Queen Margaret University

EDINBURGH

Review of Nutritional & Health Benefits for the British Trout Association

Dr Jane M McKenzie
Dr Laura Wyness

British Trout Association Client Report

Executive summary

Fish plays an important role in the diet as it provides a number of nutrients, including protein, the long-chain omega-3 polyunsaturated fatty acids (*n*-3 PUFAs), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (in particular, in oil-rich fish), and a number of vitamins and minerals. Current intakes of fat have been linked to higher risks of chronic diseases and, consequently, dietary recommendations advise reducing relatively high intakes of saturated fatty acids and increasing intakes of monounsaturated and highly unsaturated fatty acids (DH; WHO/FAO 2003). Compared to meat, poultry and eggs, fish is low in saturated fatty acids (mean saturated fat intake for adults aged 19-64 years is 12.7% of food energy, which is above the recommended 11%) (Bates *et al.* 2012). Fish is recommended as part of a healthy diet, the recommendation in the UK being that two portions of fish a week should be consumed, one of which should be oily. This is because it is thought that long-chain *n*-3 PUFAs present in oil-rich fish and fish oil are associated with beneficial health outcomes.

Fish can be described by its fat content, and is generally classified as oil-rich fish or white fish. The UK's Scientific Advisory Committee on Nutrition (SACN)[1] defines oil-rich fish (such as trout, salmon and mackerel) as containing 5-20% fat whereas white fish (such as cod, haddock and pangasius and tilapia) typically contains only 1-2% fat (SACN, 2004).

There is good evidence that shows fish consumption protects against coronary heart disease and stroke. Including fish in the diet is particularly important for women around the time of pregnancy as evidence suggests it may reduce the risk of eczema and benefit cognitive development in the offspring. Fish intake during childhood may also decrease the risk of asthma, eczema and hay fever. Oil-rich fish, such as trout, may be associated with a slower rate of cognitive decline in later life, and therefore would be beneficial to include in the diet of older people. Oil-rich fish may also be effective as a treatment for depression due to the high levels of *n*-3 PUFA, in particular the long-chain *n*-3 PUFAs. There is some evidence that suggests oil-rich fish such as trout is beneficial for the immune system and due to the high protein content, which helps satisfy appetite, fish in general, may help reduce the risk of overweight and obesity.

According to the Marine Conservation Society (MCS) rainbow trout is a good choice of fish for consumers in terms of environmental sustainability. The MCS advise that farmed brown or sea trout, as well as farmed Atlantic salmon should only be eaten occasionally as based on available information these fish should probably not be considered sustainable at this time.

Following an analysis of environmental contaminants in Scottish marine and freshwater fish and shellfish none of the sampled fish were in breach of set limits and some freshwater fish, such as trout, may show lower levels of bio-accumulation compared to other freshwater fish.

Although trout is considered an oil-rich fish, it has relatively low total fat and saturated fat compared to other oil-rich fish such as salmon, mackerel and sea bass. Trout also has a favorable ratio of *n*-6:*n*-3 ratio which would help optimize the overall *n*-6:*n*-3 in the diet and improve the cardio-protective properties of the fat within the diet. Raw trout can be considered a source of vitamin B_1, vitamin B_6 and potassium and a rich or high source of protein, *n*-3 PUFA, vitamin D, vitamin B_3, vitamin B_{12}, phosphorus and selenium. Including trout in the diet can provide many nutrition and health benefits particularly to women around pregnancy, young children and teenagers, and older adults.

[1] The Scientific Advisory Committee on Nutrition (SACN) is an advisory Committee of independent experts that provides advice to the Public Health England as well as other government agencies and Departments.

Introduction

Consumption of fish

Distinct differences in fish and seafood availability between European countries can be observed from data on food purchases and availability collected via household budget surveys on food (Elmadfa *et al.* 2009). According to data from the Expenditure and Food Survey, fish purchases have remained quite similar with only small fluctuation between 2000 and 2006, but there has been a significant downward trend in recent years which is thought to be due to the recession. Fish purchases fell by 8.6% between 2008 and 2011 from 161 to 147g/person/week. Regarding different types of fish, while average purchases of shellfish and salmon have increased over the last decade, purchases of white fish (fresh, chilled or frozen) have decreased from 36g to 17g/person/week (Defra, 2011).

Food consumption, nutrient intakes and nutritional status within the general UK population are measured through the National Diet and Nutrition Survey (NDNS) rolling programme, a continuous cross-sectional survey of UK residents living in private households aged 18 months and over. The most recent data are provided by the third annual report (Bates *et al.* 2012), which presents combined data from the first three years of the rolling survey (2008-2011). Data on the average amount of different categories of fish consumed by UK adults and children are presented in Table 1. It is worth noting that few people actually eat oil-rich fish; NDNS data indicate that around 28% of adults aged 19–64 years consume oil-rich fish (Bates *et al.* 2012). Additional data from Queen Margaret University indicates that up to 35% of the adult female population consume oil-rich fish (O'Callaghan, 2010; Ryan, 2011) however this may reflect the biased sample of those interested in health issue who participated in the research. Nevertheless, oil-rich fish is not a common constituent of the UK diet.

Table 1 Mean intake of categories of fish (g/day) in UK adults and children (2008-2011)*

	White fish, coated or fried, including fish fingers	Other white fish, shellfish, fish dishes and canned tuna	Oil-rich fish
Men (age)			
19-64	9	20	10
65+	10	22	17
All men aged 19-65+	9	21	14
Women(age)			
19-64	8	18	12
65+	10	21	14
All women aged 19-65+	9	19	13
Total adults aged 19-64	9	19	11
Total adults aged 65+	10	21	15
Total adults aged 19-65+	9	20	13
Boys (age)			
4-10	10	9	2
11-18	7	9	2
All boys aged 4-18	8	9	2
Girls (age)			
4-10	8	6	3
11-18	5	8	3
All girls aged 4-18	6	7	3
Total children aged 4-18	7	8	3

Source: Bates *et al.* (2012)

* Figures are the mean consumption of categories of fish (from fish and fish dishes), including non-consumers – *i.e.* those who did not consume from a food group during the 4-day diary. The table reports foods and dishes as consumed. Results are based on dietary assessment using a 4-day food diary and represent a daily average of the days assessed.

UK recommendation

The official recommendation from the UK Departments of Health is to eat at least two portions of fish (140g each) per week, one of which should be oil-rich (see: www.nhs.uk/Livewell/Goodfood/Pages/fish-shellfish.aspx). The current recommendation is based on the findings of a report by SACN (SACN, 2004). Two 140g portions of fish per week, including one portion of oil-rich fish, provide approximately 450mg long-chain *n*-3 PUFA per day. SACN emphasized that this recommendation represents a minimal and achievable average population goal and does not correspond to the level of fish consumption required for maximum nutritional benefit. Therefore, more benefit with higher intakes can be expected, although SACN suggested that the evidence to support benefit at higher levels of consumption was insufficient at the time the evidence was reviewed (almost 10 years ago) to enable accurate quantification (SACN, 2004). Over the last 10 years a larger number of studies have been conducted and more accurate estimates of a benefit at higher intake levels may be possible, if the report findings from 2004 were to be updated.

It is worth noting that the actual portion size of fish currently consumed is likely to be less than the 140g recommended. This should be taken into account and the number of portions advised adjusted accordingly so that a total of 280g per week is achieved. For example, if a 90g portion of fish is consumed, then at least three portions per week would be required (half of which should be oil-rich).

Consumer attitudes

A European-funded survey, SEAFOODplus, collected data from 4786 respondents from Denmark, Poland, Belgium, Spain and The Netherlands (Brunsø 2009; Pieniak *et al.* 2010). European consumers generally had a positive attitude towards fish consumption and believed that eating fish was healthy. The best predictors of regular fish consumption were age and educational level, with older, better-educated adults tending to consume more fish. Reported barriers to fish consumption included the belief that fish is expensive and concerns about bones. The smell of fish was not an issue in this sample. Low consumers of fish were less confident than higher consumers about choosing good quality fish in the supermarkets and preparing fish for cooking. Low consumers were also less knowledgeable; for example, 46% of Belgium consumers believed that fish contains dietary fibre, whereas less than 30% were aware that fish contains omega-3 fatty acids and that this nutrient is beneficial to human health (Verbeke *et al.* 2005).

In the UK, a report by the Food Standards Agency (FSA) looked at which foods UK consumers were aiming to include in their diet more often, based on a sample of 2627 adults (820 with children in their households). Only 10% of consumers said that they were aiming to eat more oil-rich fish (down from 11% in 2006). Similar figures were reported for white fish as around 10% compared with 11% on average in 2006 (FSA, 2008).

These attitudinal surveys confirm that low consumers of fish are often put off by the cooking, handling and perceived cost of fish rather than the taste or smell.

- Fish purchases seem to have decreased in recent years.
- Only around 3 in 10 people consume oil-rich fish.
- Consumers are often put off by the cooking, handling and perceived cost of fish rather than the taste or smell.
- The UK Department of Health recommendation is to eat at least two portions of fish (140g each) per week, of which should be oil-rich.

Nutrients in trout

Energy and macronutrients

Fish and fish dishes contribute, on average, 3% of total energy intake for adults aged 19-64 years in the UK, 2% in children aged 4-18 years and 5% in adults aged over 65 years (Bates *et al.* 2011). The energy content of raw fish varies greatly. For example, 127kcal (534kJ)/100g for raw trout, 74kcal (313kJ)/100g for raw pangasius and 233kcal (968kJ)/100g for raw mackerel (see Table 2). The main reason for these differences is the varying fat content between different species of fish.

