SeaHealthUCD

Issue 27B: April, 2018: This is a supplement to SeaHealth-ucd Issue 27

Omega-3 status of farmed salmon

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Outcomes are reported from a study, which is a snapshot in time, on the omega-3 polyunsaturated fatty acid (PUFA) content of raw farmed salmon samples purchased in retail outlets in Dublin and vicinity over a 6-month period with emphasis on eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids. Consumers are increasingly aware of the health benefits of oily fish via social and other media and also through promotions by health professionals and supermarkets. Farmed salmon is often the oily fish of choice due to its ready availability and dwindling supplies of wild oily fish. New information on the many beneficial health aspects of EPA and DHA is coming on stream on a daily basis and this has been has been reviewed in another supplement i.e. SeaHealth-UCD Supplement 27A, April, 2018. Recommended intakes of EPA and DHA range widely as evidenced in *Global Recommendations for EPA and DHA Intake* (Revised 16 April 2014) and an intake of 0.5g per day for an adult is a reasonable target based on current information. Oily fish is a preferred source to fish oil supplements and an average serving (150g) of most oily fish will supply this amount.

1. Sampling and testing

Trials 1a & 1b: Measuring moisture & oil content (methodology trials): Trial 1a was conducted to measure moisture content of salmon by three different methods. A side of salmon was blended and five replicate samples were dried using each method i.e. (i) oven (100°C/10h) – standard UCD-IFH procedure; (ii) vacuum oven (70°C; 560mmHg vacuum); (iii) freeze drying (72h). The standard oven procedure was then used to measure the moisture content of all fish samples in mainstream Trial 2.

In oily raw fish moisture plus oil content constitute about 80% of the composition. In Trial 1b the oil content of 10 replicate raw salmon samples from the same fish was approximated by subtracting moisture content from 80. The results were compared (verified) with oil content of the 10 replicates measured by the standard solvent/soxhlet procedure used routinely in the UCD-IFH proximate analysis laboratory. The approximation method was then used to estimate the oil content of all raw fish samples in mainstream Trial 2.

Trial 2: Omega-3 PUFA status of fish samples: This was the mainstream trial of the overall study. Sampling spanned mid-October 2017 to early-March 2018 on a weekly basis except in December when no samples were taken. Five samples were purchased from retail outlets in Dublin and vicinity each week comprising four of farmed salmon (*Salmo salar*) and one a wild species, usually mackerel. In all, 65 samples of farmed salmon and nine of mackerel were tested. The 65 salmon samples were from Scotland (25), Norway (22) and Ireland (18) and 17 were farmed organically and 48 non-organically. Two samples of wild salmon i.e. pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*) were also tested and one each of fresh sardines, canned sardines and farmed sea bass. The four farmed salmon samples purchased each week were obtained from different retail stores to ensure all were from different fish; 7 different stores were utilised in the overall study. Each sample was de-skinned, blended, vacuum-packed and stored at minus 20°C prior to analysis for fatty acid profile. When 20 frozen samples were accumulated they were thawed at 4°C and tested (circa 0.8g sample size) using the rapid microwave-assisted procedure of Brunton et al., 2015. Outputs are reported here for oil content, EPA, DHA, DPA (docosapentaenoic acid), LA (linoleic acid), ALA (alpha-linolenic acid) and total fatty acid content.

Trial 3: Omega-3 PUFA status of farmed salmon & mackerel skins: This trial was conducted by request of a health professional to determine the PUFA fatty acid status of farmed salmon and mackerel skins. The skins were removed from the flesh, and both flesh and skins were tested as for the mainstream trial above.

Trial 4: Effect of different cooking methods on omega-3 retention: A cooking trial was conducted where sub-samples from a side of raw salmon were cooked by poaching (95°C/10min), microwave (3.3min) and roasting (180°C/20min) procedures. A fourth cooked sample was obtained from a Bain Marie in a restaurant to study the effect of warm-holding on PUFA status. The omega-3 status of the samples was tested as for the mainstream trial above.

