioxidants

(from fish skins), selenium, chitin (and its derivatives), omega-3 PUFAs, taurine and other bioactive components. Some examples of fish and fish products as functional foods were presented at the first workshop of the ongoing (2006-2008) EU 6th Framework FunctionalFoodNet Project (www.functionalfoodnet.eu) in Turku, Finland in March 2006 (Gormley, 2006b). Four studies have been conducted at AFRC on seafood as a functional food.

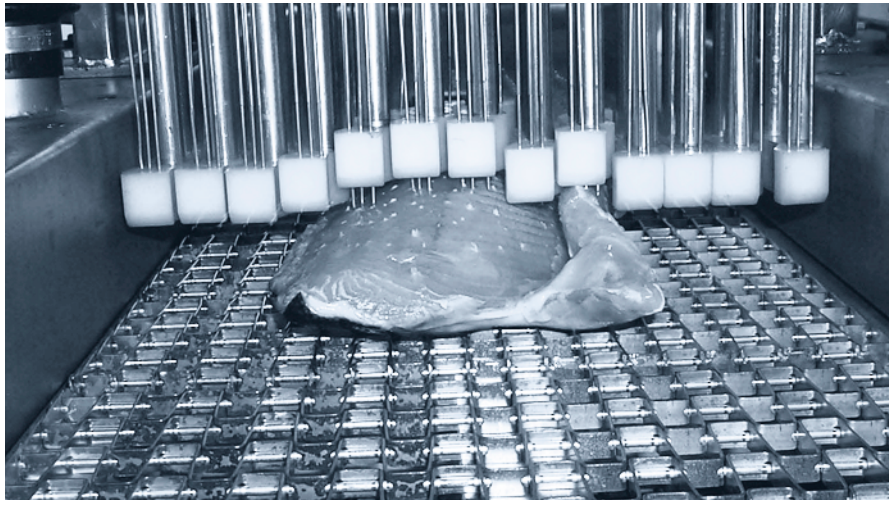
STUDY 1: Fish bone and crab shell waste as a calcium nutraceutical

There are extensive supplies of fish bones and crab shells in Ireland most of which are classified as waste. Calcium from fish bones may be highly available to humans and has potential for addition as a nutraceutical to foods. Tests were conducted on the effects of heat treatment, high pressure treatment and pH on the hardness/softness of fish bones and crab shells and also on calcium availability using *in-vitro* tests to simulate potential calcium absorption in humans. The study was funded by the Marine Institute. Bones from plaice, cod and farmed salmon (*Salmo salar*) together with crab shell waste were washed/steamed (7 min), cut (2-3 cm lengths), dried and de-fatted. Bone/shell samples were canned (1.5% brine; 35 or 50 min/121°C), hydrolysed (1h in 0.1M H_2SO_4 or 0.1M NaOH), or treated at 150 MPa for 30 min/20°C to study the effect on bone softening and calcium release. Ash, moisture and calcium contents of the powders were measured (furnace/oven/atomic absorption procedures), and dialysable/available calcium by an *in-vitro* dialysis sac method. Diffusion of calcium into the dialysis sac represented dialysable/available calcium and a sample of cheddar cheese was tested for comparison. The results showed that fish bone and crab shell powders are of limited value as calcium nutraceuticals for inclusion in food products based on the *in-vitro* tests used in these tests (Rademacher *et al.*, 2004).

STUDY 2: Taurine status of fish

Taurine is beneficial to the cardiovascular system and has particular benefit for smokers (Fennessy *et al.*, 2003). Fish is a good source of taurine and these trials investigated its content in different fish species and also its stability and

retention during fish storage, cooking and processing. The research was conducted as part of the EU-funded SEAFOODplus project. Samples of raw fish fillets were purchased (bi-weekly on eight test dates) in supermarkets (Trial 1) and spot samples of wild salmon, albacore tuna, siki shark, Greenland halibut, roundnose grenadier and Bairds smoothhead were also tested for taurine content by HPLC. Results for the first four test dates indicated taurine contents in the order plaice [range 100-160mg/100g wet weight (ww)] > cod (60-100) > mackerel (60-80) > farmed salmon (40-60). Values for the spot samples were albacore tuna (155), wild salmon (53), siki shark (44), Greenland halibut (21), roundnose grenadier (7) and Bairds smoothhead (5mg/100g ww) (Elveroll *et al*., 2006; Gormley *et al*., 2007).