Table 2 Nutrient content of trout and various other types of fish and seafood (amount per 100g)

Nutrient	Macronutrients			Vitamins (mg/100g unless stated)									Minerals and trace elements (mg/100g unless stated)								
	E (kcal / kJ)	Pro (g)	Fat (g)	A (µg)	D (µg)	E	B_1	B_2	B_3	B_6	B_{12} (µg)	Fol (µg)	Ca	Fe	Zn	Mg	K	Na	P	Se (µg)	I (µg)
Trout, rainbow, raw, flesh only	127 / 534	19.9	5.3	25	7.89	0.44	0.16	0.12	7.3	0.31	2.84	9	21	0.28	0.47	26	383	110	228	19	5
Trout, rainbow, baked, flesh only	150 / 630	23.8	6.1	44	8.19	0.89	0.13	0.13	6.4	0.19	3.11	11	19	0.40	0.56	29	434	93	254	23	N
Cod, raw, flesh only	75 / 320	17.5	0.6	2	<0.1	0.66	0.06	0.08	2.3	0.14	1.45	7	12	0.10	0.34	25	322	91	169	23	196
Haddock, raw, flesh only	75 / 317	17.8	0.4	1	N	0.49	0.13	0.15	4.9	0.29	1.90	10	11	0.12	0.31	25	315	68	163	34	320
Pangasius, raw, flesh only	74 / 313	14.9	1.6	<0.1	1.35	0.23	0.02	0.06	6.3	0.12	1.05	10	10	0.09	0.32	29	293	204	166	18	3
Tilapia, cooked, dry heat †	128 / 536	26.0	2.7	0	N	0.80	0.10	0.10	4.7	0.10	1.90	6	14	0.70	0.40	34.0	380	56	204	54	N
Mackerel, raw, flesh only	233 / 968	18.0	17.9	54	8.00	0.43	0.17	0.30	11.3	0.40	8.81	1	20	0.98	0.51	37	335	153	220	42	29
Tuna, canned in brine	109 / 460	24.9	1.0	26	1.10	0.42	<0.01	0.11	10.3	0.31	3.42	3	10	1.51	0.89	27	230	293	171	69	12
Salmon, raw*	180 / 750	20.2	11.0	13	5.9	1.91	0.23	0.13	7.2	0.75	4.00	16	21	0.04	0.60	27	360	45	250	26 **	37
Salmon, cold smoked	184 / 769	22.8	10.1	28	8.9	2.03	0.43	0.12	8.3	0.73	3.15	15	8	0.23	0.36	31	442	1184	266	19	9
Salmon, hot smoked	186 / 778	25.4	8.8	N	11.0	2.29	0.41	0.16	9.5	0.51	4.19	14	8	0.34	0.49	32	460	848	293	24	N
Sardines, chilled/frozen, raw, flesh and small bones	134 / 562	19.8	6.1	10	3.95	0.31	<0.01	0.34	10.1	0.31	8.31	7	50	1.55	0.71	32	387	136	257	51	79
Alaskan Pollack, raw, flesh only	72 / 305	16.4	0.7	N	N	0.60	0.03	0.09	2.6	0.04	2.32	5	12	0.18	0.39	30	216	68	120	27	56
Sole, raw, flesh only	73 / 310	16.7	0.7	N	N	0.73	0.15	0.08	4.3	0.15	1.01	13	17	0.12	0.31	26	177	115	124	50	23
Plaice, raw, flesh only	76 / 323	16.4	1.2	N	N	0.57	0.33	0.14	2.5	0.23	1.30	12	17	0.10	0.45	21	226	147	157	35	31
Coley, raw, flesh only	82 / 347	18.0	1.1	N	N	0.57	0.23	0.17	2.6	0.27	3.48	5	7	0.27	0.43	32	303	68	171	33	111
Sea bass, raw, flesh only	168 / 703	20.0	9.8	34	<0.1	0.48	0.39	0.20	3.0	0.37	3.01	5	14	0.27	0.62	30	370	72	202	29	8
Prawns, cold-water, purchased cooked	70 / 295	15.4	0.9	<0.1	<0.1	3.63	<0.01	0.05	<0.1	0.03	2.35	10	65	1.00	1.02	36	74	588	127	30	13
Tuna, raw, flesh only	107 / 454	25.2	0.7	76	3.20	0.04	0.13	0.07	21.9	0.43	2.21	4	4	0.72	0.39	39	444	66	266	93	18
Langoustine, boiled	86 / 369	19.7	0.8	N	N	3.55	0.08	0.06	2.7	0.10	2.45	5	125	1.68	1.37	53	214	216	197	49	139

Source: Department of Health (2013). E, energy; Pro, protein; Fol, folate; Ca, calcium; Fe, Iron; Zn, zinc; Mg, magnesium; K, potassium; Na, sodium; P, phosphorus; Se, selenium; I, iodine; N, No data; * data from FSA (2002); ** estimated values; † data from USDA SR-21 (http://nutritiondata.self.com/facts/finfish-and-shellfish-products/9244/2)

Fat

Although trout is an oil-rich fish, when compared to other oil-rich fish it has a lower total fat and saturated fat content. For example 100g of raw trout has 5.3g of fat; whereas 100g of raw salmon has 11g and raw mackerel has 17.9g of fat (see Table 2).

White fish is generally low in fat (≤3g per 100g) and low in saturated fat (≤1.5g + ≤10% of energy is from fat). Oil-rich (fatty), fish typically contain between 5-20% of fat, whereas white (lean) fish typically contain 1-2% of fat (SACN, 2004). The cooking method can also impact the fat content of the fish consumed. For example, cooking fish with fat, such as frying fish, can significantly increase the fat content of a fish dish and therefore total energy content. Coating fish in batter or breadcrumbs will increase absorption of fat if the fish is then fried.

Fatty acids are the building blocks of fat and there are three different types: saturated, monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA). Both MUFA and PUFA can lower blood cholesterol and help reduce the risk of heart disease, while saturated fatty acids can raise blood cholesterol and increase the risk of heart disease. The essential fatty acids are a specific subgroup of PUFAs: omega-3 (*n*-3) and omega-6 (*n*-6). *n*-3 PUFAs occur naturally in seeds, nuts and green leafy vegetables as alpha linolenic acid (ALA) (*e.g.* linseed, pumpkin seeds, rapeseed oil, walnuts). The body can convert ALA in to the long-chain *n*-3 PUFAs EPA and DHA, but not very efficiently. Therefore oil-rich fish plays an important role in our diet as it contains preformed EPA and DHA that the body can use easily.

Fish, in particular oil-rich fish, is the main food source of the long-chain *n*-3 PUFAs EPA and DHA (see Table 3 and section on health benefits). Trout, as well as mackerel, salmon, sardines and sea bass, are a good source of omega-3 fatty acids. In the UK, the official recommendation from the Department of Health is to eat at least two portions of fish (140g each) per week, one of which should be oil-rich (www.nhs.uk/Livewell/Goodfood/Pages/fishshellfish.aspx). Two 140g portions of fish per week, including one portion of oil-rich fish, provide approximately 450mg/day (0.45g/day) of long-chain *n*-3 PUFA (SACN, 2004). Baked trout contains 1315mg per 100g of the long-chain *n*-3 PUFAs EPA and DHA (571mg EPA + 744mg DHA).

Mackerel, salmon, trout and sea bass contain relatively high *n*-3 PUFAs compared with other types of fish (see Table 3). An analysis was conducted by Weaver *et al*. (2008), of the polyunsaturated fatty acids found in four commonly consumed fish in the US (Atlantic salmon, trout, tilapia and catfish). Weaver *et al*. (2008) reported that farmed Atlantic salmon and farmed trout have some of the highest levels of *n*-3 fatty acids, combined with low levels of arachidonic acid (a long-chain *n*-6 PUFA). Farmed tilapia and catfish have low levels of *n*-3 fatty acids along with high levels of arachidonic acid. Both farmed tilapia and catfish were found to have considerably higher concentrations of *n*-6 PUFAs when compared to *n*-3 PUFAs. In both cases, this resulted in *n*-6:*n*-3 ratios of >2. Both farmed Atlantic salmon and trout had ratio well below 1. Fish from the most intensively farmed system, such as tilapia, are typically fed higher levels of *n*-6 PUFA from vegetable oils as part of the feed (Karapanagiotidis *et al.* 2006). This leads to a high level of *n*-6 and a higher *n*-6:*n*-3 ratio (see section on asthma).

Protein

Fish is a good source of protein. Raw trout, for example, contains 19.9g of protein per 100g, (63% of energy) (see Table 2). Dietary protein is essential for growth, maintenance and repair of body tissue including muscle and bone, and can also provide energy. In the UK and most developed countries, average protein intakes for all age groups is in excess of the minimum protein requirements needed for good health, provided energy intakes are sufficient. Any excess protein in the diet is used to provide energy. As a comparison, the amount of protein per 100g of raw rump steak is 20.7g, raw, lean lamb is 20.2g, raw, lean pork is 21.8g, raw chicken is 22.3g, chicken eggs is 12.5g and baked beans in tomato sauce is 5.2g (FSA, 2002).