2.1 Results and outcomes

Trials 1a & 1b: Salmon moisture & oil content (methodology trials; Tables 1 & 2)

Table 1: Moisture content (%) with standard deviations (SDs) of raw farmed salmon sample measured by three different methods; oil (%) measured by standard solvent/soxhlet procedure

Drying method	Moisture	Oil (dry weight basis)
Oven (100°C; 16h)	67.5 (0.06)	36.8 (1.65)
Vacuum oven (70°C; 560mm vacuum)	67.3 (0.07)	36.3 (1.09)
Freeze-drying (72h)	47.7 (1.01)	36.7 (0.63)
F-test	$P<0.001$	NS
LSD	0.88	1.74

Comment: The oven and vacuum oven gave the same moisture contents. However, freeze-drying gave a lower reading. It was surmised that these samples may have been left exposed before freeze-drying resulting in some moisture loss and the introduction of partly dried material into the freeze-drier. This was confirmed by the oil content data which showed that the dried samples used to measure oil content were almost identical as indicated by almost identical oil contents. Standard deviations were all small indicating a high level of precision between replicates. On the basis of these results the oven procedure (100°C; 16h) was used to measure the moisture content of all raw oily fish samples in mainstream Trial 2.

Table 2: Raw salmon oil content measured by difference & by analysis

	Moisture (%)	Oil (%) by difference	Oil (%) by analysis
Mean	67.4	12.6	11.1
SD	0.16	0.16	0.42
%CV	0.23	1.24	3.53

Comment: The data are based on 10 replicate samples. In oily fish moisture plus oil contents comprise about 80% of the composition. Oil content is approximated by subtracting moisture content from 80. Oil content by difference was higher in all 10 replicates than oil measured by the solvent/soxhlet procedure. However, the former is still acceptable for most practical applications and was used to estimate oil content of samples in the mainstream trial. All coefficients of variability (%CV) were small indicating close agreement between replicates.

Trial 2: Omega-3 PUFA status of fish samples

In the tables below PUFA content of the samples is presented as percentage (%) i.e. gPUFA/100g raw fish unless stated otherwise. Standard deviations (SDs) and % coefficients of variation (CVs) (SD/mean x 100) are also given.

2.1 Oil, EPA, DHA & DPA contents (Tables 3, 4 & 5; Figure 1)

Table 3: Oil content (%) of raw farmed salmon & selected other species/samples

Species	No. of samples	Mean	SD	% CV
Salmon (farmed)	65	13.6	2.81	20.7
Mackerel	9	14.5	2.71	18.6
Fresh sardines	1	4.48	-	-
Seabass (farmed)	1	7.02	-	-
Comment: Mean oil contents were as expected; individual values ranged widely (see SDs & %CVs) due to stage of maturity (farmed & wild fish), feeding regime (farmed fish) & food availability (wild fish). The correlation coefficient between oil and EPA+DHA content was small (r = 0.44) indicating a weak relationship (Fig. 1). The mean value of 13.6% oil for salmon is higher than that found by Schallich & Gormley (1996) for 308 head-on farmed salmon at retail level (12.5%; SD 2.52) measured with a Torry meter. However, the approximation method used to measure oil in the current study overestimates oil content by circa 1% (see Table 2) and so makes current data identical with that of Schallich & Gormley (1996).				