In Trial 2, yellowfin tuna cubes were tumbled in a taurine/phosphate solution in order to introduce extra taurine into the fish. Taurine contents of *circa* 800-1000mg/100g ww (target 1%) were achieved in the tumbled tuna portions and these levels were largely retained in frozen, chilled, freeze-chilled and *sous vide* cooked samples. Taurine content of the microwaved samples was *circa* 10% higher than in the raw fish due, presumably, to desiccation in the former. Microwave cooking also gave a two-log reduction in TVCs compared to the uncooked samples (Neumann *et al.,* 2005; Elveroll *et al*., 2006; Gormley *et al*.,

2007). In Trial 3, salmon sides were successfully injected with taurine solution using a brine injector to give head-to-tail taurine contents of 543, 923, 1309, and 753 mg/100g raw fish in side 1 and 592, 699, 1040, 690mg/100g raw fish in side 2.

STUDY 2: Development of fish ready-meals with nutraceuticals

Ready-meals are well established in the international market place but those containing fish are a more recent feature. Ready-meals have particular benefit as carriers of functional (healthy) ingredients and nutraceuticals. Such meals have major application to the elderly who may find meal preparation difficult and who may also be lacking in trace minerals and other nutritives and non-nutritives (*e.g.* dietary fibre). This study involved the formulation, preparation and freeze-chilling of a salmon lasagne containing nutraceuticals and also a *sous vide* processed ready-meal of the same formulation except that the gluten-free pasta sheets were replaced by pasta pieces (Rigati). The research was conducted as part of the EU-funded SEAFOODplus project (Braida and Gormley, 2007).

The lasagne contained salmon sauce (50% of which was salmon pieces), Béchamel sauce, gluten-free pasta sheets and mozzarella cheese. The nutraceutical targets achieved per 400g of lasagne (or per 146g of Béchamel sauce) were apple pectin (7g), Beneo HP (5g), taurine (1.5g) and Aquamin (120mg). Apple pectin (Obipektin-ulv, Switzerland) reduces serum cholesterol and is a soluble dietary fibre; Beneo HP (ORAFTI, Belgium) is an oligosaccharide and has prebiotic properties; taurine is beneficial for cardiovascular health; Aquamin (Marigot, Ltd, Cork) is derived from algae and is a highly available form of calcium. Initially, the focus was on the Béchamel sauce and how its properties were influenced by the nutraceutical inclusions.

The gluten-free Béchamel sauce was less viscous than its wheat-containing counterpart as indicated by Brookfield viscometer readings (speed 5) of 35 *vs* 45Pa*s (5°C) and 27 *vs* 36Pa*s (20°C). The effect was more pronounced using the TAXT2i texture testing system in back extrusion mode [firmness (g)] *i.e.*

54 *vs* 108g (5°C) and 41 *vs* 62g (20°C). The gluten-free sauce was slightly whiter (Hunter L 89.8 *vs* 86.5; L/b of 12.1 *vs* 9.3) than the wheat-containing sauce. A triangle taste panel indicated a difference (P<0.001) between the sauces with 18/21 tasters correctly identifying the odd sample out. The extent of the difference was considered large by 9 tasters, moderate by 6, slight by 3, and no comment by 3. However, the difference was not significant in a preference test with 8 tasters preferring the gluten-free sauce and 13 the wheat-containing sauce. Both sauces exhibited shear thinning (Braida and Gormley, 2007).

A range of inclusions were added to the sauce, both individually and in combination (Table 6). All of the inclusions (individually) lightened sauce colour except the pectin inclusions which had a darkening effect. This was due to the slightly yellow colour of the ultra-low viscosity pectin. The Beneo HP had a thinning effect on the sauce while aquamin caused a slight thickening. Pectin also thickened the sauce especially at the higher inclusion level (Table 6)

Table 6: Effect of different inclusions on the physical properties and sensory acceptability of a gluten-free Béchamel sauce

Inclusion (%)[a]	Moisture (%)	Colour (L/b)[b]	Viscosity (Pa*s)[c]	Firmness (g)[d]	Sensory score[e]
None	76.5	10.9	51	201	3.34
Beneo HP[f] (3.4)	73.3	11.1	38	131	3.12
Aquamin[g]	76.0	13.2	67	210	2.67
Taurine (1)	76.2	11.9	53	170	2.21
Pectin (2.5)[h]	73.6	7.3	66	404	NT
Pectin (4.8)[h]	70.1	6.0	171	624	2.33
All inclusions	NT[i]	NT	NT	NT	1.72
F-test	P<0.001	P<0.001	P<0.001	P<0.001	P<0.05
LSD[j]	1.07	2.27	19.3	36.6	0.997