Table 3 Total fat and fatty acid composition of trout and other types of fish

	Fat and total fatty acids (g per 100 g food)								
	Total Fat	Sat Fat	Total MUFA	Total PUFA	*n*-6 PUFA	*n*-3 PUFA	EPA	DHA	DPA
Trout, rainbow, raw, flesh only	5.3	1.12	1.44	1.80	0.40	1.41	0.4505	0.5755	0.1686
Trout, rainbow, baked, flesh only	6.1	1.44	1.55	2.16	0.44	1.72	0.5706	0.7441	0.1922
Cod, raw, flesh only	0.6	0.16	0.14	0.11	0.03	0.08	0.0240	0.0507	0.0020
Haddock, raw, flesh only	0.4	0.09	0.08	0.10	0.01	0.09	0.0192	0.0616	0.0023
Pangasius, raw, flesh only	1.6	0.49	0.44	0.17	0.15	0.02	0.0015	0.0119	0.0127
Tilapia, cooked, dry heat†	2.7	0.90	1.00	0.60	0.30	0.24	N	N	N
Mackerel, raw, flesh only	17.9	3.85	6.68	4.46	0.41	4.05	0.9531	1.6466	0.1628
Tuna, canned in brine	1.0	0.30	0.17	0.40	0.08	0.32	0.0435	0.2546	0.0081
Salmon, raw*	11.0	1.90	4.40	3.10	N	N	0.5000	1.3000	0.4000
Salmon, cold-smoked	10.1	2.15	3.10	2.84	0.66	2.18	0.6321	0.7575	0.2669
Salmon, hot smoked	8.8	1.94	2.63	2.92	0.64	2.28	0.7914	0.7287	0.3313
Sardines, chilled/frozen, raw, flesh & small bones	6.1	1.83	1.80	1.56	0.24	1.32	0.4924	0.6228	0.0774
Alaskan Pollack, raw, flesh only	0.7	0.14	0.17	0.16	0.01	0.14	0.0418	0.0919	0.0073
Sole, raw, flesh only	0.7	0.16	0.14	0.16	0.02	0.14	0.0465	0.0476	0.0345
Plaice, raw, flesh only	1.2	0.22	0.25	0.25	0.03	0.22	0.0732	0.0892	0.0326
Coley, raw, flesh only	1.1	0.20	0.26	0.27	0.02	0.25	0.0372	0.1881	0.0108
Sea bass, raw, flesh only	9.8	2.16	3.40	2.91	1.20	1.71	0.4850	0.7156	0.1546
Prawns, cold-water, purchased cooked	0.9	0.15	0.19	0.22	0.02	0.20	0.1099	0.0849	0.0034
Tuna, raw, flesh only	0.7	0.21	0.19	0.13	0.04	0.09	0.0127	0.0703	0.0045
Langoustine, boiled	0.8	0.15	0.15	0.21	0.04	0.17	0.0829	0.0786	0.0065

Source: Department of Health (2013); *Data from FSA (2002) † data from USDA SR-21 (http://nutritiondata.self.com/facts/finfish-and-shellfish-products/9244/2); N, No data; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; DPA, docosapentaenoic acid.

- Trout is considered to be an oil-rich fish (contains 5-20% fat), but compared to other oil-rich fish, trout has a relatively low fat content.
- Oil-rich fish such as trout are a good source of omega-3 PUFAs and the beneficial long-chain omega-3 PUFAs (EPA and DHA).
- Like other fish, trout is a good source of protein.

Micronutrients

Fish contain a variety of vitamins and minerals. The key micronutrients provided by fish are the minerals phosphorus, selenium, potassium, iodine, zinc and magnesium. These are often known as ‘sea minerals’. Intakes of some of these minerals, notably selenium and magnesium, are lower than recommendations in some groups (Bates *et al.* 2010) and therefore increased fish intakes could make a major contribution towards diet adequacy in the UK.

Most methods of cooking fish (*e.g.* baking, steaming, microwaving, frying and grilling) cause little loss of nutrients. However, poaching fish can cause leaching of micronutrients into the cooking medium, although if the liquid used during cooking is included in a sauce the micronutrients are not lost (Bord Iascaigh Mhara & Irish Sea Fisheries Board, 2006).

Vitamin D

Vitamin D is mainly made in the skin on exposure to sunlight, when skin is exposed to UV radiation. During winter months in Northern European countries, UV radiation is not strong enough for vitamin D production and the body has to rely on body stores and dietary sources. UK population groups at risk of vitamin D insufficiency include people with dark skin, people who cover most of their skin, people who are housebound, children, and people living in higher latitudes (*e.g.* in Northern parts of the UK). For these population groups, as well as for the general population during the winter months, vitamin D from dietary sources becomes more important (Weichselbaum *et al.* 2013). Vitamin D deficiency (plasma 25-OH-vitamin D levels below 25nmol/l) is prevalent in the UK population, with the highest proportions of people with vitamin D deficiency found in young adults, older adults (in particular institutionalized) and in ethnic minorities (Prentice 2008; Lanham-New *et al.* 2011). Plasma levels suggestive of vitamin D deficiency were found in 24% of men and 28% of women aged 19-24 years. Prevalence in institutionalised older adults was 36% in men and 38% in women respectively. A quarter (25% of 2 year olds from the British Asian ethnic groups have vitamin D levels that are putting them at risk of developing rickets (Lanham-New *et al.* 2011). Also of concern is the data from Cardiff, Wales that suggests more than half of pregnant women from minority ethnic groups have plasma vitamin D levels suggestive of vitamin D deficiency (Datta *et al.* 2002).

There are only a few habitual dietary sources of vitamin D, with oil-rich fish being the richest source (Lanham-New *et al.* 2011). The UK currently has no dietary reference value for vitamin D for most population groups. The European Recommended Daily Allowance (RDA) for vitamin D is 5µg (EC, 2008). Trout is a rich source of vitamin D providing over 150% of the RDA (7.89µg per 100g in raw trout). Salmon is also a rich source of vitamin D providing 5.9µg vitamin D per 100g, whereas white fish such as pangasius provides 1.35µg vitamin D per 100g and is considered a ‘source of’ vitamin D (see Tables 2 and 4). Lower vitamin D levels in farmed fish, such as farmed salmon and trout have been suggested (Hallund *et al*. 2010). Farmed trout fed on marine-based feed had less than 1µg vitamin D per 100g, which was only slightly higher than in trout fed on vegetable-based feed (Hallund *et al.* 2010). Of note, far higher vitamin D levels in trout was reported in the Department of Health analysis (7.89µg per 100g in raw trout). This was an average of nine samples (8 were UK farmed trout and 1 farmed trout from Turkey). Further investigation on the reasons for this is warranted given the increasing amounts of farmed fish on the market.

Table 4 Nutrition claims for different types of fish, in the context of European nutrition claims legislation*

Nutrient	Macronutrients				Vitamins									Minerals and trace elements								
	Pro	Low fat	Low sat fat	*n*-3	A	D	E	B_1	B_2	B_3	B_6	B_{12}	Folate	Ca	Fe	Zn	Mg	K	Na	P	Se	I
Trout, rainbow, raw, flesh only	HI	-	-	HI	-	HI	-	SO	-	HI	SO	HI	-	-	-	-	-	SO	LO	HI	HI	-
Trout, rainbow, baked, flesh only	HI	-	-	HI	-	HI	-	-	-	HI	-	HI	-	-	-	-	-	SO	LO	HI	HI	N
Cod, raw, flesh only	HI	Y	Y	-	-	-	-	-	-	-	-	HI	-	-	-	-	-	SO	LO	SO	HI	HI
Haddock, raw, flesh only	HI	Y	Y	-	-	-	-	-	-	HI	SO	HI	-	-	-	-	-	SO	LO	SO	HI	HI
Pangasius, raw, flesh only	HI	Y	-	-	-	SO	-	-	-	HI	-	HI	-	-	-	-	-	-	-	SO	HI	-
Tilapia, cooked, dry heat†	HI	Y	Y	-	-	N	-	-	-	SO	-	HI	-	-	-	-	-	SO	LO	SO	HI	N
Mackerel, raw, flesh only	HI	-	-	HI	-	HI	-	SO	SO	HI	SO	HI	-	-	-	-	-	SO	-	HI	HI	SO
Tuna, canned in brine	HI	Y	Y	SO	-	SO	-	-	-	HI	SO	HI	-	-	-	-	-	-	-	SO	HI	-
Salmon, raw*	HI	-	-	HI	-	HI	SO	SO	-	HI	HI	HI	-	-	-	-	-	SO	LO	HI	HI	SO
Salmon, cold-smoked	HI	-	-	HI	-	HI	SO	HI	-	HI	HI	HI	-	-	-	-	-	SO	-	HI	HI	-
Salmon, hot smoked	HI	-	-	HI	-	HI	SO	HI	-	HI	HI	HI	-	-	-	-	-	SO	-	HI	HI	N
Sardines, chilled/ frozen, raw, flesh and small bones	HI	-	-	HI	-	HI	-	-	SO	HI	SO	HI	-	-	-	-	-	SO	-	HI	HI	HI
Alaskan Pollack, raw, flesh only	HI	Y	Y	-	-	N	-	-	-	SO	-	HI	-	-	-	-	-	-	LO	SO	HI	HI
Sole, raw, flesh only	HI	Y	Y	-	-	N	-	-	-	SO	-	HI	-	-	-	-	-	-	LO	SO	HI	SO
Plaice, raw, flesh only	HI	Y	-	-	-	N	-	HI	-	SO	SO	HI	-	-	-	-	-	-	-	SO	HI	SO
Coley, raw, flesh only	HI	Y	-	-	-	N	-	SO	-	SO	SO	HI	-	-	-	-	-	SO	LO	SO	HI	HI
Sea bass, raw, flesh only	HI	-	-	HI	-	-	-	HI	-	SO	SO	HI	-	-	-	-	-	SO	LO	SO	HI	-
Prawns, cold-water, purchased cooked	HI	Y	-	-	-	-	HI	-	-	-	-	HI	-	-	-	-	-	-	-	SO	HI	-
Tuna, raw, flesh only	HI	Y	Y	-	-	HI	-	-	-	HI	HI	HI	-	-	-	-	-	SO	LO	HI	HI	-
Langoustine, boiled	HI	Y	Y	-	-	N	SO	-	-	SO	-	HI	-	SO	-	-	-	-	-	SO	HI	HI