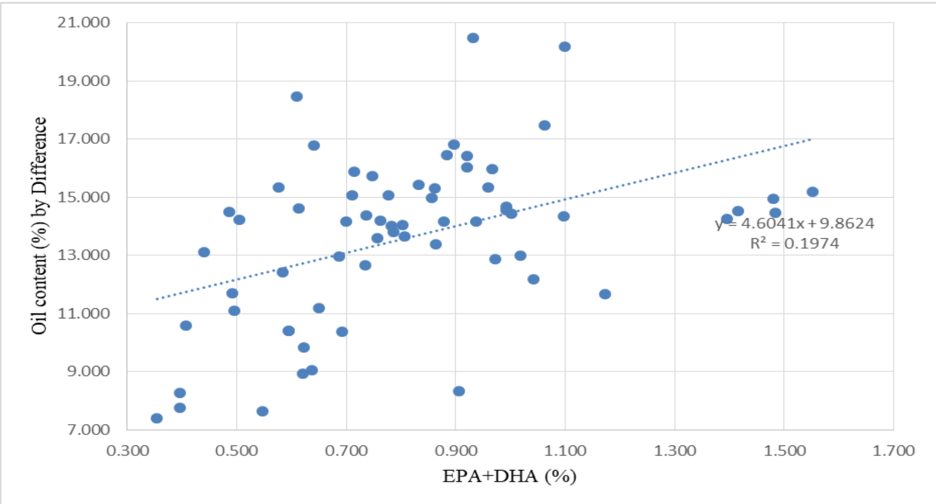

Figure 1: Correlation between EPA+DHA (%) and oil content (%) of 65 raw farmed salmon samples.

Table 4: Mean EPA & DHA contents (%) (SDs) of raw farmed salmon, mackerel & selected other species purchased from retail outlets in Dublin & vicinity (n = number of samples)

Species	n	EPA	DHA	EPA+DHA
Salmon (farmed)	65	0.30 (0.134)	0.52 (0.149)	0.81 (0.272)
Mackerel	9	0.75 (0.201)	1.29 (0.379)	2.04 (0.571)
Fresh sardines	1	0.34	0.75	1.09
Canned sardines	1	0.27	0.33	0.59
Pink salmon	1	0.11	0.33	0.44
Chum salmon	1	0.15	0.29	0.44
Seabass (farmed)	1	0.15	0.31	0.46

Comment: Mackerel and fresh sardines had higher EPA+DHA contents than farmed salmon showing they are very valuable species in terms of consumer health. Farmed salmon is also a good supplier of EPA and DHA and a 150g of raw salmon portion will deliver circa 1.2g. The 65 farmed salmon samples bought at retail level in Dublin and vicinity came from Scotland (25). Norway (22) and Ireland (18) (Table 8). Pacific pink and chum salmon delivered less as did farmed seabass and canned sardines. The Norwegian Institute of Nutrition & Food Research (NIFES; 2016) showed that EPA+DHA levels in Norwegian farmed salmon fell from 2.74% in 2010 to 1.15% in 2015 – a fall of 58%. Tests on Norwegian farmed salmon in the current study (Table 8) showed a mean EPA+DHA content of 0.81% suggesting a further fall of circa 30% in the period 2015 to 2018. This fall off is due the inclusion of vegetable oil in the fish feed brought about by the shortage of fish oil and its increasing price (see LA levels – Table 9). The mean value of 0.77% EPA+DHA for the 18 samples of Irish farmed salmon tested in the current study (Table 8) compares with that of 1.03% found by Cronin et al. (1991) showing a fall in EPA+DHA in a 27 year period of about 25%.

Table 5: Mean DPA content (%) (SDs) of raw farmed salmon, mackerel & selected other species purchased from retail outlets in Dublin & vicinity (n = number of samples)

Species	n	DPA	SD	%CV
Salmon (farmed)	65	0.13	0.057	43.2
Mackerel	9	0.11	0.064	57.7
Fresh sardines	1	0.06	-	-
Canned sardines	1	0.05	-	-
Pink salmon	1	0.02	-	-
Chum salmon	1	0.03	-	-
Seabass (farmed)	1	0.05	-	-

Comment: Salmon and mackerel had higher levels of DPA than the other species but there was a wide variation in content as evidenced by the large %CV values for salmon and mackerel. DPA (docosapentaenoic acid; 22:5ω-3) is sometimes called the forgotten omega-3 PUFA as it has been overshadowed by its relatives EPA and DHA. DPA has not been extensively studied because of the limited availability of the pure compound. It is an intermediate product between EPA and DHA and its presence leads to higher levels of EPA and DHA in fish flesh. The literature on DPA is limited; however, the available data suggests it has beneficial health effects e.g. DPA is associated with a lower risk of heart disease (Del Gobbo et al., 2016).