[a]As % in Béchamel sauce; [b]White/yellow Hunter ratio; [c]Pascal seconds; [d]Back extrusion force; [e]Acceptability on 6-cm scale with end-points 0 (unacceptable) and 6 very acceptable; [f]Oligofructose; [g]Soluble algal calcium; 20mg in 146g of Béchamel sauce; [h]Ultra low viscosity pectin; [i]Not tested; [j]Least significant difference

Each of the inclusions reduced sauce acceptability score (Table 6) and all the inclusions combined gave the lowest score. However, the data for this treatment had the highest coefficient of variation indicating that some of the panellists liked this sauce while others did not (Braida and Gormley, 2007). It was decided, therefore, to use the 'all inclusions' sauce in the lasagne. Paired comparison and acceptability tests [6-cm scale with end-points of 0 (unacceptable) and 6 (very acceptable); 20 tasters] between the all-inclusions, gluten-free salmon lasagne and a commercial wheat-containing salmon lasagne showed a preference ratio of 5/15 ($P<0.05$) and a score of 2.59 *vs* 3.59 in favour of the latter. This difference was attributed to differences in spice content rather than to the Béchamel sauce with the inclusions (Braida and Gormley, 2008). The gluten-free sample was also tested by the commercial company who produced the wheat-containing lasagne and they attributed the difference to the salmon sauce (less spice/flavour) rather than to the Béchamel sauce. The company are now carrying in-house trials on the gluten-free product. The *sous vide* processed gluten-free pasta product (*i.e.* with Rigati) received good acceptability scores in small scale sensory trials. Both the gluten-free salmon lasagne and the *sous vide* Rigati product was subjected to freeze-chilling. The former had a chilled shelf-life of at least 10 days and the latter of at least 30 days at 2-4°C. No pathogenic bacteria were present in either product.

CONCLUSIONS

- Outcomes from a range of seafood trials have been reported which have wide application to the seafood sector, to food processors, to nutritionists, to wholesalers and retailers, and to consumers.
- Many of the data have been disseminated to industry via workshops, personal contacts and publications, and most aspects will continue to be relevant to end-users for a number of years to come.
- Technology transfer to industry has been achieved for a number of the outcomes and the drive towards technology transfer will continue.

RECOMMENDATIONS TO INDUSTRY

- Food companies should not underestimate the importance of surveys on consumer preference for seafood products in their planning of future activities in product development.
- Retailers are encouraged to use the condition factor as a purchasing standard for farmed salmon. This will ensure well conditioned salmon for sale to the consumer.
- Product development is essential for the survival of many seafood companies. In this context there should be major emphasis on the use of the so-called underutilised species both for sale as fillets and also in the development of new products.
- Seafood processors should build on the high reputation of seafoods as healthy foods and should exploit this in their marketing. The full potential of fish and their by-products as functional foods should be explored and utilised. This is a rapidly expanding and potentially remunerative area.

- Seafood processors should fully utilise the grant-aid packages available from state agencies especially in the areas of new process and product development.

GLOSSARY OF FISH SPECIES TESTED

Albacore tuna (*Thunnus alalunga)*
Baird's smoothhead (*Alepocephalus bairdii*)
Birdbeak dogfish *(Deania calceus)*
Black scabbard (*Aphanopus carbo*)
Blue hake *(Antimora rostrata)*
Blue whiting *(Micromesistius poutassou*)
Blue ling (*Molva dipterygia*)
Bluemouth rockfish *(Helicolenus dactylopterus)*
Cardinal fish (*Epigonus telescopus*)
Cod (*Gadus morhua*)
Flying squid *(Todarodes sagittatus)*
Forkbeard *(Phycis blennoides)*
Greenland halibut (*Reinhardtius hippoglossoides*),
Haddock (*Melanogrammus aeglefinus*)
Herring *(Clupea harengus)*
Ling *(Rachycentron canadum)*
Longnose velvet dogfish *(Centroscymnus crepidater)*
Mackerel (*Scomber scombrus*)
Megrim (*Lepidorhombus whiffiagonis*)
Monkfish *(Lophius piscatorius)*
Morid cod *(Mora moro)*
Orange roughy *(Hoplostethus atlanticus)*
Plaice (*Pleuronectes platessa*)
Pollock (*Pollachius virens*)
Rabbit fish *(Chimaera monstrosa)*
Ray wing (*Raja claviata*)
Redfish (*Sebastes mentella*)