HI, High in; SO, Source of; Y, meets criteria; LO, low in; Pro, protein; low sat fat, low saturated fat; n-3, omega-3 PUFA; Ca, calcium; Fe, Iron; Zn, zinc; Mg, magnesium; K, potassium; Na, Sodium; P, phosphorus; Se, selenium; I, iodine; N, No data available; † data from USDA SR-21 (http://nutritiondata.self.com/facts/finfish-and-shellfish-products/9244/2)

B-vitamins

Fish contain several B-vitamins. In particular, many fish are a rich source of niacin (vitamin B_3) which helps produce energy from the foods we eat and helps keep the nervous and digestive systems healthy. Vitamin B_{12} has several important functions and is involved in making red blood cells and keeping the nervous system healthy, releasing energy from the food we eat and processing folic acid. Dietary deficiency of vitamin B_{12} is rare in young people and only occurs among strict vegans. However, it is more common in older people as a result of impaired absorption, usually due to chronic inflammation of the stomach lining or lack of intrinsic factor, which is required for vitamin B_{12} absorption. Most types of fish, including trout, are considered to be a rich source of vitamin $B_{12.}$

Selenium

Selenium plays an important role in our immune system's function and in reproduction. It also helps prevent damage to cells and tissues. A relatively large proportion of the UK population has low selenium intakes when compared with current recommendations. In the UK, boys and girls aged 4-18 years (12% and 25%, respectively) have intakes below the Lower Reference Nutrient Intake (LRNI)[2]. The proportion of adult men and women with intakes below the LRNI is even higher: 25% of men aged 19-64 years and 31% of men aged 65+ years, and 52% of women aged 19-64 years and 54% of women aged 65+ years (Bates *et al.* 2012). Most fish, including trout, are good sources of selenium.

Iodine

Iodine helps make the thyroid hormones. These hormones help keep cells and the metabolic rate healthy. In the UK, young women are particularly prone to having inadequate iodine intakes. The most recent NDNS showed that 21% of girls aged 11-18 years have intakes that are below the LRNI (Bates *et al.* 2012). The main contributors to iodine intake in the UK diet are milk and milk products. Fish and fish dishes also make an important contribution to iodine intake, together contributing 8% in both boys and girls aged 4-18 years (Gregory *et al.* 2000). Iodine is a trace element found in seawater, rocks and some types of soil. The iodine content of trout is low (5µg per 100g). White fish such as haddock and cod are considered good sources of iodine with 320µg and 196µg of iodine per 100g respectively.

Potassium

Potassium has many important functions including controlling the balance of fluids in the body and it is essential for the normal functioning of cells, including nerves. Increased dietary intakes of potassium have been associated with a decrease in blood pressure, as it promotes loss of sodium in the urine. It is suggested that an increase in potassium intake may offset the impact of some of the sodium in the diet, therefore helping to protect cardiovascular health (Weichselbaum *et al.* 2013). Many types of fish, including trout, are considered a source of potassium. Potassium is found in a wide range of foods such as fruit and vegetables, pulses, nuts and seeds, milk, beef, chicken, turkey and bread. Therefore, fish only contributes a small proportion of potassium in the UK diet (2% of total potassium intake in children and 3% in adults) (Gregory *et al.* 2000; Henderson *et al.* 2003).

- Fish, such as trout, contain a variety of vitamins and minerals. Like other oil-rich fish (mackerel, salmon and sardines) trout is a good source of vitamin D, and therefore a useful dietary source as vitamin D deficiency is prevalent in the UK population.
- Most fish, including trout, are good sources of selenium and therefore is useful to include in the diet as a relatively large proportion of the UK population has low selenium intakes.
- Only a small amount of iodine is found in trout. White fish such as haddock and cod are considered good sources of iodine.

[2] The Lower Reference Nutrient Intake is only adequate for 2.5% of the population. Intakes below this level are almost certainly inadequate for most individuals.

Associated health benefits related to the nutrients in trout

Cardiovascular disease (coronary heart disease and stroke)
Coronary heart disease

A meta-analysis of prospective cohort studies by He *et al.* (2004a) included 13 cohorts from 11 studies comprising a total of 222,364 participants who were followed-up for an average of 11.8 years. The authors found that participants who ate fish once a week had significantly lower coronary heart disease (CHD) mortality rates compared with those who never consumed fish or ate fish less than once a month. The overall risk of a fatal CHD event was reduced by 15% [pooled relative risk (RR) 0.85; 95% CI, 0.76-0.96]. Individuals who ate fish five or more times per week had a 38% lower risk of CHD mortality [RR 0.62; 95% CI, 0.46-0.82] compared with those who never consumed fish or ate fish less than once a month. He and colleagues found that beneficial effects on CHD mortality gradually increased with increasing fish consumption and estimated that an increment of 20g/day in fish intake could potentially lower CHD mortality rates by 7% (He *et al.* 2004a).

Another systematic review and meta-analysis of 19 studies (cohort and case-control studies) with a total of 228,864 participants found that participants who ate any amount of fish had a 17% lower risk of fatal CHD and 14% lower risk of total CHD compared with those consuming little to no fish (Whelton *et al.* 2004). The most recent meta-analysis of cohort studies included 22 cohorts with a total of 256,000 participants who were followed-up for periods ranging from 5 to 40 years (Skeaff and Miller 2009). The authors reported that participants with the highest fish consumption (average consumption 22-180g/day) had an 18% reduced risk of fatal CHD compared to participants with the lowest fish consumption (average consumption 0-23g/day).

Stroke

A meta-analysis by He *et al.* (2004b) that included eight prospective cohort studies with a total of 200,575 participants and 3491 stroke events, found that fish consumption was associated with a lower risk of stroke. Those who ate fish once a week had a statistically significant 13% lower risk of stroke compared with those who ate no fish or ate fish less than once a month (RR 0.87; 95% CI, 0.77-0.98). The protective effect on stroke appeared to increase with higher fish intakes, with a 31% reduced risk of stroke among those who ate fish five or more times a week compared with those who ate no fish or ate fish less than once a month (RR 0.69; 95% CI, 0.54-0.88) (He *et al.* 2004b).

Meta-analysis of data from four studies, where separate data for white fish and oil-rich fish were available, resulted in a significantly reduced risk of 16% when comparing highest intakes of oil-rich fish with lowest intakes (RR 0.84; 95% CI, 0.72-0.98), but no risk reduction with white fish was found (RR 1.03; 95% CI, 0.90-1.19) (Chowdhury *et al.* 2012). Chowdhury and colleagues suggest that differences observed for white and oil-rich fish may be explained by the distinct way in which these fish are typically prepared (*e.g*. white fish data included battered and deep fried fish). Therefore if cooking method was taken into account white fish may have a similar effect to oil-rich fish (Chowdhury *et al.* 2012). Further research is also needed to determine whether the association of fish intake is stronger for one sub-type of stroke than for the other (*e.g.* ischaemic or haemorrhagic stroke, caused by a blockage or rupture of blood vessels respectively).

Cardiovascular disease

Most, but not all, population studies show a protective effect of fish intake on risk of cardiovascular disease (CVD) (including stroke) (Weichselbaum et al, 2013). Evidence from randomized controlled trials (RCTs) (often considered the 'gold standard' of study design) on the effects of long-chain *n*-3 PUFA on CVD risk has come mainly from secondary prevention studies (*i.e.* in those who have already experienced CVD). This evidence is not consistent. In particular, recent studies do not support the hypothesis that long-chain *n*-3 PUFA is beneficial in secondary prevention of CVD, although older studies do support the hypothesis (Weichselbaum et al, 2013). It has been suggested that people who recover from a recent myocardial infarction (MI) event (heart attack) may benefit most from including oil-rich fish or fish oils in their diet, and may only do so in the first few (about 4) months after a MI event. Intervention with fish oils after this time may even be harmful for people at other stages of heart disease (Burr 2007). Long-chain *n*-

3 PUFA may have anti-arrhythmic effects (therefore reducing the risk of sudden death), but may have pro-arrhythmic effects (therefore increasing the risk of sudden death), depending on the pathophysiological state of patients (Burr 2007). Further investigation is needed to identify in which situation fish oil supplements have a protective effect on heart health and whether there are any situations in which fish oil supplementation may be detrimental to health (Weichselbaum et al, 2013).

The *n*-6:*n*-3 ratio provides an indication of the overall cardio-protective properties of the fat intake of the diet. It is well-established that current intakes in Europe have a higher *n*-6:*n*-3 ratio than recommended (Russo 2009). The current *n*-6:*n*-3 ratio of the dietary intake for the UK is approximately 4.7:1 (NDNS 2011), which although an improvement on previous data, is not considered optimal. As this ratio is based on the overall diet, there has been reluctance to adopt a guideline for the whole population (FAO 2008), however it is recognized that the current ratio in the diet of developed nations remains high. Although a valuable tool in evaluating dietary intake, this ratio does not take into account the total intake of fat or the actual intakes of either the *n*-6 or *n*-3 fatty acids, and hence a favorable ratio could result from an inappropriate reduction in both *n*-6 and *n*-3 fatty acid intakes. However, reductions in the ratio that clearly result from a decrease in *n*-6 and a corresponding increase in *n*-3 fatty acid consumption have been linked to positive health outcomes (Russo 2009). As an oil-rich fish, trout contains relatively high levels of *n*-3 PUFAs compared to other types of fish, which would help optimize the *n*-6:*n*-3 ratio and therefore improve the cardio-protective properties of the fat within the overall diet.

There may be factors other than the fatty acid profile of fish that contribute to the associated health effects. For example, other components of fish may have a beneficial role in preventing CVD (*e.g*. vitamin D or B vitamins), or people who eat more fish have this in place of foods with less beneficial effect on CVD (*e.g.* foods that are high in saturated fatty acids). It may also be that long-chain *n*-3 PUFAs do have a beneficial effect on CVD, but this is not seen in patients taking statins, as the effect of long-chain *n*-3 PUFA is more subtle than that of statins (Weichselbaum et al, 2013).