2.2 LA, ALA & EPA+DHA/LA ratios (Table 6)

Table 6: Mean LA & ALA contents (%) (SDs) of raw farmed salmon, mackerel & selected other species; also EPA+DHA/LA ratios (n = number of samples)

Species	n	LA	ALA	EPA+DHA/LA
Salmon (farmed)	65	1.44 (0.534)	0.47 (0.240)	0.64
Mackerel	9	0.24 (0.079)	0.14 (0.069)	8.52
Fresh sardines	1	0.10	0.06	10.61
Canned sardines	1	0.04	0.01	13.34
Pink salmon	1	0.02	0.01	23.58
Chum salmon	1	0.13	0.05	3.53
Seabass (farmed)	1	0.77	0.14	0.59

Comment: LA (omega-6) and ALA (omega-3) are both PUFAs of plant origin; both are essential fatty acids. Modern diets are very high in LA due to mass consumption of foods containing vegetable oils and, therefore, the inclusion of vegetable oil in fish feeds is considered a negative. The difference between EPA+DHA/LA ratios for farmed and wild fish is marked with very low ratios for the former and desirable high ratios for the latter. This may have a negative effect on the omega-3 index (O3I) in humans (see SeaHealth-ucd, April 2018, Supplement 27A). Farmed salmon had the highest ALA content but differences between wild and farmed fish were much less than for LA. Conversion of ALA to EPA/DHA *in-vivo* is minimal.

2.3 EPA+DHA: by salmon production method & country of origin (Tables 7 & 8)

Table 7: EPA+DHA content (%) of organic & non-organic raw farmed salmon samples (n = number of samples)

Sample	n	Mean	SD	%CV
Organic	17	0.77	0.200	26.0
Non-organic	48	0.83	0.293	35.3

Comment: Salmon produced organically had a slightly lower EPA+DHA content than non-organic samples. This was unexpected as it was assumed that organic would contain more than non-organic samples. Organic salmon samples sold for a mean price of €2.50/100g compared with €2.33 for non-organic. Some of the organic samples were sold as 'special offers' by retailers thus distorting the average price/100g downwards.

Table 8: EPA+DHA content (%) of farmed salmon by country of origin (n = number of sample)

Sample	n	Mean	SD	%CV
Scotland	25	0.86	0.309	36.0
Norway	22	0.81	0.281	34.7
Ireland	18	0.77	0.198	25.7

Comment: Of the 65 farmed salmon samples bought at retail outlets in Dublin those from Scotland had the highest EPA+DHA content and those from Ireland the lowest. Irish samples had least variation as indicated by the %CV.

2.4 LA and EPA+DHA/LA: by country of origin (Table 9)

Table 9: LA content (%) & EPA+DHA/LA ratios of farmed salmon by country of origin (n = number of sample)

Sample	n	LA	SD	EPA+DHA/LA	SD
Scotland	25	1.30	0.492	0.77	0.479
Norway	22	1.46	0.503	0.59	0.256
Ireland	18	1.64	0.610	0.52	0.204

Comment: Irish farmed salmon had the highest LA content and Scottish the lowest suggesting that feed used in Ireland had more vegetable oil than that in Scotland. Scottish salmon had a much higher EPA+DHA/LA ratio (desirable) than Irish produced salmon.

2.5 EPA+DHA: by month & store of purchase (Tables 10 & 11)

Table 10: EPA+DHA content (%) of raw farmed salmon & mackerel samples purchased in different months (2017/2018)

	Salmon (n=number of samples)			Mackerel (n=number of samples)		
Month	n	Mean	SD	n	Mean	SD
October	12	0.57	0.161	2	1.347	-
November	15	0.79	0.248	3	2.530	-
December	0	-	-	0	-	-
January	16	0.89	0.233	2	2.005	-
February	16	0.95	0.313	2	2.036	-
March	6	0.77	0.172	0	-	-

Comment: EPA+DHA values for salmon were lowest in October and highest in February and depend, presumably, on the condition and maturity of the fish, and on feeding patterns. Values were also lowest in October for mackerel; however, the small number of samples means that valid comparisons cannot be made.