Red gurnard *(Aspitrigla cuculus)*
Roughhead grenadier *(Macrourus berglax)*
Roundnose grenadier (*Coryphaenoides rupestris*)
Salmon (*Salmo salar*)
Siki shark (*Centroscymnus coelolepis*)
Silver roughy *(Hoplostethus mediterraneus)*
Silver smelt (*Argentinus silus*)
Small eyed rabbit fish *(Hydrolagus affinis)*
Sole *(Solea solea)*
Trout *(Salmo trutta)*
Tusk *(Brosma brosma)*
Whiting (*Merlangius merlangus*)
Yellowhead tuna (*Thunnus albacares*)

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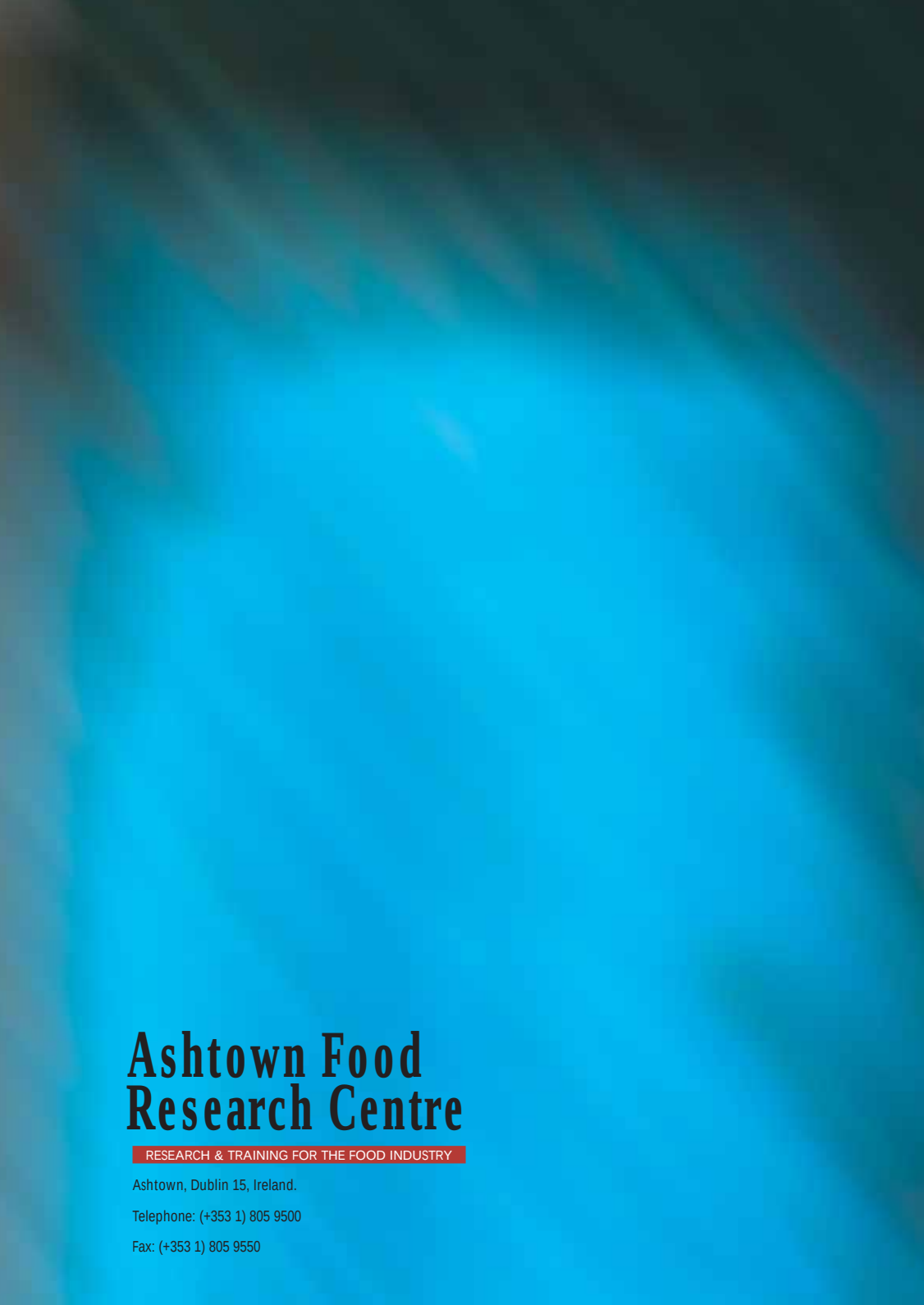

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