Hallund and colleagues examined the effect of intake of farmed trout on CVD risk markers in healthy men and evaluated whether the fish feed composition (100% marine or vegetable-based feed) had any effect on the measured parameters (Hallund *et al*. 2010). In this parallel, 8-week intervention study, 68 healthy male volunteers were randomized to consume either a daily meal with 150g farmed trout raised on either marine or vegetable-based feed, or a reference meal containing 150g chicken. A significantly higher increase in red blood cell (RBC) long-chain *n*-3 PUFA status was found after two months of daily intake of traditionally marine-fed trout compared with a daily intake of trout raised on vegetable-based feed. This reflects the difference in the long-chain *n*-3 PUFA content of the trout meat. Thus, in this respect, the trout raised on vegetable feed may be equivalent to a lean type of fish (Hallund *et al*. 2010). Intake of both types of trout resulted in an increase in RBC long-chain *n*-3 PUFA compared with the intake of chicken or baseline values. However, intake of marine trout was not associated with a reduction in plasma triacylglycerol or clear beneficial effects in any of the other CVD risk markers that were assessed by the authors.

- There is good evidence of beneficial health outcomes from fish consumption for the reduction in risk of cardiac death and it is likely that fish consumption also reduces the risk of stroke.
- As an oil-rich fish, trout contains relatively high levels of omega-3 PUFAs compared to other types of fish, which would help optimise the omega-6:omega-3 ratio and therefore improve the cardio-protective properties of the fat within the overall diet.
- Other components of fish, such as vitamin D or B vitamins may also have a beneficial in preventing coronary heart diseases.

Inflammatory conditions

Asthma

It has been suggested that increased intakes of *n*-6 PUFA present in spread and oils derived from plant sources coupled with decreased intakes of long-chain *n*-3 PUFAs, have contributed to an increase in allergic disease and consequently asthma and eczema (Black and Sharpe, 1997). An increased *n*-6:*n*-3 ratio is thought to increase levels of arachidonic acid (a long-chain *n*-6 PUFA) in cell membranes, which in turn leads to increased synthesis of prostaglandin E_2 that is involved in allergic reactions. However, the suggestion that increased *n*-6 PUFA intakes are linked to atopic disease has been questioned in a recent review (Sala-Vila *et al.* 2008). Several observational studies have investigated whether eating fish as a source of *n*-3 PUFA during pregnancy and in early childhood is associated with a reduced risk of allergic disease. The current available evidence suggests that eating fish during pregnancy may be of benefit, particularly regarding eczema and there is some evidence that fish intake during early childhood is associated with a decreased risk of atopic conditions such as asthma, eczema and hay fever. However, further investigation on the effects of different types of fish on the risk of atopic conditions and the potential mechanisms is required (Weichselbaum *et al.* 2013).

Rheumatoid arthritis

Rheumatoid arthritis (RA) is an inflammatory condition that affects the body's joints leading to pain and stiffness. Findings of a recent systematic review suggest that there is good evidence that fish oil supplements containing long-chain *n*-3 PUFAs (EPA and DHA) are modestly useful in alleviating some symptoms suffered by patients with long-standing RA (*e.g.* reduced patient assessed pain, decreased morning stiffness, fewer painful or tender joints and decreased use of anti-inflammatory medication) (Miles and Calder, 2012). There is a lack of studies that look at fish intake and RA and currently, no conclusions on fish intake and risk of RA can be made (Weichselbaum *et al.* 2013).

Chronic obstructive pulmonary disease

Chronic obstructive pulmonary disease (COPD) includes chronic bronchitis and emphysema and is an important cause of morbidity and mortality linked with cigarette smoking. A small number of studies have investigated a potential protective effect of fish and long-chain *n*-3 PUFAs on COPD with mixed findings. A cross-sectional analysis of 8960 men and women aged 45-64 years, who had smoked at some stage of life (55% were current smokers), found that COPD was strongly and inversely associated with fish consumption. Those who consumed the most fish (average of four servings a week) had a significantly reduced risk (by 45%) of COPD compared with those who consumed the least fish (average of half a serving per week) (RR 0.55; 95% CI, 0.43-0.71) (Shahar *et al*. 1994). The authors however, did not adjust for potential confounding dietary factors such as fruit and vegetable intake. Other studies (Tabak *et al.* 2001; Walda *et al.* 2002) have not found an association between fish intake and COPD.

- There is some evidence that suggests that eating oil-rich fish such as trout during pregnancy and during early childhood may be of benefit, particularly regarding eczema, asthma or hay fever.
- Although there is good evidence that fish oil supplements containing EPA and DHA can help alleviate some symptoms suffered by patients with rheumatoid arthritis there is not enough evidence that similar findings would occur with oil-rich fish.

Cognitive function and development

Cognitive development in early life

A healthy diet during pregnancy is important for the offspring's brain development, with implications for subsequent mental function throughout life (BNF 2013). In particular, the long-chain PUFA DHA is crucial for the development of the brain and nervous system, therefore adequate intakes of DHA is important during pregnancy and breastfeeding. The European Food Safety Authority (EFSA) suggests that pregnant and breastfeeding women increase their intake of pre-formed DHA by 100-200mg/day in addition to the suggested intake level of long-chain *n*-3 PUFA for adults (250mg EPA + DHA). An intake of 1-2 portions of oil-rich fish per week should provide adequate DHA supply during pregnancy and breastfeeding (EFSA, 2010). It is useful for women to build up their stores of *n*-3 PUFAs before pregnancy. A woman's own stores of *n*-3 PUFAs may have been used to meet the baby's needs during pregnancy and therefore may be low and need to be replenished after pregnancy (BNF, 2013).

Cognitive function in later life

There is some evidence to suggest that higher fish intake, dietary DHA intake and DHA levels in the blood may be positively associated with a lower risk of dementia and Alzheimer's disease, and a slower rate of cognitive decline, although not all studies have found an association. The relation of fish consumption to Alzheimer's disease risk appears to be specific to oil-rich fish and not to fried fish (Huang *et al*. 2005) as frying reduces the *n*-3 levels and increases saturated fat intake.

Fish intake may be associated with a slower cognitive decline, but more evidence is needed. Data from the Chicago Health and Ageing project showed that fish intake was associated with a slower rate of cognitive decline over a follow-up period of six years, even after adjusting for several potential confounders. Compared with those who consumed fish less than weekly the rate of cognitive decline was 10% slower among those who consumed one fish meal per week ($p=0.03$), and 13% slower among those who consumed two or more fish meals per week ($p=0.04$). However, the authors found no association between total *n*-3 PUFA, DHA or EPA intake and cognitive decline (Morris *et al.* 2005). Data from RCTs do not suggest that long-chain *n*-3 PUFA supplements are effective in preventing cognitive decline (Weichselbaum *et al.* 2013).

Impact on mental health

Depression and n-3 PUFA

Depression affects 1 in 5 people in the UK (Mental Health Foundation, 2013). A meta-analysis of 14 studies that included 3318 participants (648 depressive and 2670 control participants) compared levels of EPA, DHA and total PUFA (Lin *et al*. 2010). Compared with control subjects, the levels of EPA, DHA and total *n*-3 PUFA were significantly lower in depressive patients. The authors reported that these findings imply that *n*-3 PUFAs play a role in the cause of depression and *n*-3 PUFAs could be used as an alternative treatment for patients with depression (Lin *et al*. 2010).

Evidence from supplementation trials, although limited, suggests that long-chain *n*-3 PUFA are useful in the treatment of depression at dosages of 0.2-9.6g EPA + DHA (Ruxton *et al.* 2004). Postnatal depression has also been linked with low *n*-3 PUFA status, which fits with evidence for high fetal requirements for DHA in the third trimester (see section on cognitive development in early life).

- The long-chain omega-3 PUFAs found in oil-rich fish such as trout, salmon and sea bass may be of particular benefit to pregnant women in order to meet their baby's needs for DHA for brain development.
- Fish intake, in particular oil-rich fish such as trout, may be associated with a slower rate of cognitive decline in later life, although more research is needed.
- Long-chain omega-3 PUFAs, EPA and DHA, found in trout and other oil-rich fish may help treat people with depression.

Bone health

Genetics plays a major role in bone development and bone health, accounting for 70-75% of bone strength. However lifestyle and dietary factors are also known to have a key role to play (Lanham-New *et al*. 2007), in particular calcium and vitamin D play critical roles in bone mineralization. Fish that is consumed with soft edible bones (*e.g.* whitebait, canned sardines or canned salmon) provide a good source of calcium. A role for PUFAs in bone metabolism has been suggested, in particular long-chain *n*-3 PUFA. Animal studies have shown that long-chain *n*-3 PUFAs may influence bone metabolism and that supplementation with a combination of PUFAs in animals may lead to increased bone mass in offspring (BNF, 2013). However the effect of long-chain *n*-3 PUFAs on bone health in humans is not clear due to the small number of existing RCTs in humans with modest sample sizes (Orchard *et al.* 2012).

Immune function

Oil-rich fish is believed to help support normal immune function by encouraging incorporation of the anti-inflammatory EPA and DHA into immune cells and displacing the pro-inflammatory long-chain *n*-6 PUFA, arachidonic acid (Miles *et al.* 2003). Fish also contain significant amounts of other nutrients that are known to support immune function (*e.g.* selenium, zinc, vitamin B_6 and vitamin B_{12} and copper). Several observational studies have examined associations between regular fish consumption and conditions affecting the immune system in different populations. In a survey of the diets of 16,187 adults, Laerum *et al.* (2007) found that eating fish less than once a week was associated with a significant increase in asthma symptoms, while a lack of fish during childhood was linked with an increased risk of developing asthma. The type of fish was not specified). In a more recent intervention trial, Ramel *et al.* (2010) recruited 388 healthy adults to consume 1 of 4 low-energy diets. Two of these diets contained 150g of fish three times a week (salmon or cod), one diet contained no seafood, while the forth was supplemented with EPA + DHA. After 8 weeks, markers of immune function (*e.g.* C-reactive protein, interleukin-6 and prostaglandin levels) significantly decreased in the salmon group only compared with the other study groups, which suggest that salmon consumption improved immune function. A similar finding may be observed in other oil-rich fish such as trout, although no such study appears to have been conducted.