Table 11: EPA+DHA content (%) of raw farmed salmon samples purchased from different stores

Store	No. of samples (n)	Mean	SD	%CV
A	23	0.83	0.235	28.4
B	15	0.70	0.199	28.3
C	8	0.74	0.232	31.2
D	7	0.92	0.297	32.1
E	6	0.97	0.438	45.2
F	5	0.91	0.371	41.0
G	1	0.62	-	-

Comment: EPA+DHA values fell into four groups i.e. stores D, E , F salmon had the highest content followed by store A, and then another group B and C, and finally store G (this can be left out of the comparison as there was only one sample). It is not possible to pinpoint the exact reasons for the differences. For example, stores D, E, F may have had a higher purchasing specification.

Trial 3: Omega-3 PUFA status of farmed salmon & mackerel skins (Table 12)

Table 12: EPA+DHA & LA contents (%) of skin & flesh of raw farmed salmon & of mackerel

Sample	EPA+DHA	LA	EPA+DHA/LA
Salmon skin	1.13	1.86	0.63
Salmon flesh	0.99	1.77	0.63
Mackerel skin	5.88	0.61	9.59
Mackerel flesh	2.24	0.19	11.62

Comment: This trial was conducted following a request from a health professional. There was not much difference between values for salmon flesh and skin. However, mackerel skins had much higher levels of EPA+DHA than the flesh; LA values were much higher in mackerel skin than in flesh but both were much lower than LA values for salmon flesh/skins. This was reflected in the EPA+DHA/LA values which were much more favourable in the mackerel samples. It is recommended that salmon and mackerel skins should not be eaten frequently as the oily skin may have contaminants picked up from the environment, e.g. traces of dioxins and PCBs.

Trial 4: Effect of different cooking methods on omega-3 retention (Table 13)

Table 13: Effect of cooking on EPA+DHA retention in farmed salmon samples

Cooking method	EPA+DHA (%)	Weight loss (%) during cooking	Retention (%) of EPA+DHA
Poached (95°C/10min)	0.75	6.1	86.2
Microwaved (3.3min)	0.82	13.6	86.8
Roasted (180°C/20min)	0.77	6.9	87.6
Warm-held	0.82	Unknown	-
Raw salmon (control)	0.92	Not cooked	-

Comment: The retention of EPA+DHA during cooking by the three methods was excellent (>86%) which shows the resistance of these PUFAs to oxidation. Even more remarkable was the EPA+DHA content of the warm-held sample form a local restaurant. This sample had undergone cooking and warm-holding in a Bain marie with overhead 'warming' lights. The content of 0.82% may be artificially high due to moisture loss in the salmon during warm-holding. However, it still means that this 150g portion of cooked salmon would deliver 1.2g of EPA+DHA. These high levels of retention agree with previous findings for heat treated oily fish samples by Cronin *et al.* (1990).

3. Conclusions

- Farmed salmon samples purchased in retail outlets contained satisfactory amounts of EPA+DHA
- 150g of raw farmed salmon delivers circa 1.2g of EPA+DHA while cooked delivers about 1g. This equates to a 2-day supply based on a target intake of 0.5g/adult/day
- Salmon produced organically had less EPA+DHA than those produced non-organically despite the fact that the former sell for a higher price
- Scottish farmed salmon had a higher EPA+DHA content than Norwegian which in turn had higher levels than farmed salmon produced in Ireland
- EPA+DHA in Norwegian farmed salmon decreased by 58% between 2010 and 2015 and results from the current trial suggest it fell again by 30% between 2015 and 2018.

EPA+DHA in Irish farmed salmon fell by about 25% in the period 1991-2018

- High levels of LA in farmed salmon compared to wild oily fish is a negative and indicates use of vegetable oil in formulated fish feed

- EPA+DHA showed good stability to oxidation during cooking of farmed salmon

4. Acknowledgements

Sincere thanks to Dr Sabine Harrison, Eamon Power and Vincenzo del Grippo for their direction and help with this project. Thanks also to The Food Safety Authority of Ireland for part-funding the project and to BIM for some of the pictures.

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6. More information

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