Obesity and satiety

Dietary patterns that typically include fish have been associated with a lower risk of overweight and obesity (Weichselbaum *et al.* 2013). Prospective data from the EPIC study do not suggest that fish intake *per se* has a significant effect on waist circumference, but fish is an important source of protein and protein had been found to have a stronger satiating[3] effect than carbohydrates and fat. There is limited evidence that suggests that fish protein may be more satiating than protein from other animal sources. For example, a crossover study in 23 normal-weight young men (20-32 years) found that a protein-rich (40% energy) fish-based lunch meal compared with a beef-based lunch meal (same amount of energy and protein), which were similar in taste and appearance, led to a significantly decreased energy intake in the test evening meal four hours later (2765 *vs.* 3080 kJ; $p<0.01$). Directly after the fish lunch meal, participants felt significantly less hungry and more satiated compared with the beef lunch, although the difference did not remain significant throughout the afternoon (Borzoei *et al.* 2006).

A small number of RCTs suggest that long-chain *n*-3 PUFA found in fish may have the potential to help reduce body fat, in particular to decrease the size of adipocytes, but not all studies found a protective effect (Weichselbaum *et al.* 2013). Thorsdottir *et al.* (2007) suggest that white fish, as part of an energy restricted diet, may help to reduce body weight and waist circumference. In particular, the amino acid taurine has been shown to decrease body weight in genetically obese mice when fed an unrestricted amount of commercial diet alone or supplemented with 5% taurine (Fujihira *et al.* 1970).

[3] Satiety and satiation are part of the body *n*-6:*n*-3's appetite control system and therefore involved in limiting energy intake.

- Fish such as trout contain nutrients (long-chain omega-3 PUFA, selenium and vitamins B_6 and B_{12}), that are known to support immune function.
- Diets that typically include fish have been associated with a lower risk of overweight and obesity, which may be due to the high protein content of fish which makes an individual feel full for longer.

The nutritional, economic and sustainability benefits of trout compared to other types of fish.

Nutritional benefits of trout

The protein content of trout and salmon are similar (19.9g *vs.* 20.2g), whereas pangasius, although still considered a high source of protein, has a relatively lower protein content at 14.9g per 100g.

Compared to 100g of raw salmon, 100g of raw trout has approximately half the fat (5.3g *vs*. 11.0g). Another benefit of trout is that compared to other oil-rich fish, trout has a relatively low saturated fat content (1.12g/100g) compared to salmon: 1.9g/100g, sea bass: 2.16g/100g and mackerel: 3.85g/100g. Current saturated fat intake of the UK population is above the recommended 11% of food energy. The average women should eat no more than 20g of saturated fat a day and the average man should eat no more than 30g per day. A diet high in saturated fat can raise the level of cholesterol in the blood, which increases the risk of heart disease.

The white fish pangasius and tilapia provide more *n*-6 than *n*-3 PUFAs than most other fish including trout and salmon. 100g of raw trout has 1.41g of *n*-3 PUFA and 0.4g *n*-6 PUFA whereas pangasius and tilapia both have very low *n*-3 PUFA (0.02g and 0.24g respectively) and relatively higher *n*-6 PUFA (0.15g and 0.30g respectively). Therefore the ratio of *n*-6:*n*-3 PUFA in trout would help optimize the overall *n*-6:*n*-3 in the diet and improve the cardio-protective properties of the fat within the diet.

Farmed trout, like other oil-rich fish (*e.g.* mackerel, salmon, sardines, sea bass) is high in vitamin D. As many people have low levels of vitamin D, trout is a useful source of vitamin D to include in the diet.

- Compared to other oil-rich fish, trout has a lower fat content and saturated fat content.
- The omega-3 content of oil-rich fish such as trout is far higher than that of white fish.
- The ratio of omega-6:omega-3 in trout could help optimize the overall omega-6:omega-3 in the diet and improve the cardio-protective properties of the fat within the diet.
- In terms of vitamin D, oil-rich fish such as trout have higher vitamin D compared to white fish.
- Many fish, both oil-rich and white, are considered low in salt, including trout. The salt content of some fish, such as pangasius, mackerel, canned tuna in brine, smoked salmon, sardines, plaice and prawns is too high to be considered ‘low salt’.

Sustainability of trout

The Marine Conservation Society (MCS) (a UK charity) has developed a rating system which can be used by consumers to identify fish that are more resilient to fishing pressure from well-managed sources and caught using methods that minimize damage to wildlife and habitats. The ratings appear in a traffic light format as indicated in the Table 5 below:

Table 5 Marine Conservation Society (MCS) rating system for choosing the most environmentally sustainable fish

Rating	Description of rating	Examples of white fish	Examples of oily fish
1 (light green)	Associated with the most sustainably produced seafood.	Tilapia farmed.	Artic Char, farmed.
2 (pale green)	Still a good choice, although some aspects of its production or management could be improved	Alaskan Pollock, caught at sea; Atlantic Halibut, farmed.	Anchovy, caught at sea; Herring, caught at sea; Sardine/European Pilchard, caught at sea; Skipjack Tuna, caught at sea; **Rainbow Trout, farmed**; Turbot, farmed.
3 (yellow)	Based on available information; these species should probably not be considered sustainable at this time. Areas requiring improvement in the current production may be significant. Eat only occasionally and check www.fishonline.org for specific details.	Bream/Gilthead, farmed; Coley/Saithe, caught at sea; Haddock, caught at sea; Sole/Dover Sole/Common Sole/Lemon sole, caught at sea.	Mackerel, caught at sea; Atlantic Salmon, farmed; **Brown/Sea Trout, farmed;** Yellowfin Tuna, caught at sea.
4 (orange)	Should not be considered sustainable, and the fish is likely to have significant environmental issues associated with its production. While it may be from a deteriorating fishery, it may one which has improved from a 5 rating, and positive steps are being taken. However, MCS would not usually recommend choosing this fish. Follow developments for these species at www.fishonline.org.	Bass/Sea bass, farmed or caught at sea; Atlantic cod, caught at sea; Plaice, caught at sea; Pollack/Lythe, caught at sea.	Albacore Tuna /Bigeye Tuna, caught at sea; Turbot, caught at sea.
5 (red)	Associated with fish to be avoided on the basis that all or most of the above bullet points apply.	Greenland Halibut, caught at sea; Whiting, caught at sea.	Eel, farmed; Marlin, caught at sea; Northern and Southern Bluefin Tuna, farmed or caught at sea; Pacific Bluefin tuna, caught at sea; Atlantic Salmon, caught at sea; Whitebait, caught at sea.

Source: http://www.goodfishguide.co.uk/ (accessed July 2013), note: Pangasius was not rated in the Good Fish Guide

The current sustainability label for fish – MSC of the Marine Stewardship Council – only applies to fish, crustaceans and shellfish which have been caught in the wild. The Aquatic Stewardship Council (ASC) (an independent, international, non-for-profit organization) has developed a certification programme that applies to responsibly farmed fish. Fish bearing the ASC quality mark comes from farms that demonstrably respect the environment and adhere to guidelines pertaining to food additives and social conditions.

Common issues to the farmed fish as identified by the ASC include the detrimental effect of escaped farmed fish on the wild fish stock (*e.g.* competing with wild stocks for habitat and breeding grounds or altering the genetic diversity). Excessive waste from the fish farms can pollute the water and negatively affect the living environment. Conflicts may also arise regarding the use of the area for recreational purposes or the reliance on landscape for scenic vistas. Further issues are discussed below in relation to selected types of farmed fish.

Trout
Most freshwater trout is farmed rainbow trout. The main rainbow trout producing countries in descending order of production are: Iran, Turkey, France, Italy, Denmark, the USA and Spain, which are also the countries where most trout is consumed.

Issues of freshwater trout aquaculture include the fact that the carbon footprint associated with many farms can be high because of the amount of energy used for water pumps, recirculation systems and other equipment. The amount of water used on the farm can exceed the carrying capacity of local freshwater resources, and alterations of natural water flows may negatively impact the environment. The feed used in trout production includes a high level of wild caught fish, some from fisheries that are not environmentally sustainable and birds and other predators can consume considerable volumes of fish from the farms resulting in serious economic losses to the producers.

Pangasius
Pangasius fish farms are prone to health problems that can impact farmed and wild stocks. The inappropriate use of veterinary medicines and chemicals can have unintended consequences for the environment and human health, such as antibiotic resistance and unsafe products. The use of fishmeal, fish oil and waste-fish as pangasius feed is resulting in depletion of food sources that other fish rely on. Also, feeding waste-fish to pangasius can cause unsustainable harvesting and water pollution.

Tilapia
Overstocking, stress and other factors can make farmed tilapia susceptible to viruses and diseases. Excess nutrients from food can be released into the environment, which can limit the amount of oxygen available to aquatic plants and animals. Natural habitats may be altered or water diverted for other uses in order to establish areas for aquaculture and tactics, such as killing birds may be used to minimize the number of species preying on farmed tilapia.

Salmon
Issues relating to salmon aquaculture include the detrimental impact of chemicals and excess nutrients from food and feaces associated with salmon farms on the flora and fauna on the ocean bottom. Excess food and fish waste in the water can potentially increase the levels of nutrients in the water. This can cause the growth of algae, which can consume oxygen that is meant for other plant and animal life. Excessive use of chemicals, such as antibiotics, anti-foulants and pesticides can have unintended consequences for marine organisms and human health.

Economic issues

Trout
Rainbow Trout remains the most commonly farmed species of fish across the EU, but as noted is also farmed in third countries including Turkey, Iran, the USA and South America. Production across the EU has been falling in recent years.

The vast majority of the trout farmed in the UK is sold in the UK, although the market for exports in large trout (trout farmed in salt water to a larger harvest weight) is continuing to grow. The UK has a limited import market for trout, although both smoked and frozen products have been noted.

The UK table trout production industry has remained stable during the past decade at approximately 12,000 tonnes. Up to a further 3,000 of large trout may also be produced on an annual basis.

Whilst the cost of trout production has risen, principally due to increases in fish feed, transport and energy costs, the farm gate price for trout has not seen a corresponding increase and remains low. Trout continues to sell at a very competitive price point to other species of oily fish.

The UK trout industry remains in private ownership, with most businesses falling into the category of SME. Whilst there has been a certain degree of consolidation, there remain a number of producers supplying to different markets including the multiple retailers, farmers markets, farm shops, restocking of live fish for angling, mail order and the hospitality and catering trade.

The first sale value of the UK table trout industry is c. £34 million p.a.
(source, BTA.)

Pangasius

The farming of pangasius (mainly tra (*Pangasianodon hypophthalmus*) and basa (*Pangasius bocourti*)) is one of the fastest growing types of aquaculture in the world. In Vietnam, where 90% of pangasius farming occurs, 1.1 million tonnes of pangasius were produced in 2008. Global production of pangasius was just 10,000 tonnes in 1995. Pangasius is sold to more than 130 countries mainly in the form of white fillets, with 35% of the exports sold within the EU countries (Aquaculture Stewardship Council, 2013). Eurostat reports that in 2012, the EU imported 22% less pangasius than a year ago with the largest markets in the EU being Spain, the Netherlands, Poland and Germany. In Germany, pangasius is the fifth most consumed fish and products labeled with the ASC logo are now available in many supermarkets across the country. Demand is expected to remain firm and it is likely that pangasius will remain an affordable choice (FAO GLOBEFISH, 2013).

Tilapia

Approximately 2.3 million tonnes of tilapia is produced annually of which 73% is farmed. The largest producer of tilapia is China, followed by Egypt, Indonesia, Thailand and the Philippines. Most tilapia is imported to the USA, the EU and Japan (Aquaculture Stewardship Council, 2013).

In terms of supply, exports from China in 2010 grew 25% in volume reaching 321,885 tonnes. Demand is expected to increase within China as the government continues to develop the transportation and infrastructure in the country. Higher production is also reported from Brazil (mainly for the domestic market) and in Paraguay. In Europe, the popularity of tilapia is growing at a steady pace. Nearly 19,000 tonnes of tilapia fillets were imported in 2010 into the EU-27, with 85% originating from China. Almost 7000 tonnes of tilapia fillets were imported by Poland, followed by Spain, Germany and The Netherlands. The demand for certified tilapia in Europe is growing and imports to Europe are expected to increase as tilapia provides a cheaper alternative to popular fish varieties such as cod or salmon (FAO GLOBEFISH, 2011).

Salmon

Approximately 60% of the 1.26 million tons of the world's salmon comes from fish farms. Norway and Chile produce almost two thirds of the world's farmed salmon, although the UK and Canada are also significant producers (Aquaculture Stewardship Council, 2013).

UK salmon production stagnated in 2012 and is expected to decline in 2013 (FAO GLOBEFISH, 2013). Stocks in Scottish farms have been badly hit by the spread of amoebic gill disease blamed on warmer sea temperatures. However, salmon exports in 2012 increased in volume by 12.7% compared with 2011. Total value of these exports remained stable year-on-year as a result of lower prices. Of particular note, there has been a recent upsurge in exports to Asia (especially China), which seems to be continuing (FAO GLOBEFISH, 2013).

Toxicity: effect on preferential consumption for maximum health benefits

Due to the presence of pollutants in fish, SACN considered whether an upper limit for fish intake is required to avoid any potential detrimental effects on health. Guideline ranges for oil-rich fish consumption and upper limits for specific types of fish suggested by SACN are summarized in Table 6 below:

Table 6 Summary of UK fish guidelines

Women of reproductive age and girls	should aim to consume within the range of 1-2 portions of oil-rich fish per week.
Women past reproductive age, boys and men	should aim to consume within the range of 1-4 portions of oil-rich fish per week.
Women intending to become pregnant and children under 16 years	should avoid eating shark, marlin and swordfish; one weekly portion of these would not be harmful for other adults.
Pregnant women and women intending to become pregnant	may eat up to 4 medium-sized cans or 2 tuna steaks per week.
Children and other adults	do not need to restrict the amount of tuna they eat.

Source: www.nhs.uk/Livewell/Goodfood/Pages/fish-shellfish.aspx

Exceeding these guideline ranges over the short-term is unlikely to be detrimental to health, but in the long-term could have deleterious effects in sensitive individuals (SACN, 2004). An update of the SACN recommendations is warranted as more studies on the health benefits of fish are now available and much has been done to reduce pollutant levels in the sea (*e.g.* banning of waste burning at sea). A comprehensive analysis of samples of marine fish from Scottish waters was conducted in 2008. Farmed and wild trout were not included in the analysis as the project remit was focused on uncontrolled fisheries of species for which the Food Standards Agency Scotland do not hold any contaminants information on (Aquaculture Stewardship Council, 2013). The report found that for organic contaminants (*e.g.* dioxins and PCBs) and heavy metals (*e.g.* methylmercury), levels detected in fish were below the existing regulatory limits (except for a minor excursion beyond the maximum limits for mercury in ling and blue ling) (Fernandes *et al*. 2009).

Methylmercury (MeHg)

Fat-soluble methlylmercury (MeHg) accumulates up the marine food chain, with highest levels found in large predatory species (*e.g.* swordfish, shark or marlin). SACN considered that one portion of swordfish, shark or marlin (140g), while rich in *n*-3 fatty acids, would result in a dietary MeHg intake close to or above the 3.3μg/kg bodyweight per week limit (SACN, 2004). Intake at this level could harm the fetus of women who are pregnant or become pregnant within a year, given the half-life in humans of MeHg is about 70 days (Brunner *et al*. 2009).

Evidence from a combination of 20 different prospective cohort studies and clinical trials has shown a consistent decline in CHD mortality with increasing intake of *n*-3 PUFAs EPA and DHA, with an apparent saturation of this benefit at intakes over 250mg/day (Mozaffarian and Rimm, 2006). Below an ingestion rate of 250mg/day, there was a 14.6% decrease in CHD mortality per 100mg/day omega-3 fatty acids ingested (95% confidence interval, 8-21% reduction). Saturation of benefit above 250mg *n*-3 fatty acids intake per day may not be an actual plateau, because as fish ingestion increases, so does the intake of MeHg. MeHg is a risk factor for CVD and therefore may counter-balance the beneficial effect of *n*-3 fatty acids on CHD mortality (Ginsberg and Toal, 2009). Mother-child studies suggest maternal *n*-3 intake during pregnancy is associated with improved cognitive performance in the infant and child, but maternal MeHg intake has an opposing effect (Oken *et al.* 2005; Oken *et al.* 2008).

Dioxins and PCBs

Animal fat in milk, meat, fish, eggs (and their products) is the main source of dioxins and polychlorinated biphenyls (PCBs) in the diet. The levels of dioxins and PCBs in any individual's diet will vary depending on the amounts and types of foods they eat. Dioxins and PCBs are also lipophilic compounds which accumulate in the flesh of oil-rich fish.

When the samples of marine fish from Scottish waters were ranked according to the concentrations of major organic contaminants (*e.g.* dioxins, PCBs), freshwater fish samples generally showed the higher average concentrations than marine fish or shellfish. However, some species may show lower levels of bio-accumulation, such as trout (among the freshwater fish) (Fernandes *et al.* 2009). It is likely that the occurrence of organic contaminants in fish, in particular freshwater fish is influenced by location, in addition to the type of species and size. Given the bio-accumulative nature of these contaminants, it is likely that larger and older fish, within the same location would tend to show higher levels of contamination (Fernandes *et al.* 2009).

The dioxin and PCB WHO-TEQ[4] content of fish has been regulated by the European Commission (EC) since 2002, with maximum permitted limits set at 4ng/kg WHO-TEQ on a whole weight basis for dioxins and 8ng/kg WHO-TEQ for combined dioxin and PCB WHO-TEQ (Council regulation 118/2006). The maximum detected dioxin and PCB WHO-TEQ found by Fernandes *et al.* (2009) was 3.5ng/kg for a sample of Roach from the Forth and Clyde canal. Therefore it is clear that none of the fish sampled were in breach of these limits.

- The occurrence of organic contaminants in fish, in particular freshwater fish is influenced by location, in addition to the type of species and size.
- Freshwater fish samples generally show higher average concentrations than marine fish or shellfish, although some species of freshwater fish, such as trout, may show lower levels of bio-accumulation.

Trout: Relevant guidelines and food/nutrient labeling

European regulations permit nutrition claims to be made on food and beverage products when specific criteria are met (European Parliament and Council, 2012). Some white fish and shellfish comply with the ‘low in fat’ criteria (less than 3g per 100g as sold). As oil-rich fish are higher in fat than white fish and shellfish, low-fat claims cannot be made. However, a significant proportion of the additional fatty acids are from the long-chain *n*-3 PUFA group, which has been linked with health benefits.

The long-chain *n*-3 PUFA, specifically EPA and DHA, have cardio-protective benefits that are distinct from the benefits of ALA and are considered more effective in reducing the risk of CVD. ALA is an *n*-3 PUFA found abundantly in vegetable oils. Consumers may well be confused about the difference between *n*-3 PUFA and long-chain *n*-3 PUFA. This is, in part, due to the widespread use of the marketing term ‘omega-3 fatty acids’, which does not differentiate between *n*-3 PUFA (such as ALA) and long-chain *n*-3 PUFAs (such as EPA and DHA). Although the long-chain *n*-3 PUFAs are included in the overall *n*-3 PUFA content of the diet, they are only likely to contribute significantly in individuals who routinely consume oil rich fish and/or specific supplements. Therefore, describing a food as ‘rich in omega-3 fatty acids’ cannot guarantee provision of EPA and DHA, but will definitely imply a high content of ALA.

The Front of Pack (FoP) label for trout will generally be low in sugar, saturates and salt and medium in fat. Other oil-rich fish such as salmon, mackerel and sea bass contain more than 1.5g per 100g of saturates and would therefore be labeled as medium (amber) on FoP labeling (See Figure 1 below). For the nutrient claims that can be made for trout and other types of fish in the context of European nutrition claims legislation (see Table 4 and Table 7). Raw trout can be

[4] Dioxins and dioxin-like PCBs are chemicals with different degrees of dioxin-like toxicity. The use of Toxic Equivalency Factors (TEFs) allows concentrations of the less toxic compounds to be expressed as an overall equivalent concentration of the most toxic dioxin, 2,3,7,8-TCDD. These toxicity-weighted concentrations are then summed to give a single concentration expressed as a Toxic Equivalent (TEQ). The system of TEFs used in the UK and a number of other countries is that set by the World Health Organization (WHO), and the resulting overall concentrations are referred to as WHO-TEQs (see: http://www.food.gov.uk/multimedia/faq/dioxins_qanda/)

considered a source of vitamin B_1, vitamin B_6 and potassium and a rich or high source of protein, omega-3 fatty acids, vitamin D, vitamin B_3, vitamin B_{12}, phosphorus and selenium. Trout has less than 0.3g salt per 100g and therefore is considered low in salt. Other fish including pangasius, mackerel, canned tuna, prawns and langoustine are considered to have a medium salt content and would therefore have a medium (amber) FoP label. Urinary sodium analysis of a representative sample of the Scottish population in 2009 found the average salt intake was 8.8g/day among adults aged 19-64 years, which indicated that 89% of men and 72% of women had a daily intake higher than the recommended 6g/day (Scottish Centre for Social Research, 2011). A similar analysis conducted in England in 2011 reported that the mean estimated salt intake was 8.1g per day among adults aged 19-64 years, which indicated that 7 out of 10 adults had intakes higher than the recommended 6g/day (Sadler *et al*. 2011).

A health claim is any statement on labels, advertising or other marketing products that health benefits can result from consuming a given food. The European Commission authorises different health claims provided they are based on scientific evidence and can be easily understood by consumers. Approved health claims relating to the long-chain *n*-3 PUFA DHA and EPA found in oil-rich fish are presented in table 8 below. Article 13 health claims relate to function, for example the normal growth, development and functions of the body.

Figure 1: Traffic light labeling on front of pack

Source: FSA (2010) http://www.food.gov.uk/northern-ireland/nutritionni/niyoungpeople/survivorform/bestreadbefore/signposting

Figure 2a: Example of a front of pack label for raw trout.

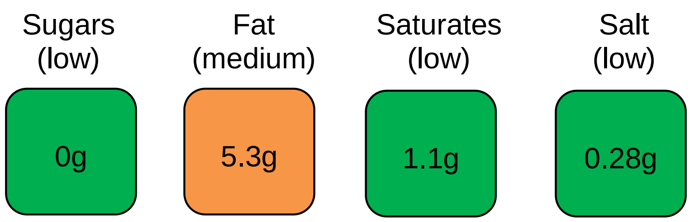
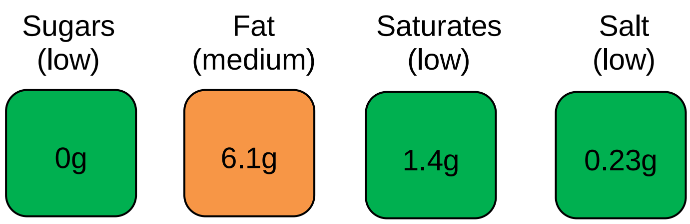


Figure 2b: Example of a front of pack label for baked trout.



When fish is brined and/or smoked, its sodium content will increase due to the addition of salt water, as well as the dehydration that occurs when the fish is smoked (Bord Iascaigh Mhara and Irish Sea fisheries Board, 2006). Nutritional content data for smoked trout was not included in the recent nutritional analysis of fish published by the Department of Health (DH, 2013). Nutritional data from smoked trout products indicate that salt levels would be considered 'high' (over 1.5g per 100g). The salt content (per 100g) of smoked trout from two Supermarkets was 2.98g (Waitrose's smoked trout fillets) and 2.77g (Sainsbury's smoked Rainbow trout). This is well above the 1.5g salt per 100g that is considered to be 'high'. The lower water content of smoked fish, results in the increased concentration of some nutrients. See Table 2 for differences between the nutrient contents of fresh salmon and smoked salmon. From the data in Table 4, there is little difference in the nutrition claims for fresh and smoked salmon.

Nutrient profiles are to be established by the EC. These will be used to determine whether foods are eligible or not to bear claims, on the basis of their nutrient composition. The EC planned to establish nutrient profiles by 2009, although they are still being worked on by the Commission. Once established, the nutrition and health claims made on a product will depend on the extent to which a product complies with the nutrient profiles (note: food business operators will have two years to comply with these controls once the nutrient profiles are adopted). For example, if a product fails on one nutrient (*i.e.* is high in salt) then no health claim can be made. Nutrition claims can only be made if a statement such as "high in salt" is also made in close proximity to, and with the same prominence as the nutrition claim (*e.g.* "high in vitamin D"). For further guidance to compliance with EC Regulations on nutrition and health claims see: DH, 2011.

Table 7 Selected nutrition claims and conditions applying to them

Permitted nutrition claims	Criteria/100g as sold
Source of protein	≥12% energy as protein
High protein	≥20% energy as protein
Low fat	≤3 g
Low in saturated fat	≤1.5 g + ≤10% energy as fat
Source of omega-3	≥40mg EPA +DHA/100g and per 100kcal, or ≥0.3g ALA per 100g and per 100kcal
Rich in omega-3	≥80mg EPA +DHA/100g and per 100kcal, or ≥0.6g ALA per 100g and per 100kcal
Low sodium/salt	≤0.12g sodium, or equivalent of salt per 100g
Source of (vitamin/mineral)	≥15% of the RDA
Rich in (vitamin/mineral)	≥30% of the RDA

Source: European Parliament and Council, 2012 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2006R1924:20121129:EN:PDF

Table 8 European Commission authorised health claims

Claim type	Nutrient	Claim	Condition of use	Could the claim be applied to trout?
Article 13	DHA	DHA contributes to maintenance of normal brain function	The claim may only be used for food which contains at least 40mg of DHA per 100g and per 100kcal. In order to bear the claim, information shall be given to the consumer that the beneficial effect is obtained with a daily intake of 250mg of DHA.	Yes
Article 13	DHA	DHA contributes to the maintenance of normal vision	The claim may only be used for food which contains at least 40mg of DHA per 100g and per 100kcal. In order to bear the claim, information shall be given to the consumer that the beneficial effect is obtained with a daily intake of 250mg of DHA.	Yes
Article 13	EPA and DHA	EPA and DHA contribute to the normal function of the heart	The claim may be used only for food which is at least a source of EPA and DHA as referred to in the claim 'source of omega-3 fatty acids'. In order to bear the claim, information shall be given to the consumer that the beneficial effect is obtained with a daily intake of 250mg of EPA and DHA.	Yes
Article 13	DHA	DHA contributes to the maintenance of normal blood triglyceride levels	The claim may be used only for food which provides a daily intake of 2g of DHA and which contains DHA in combination with EPA. In order to bear the claim, information shall be given to the consumer that the beneficial effect is obtained with a daily intake of 2g of DHA. When the claim is used on food supplements and/or fortified foods, information shall be given to consumers not to exceed a supplemental daily intake of 5g of EPA and DHA combined. The claim shall not be used for foods targeting children.	A portion of around 270g of baked trout would be required to provide 2g of DHA.
Article 13	DHA and EPA	DHA and EPA contribute to the maintenance of normal blood pressure	The claim may be used only for food which provides a daily intake of 3g of EPA and DHA. In order to bear the claim, information shall be given to the consumer that the beneficial effect is obtained with a daily intake of 3g of EPA and DHA. When the claim is used on food supplements and/or fortified foods, information shall be given to consumers not to exceed a supplemental daily intake of 5g of EPA and DHA combined. The claim shall not be used for foods targeting children.	A portion of around 230g of baked trout would be required to provide 3g of DHA and EPA.
Article 13	DHA and EPA	DHA and EPA contribute to the maintenance of normal blood triglyceride	The claim may be used only for food which provides a daily intake of 2g of EPA. In order to bear the claim, information shall be given to the consumer that the beneficial effect is obtained with a daily intake of 2g of EPA and DHA. When the claim is used on food supplements and/or fortified foods, information shall be given to consumers not to exceed a	A portion of around 350g of baked trout would be required to provide 2g of EPA.

		levels	supplemental daily intake of 5g of EPA and DHA combined. The claim shall not be used for foods targeting children.	

Source: http://ec.europa.eu/nuhclaims/

- Raw trout can be considered a source of vitamin B_1, vitamin B_6 and potassium
- Raw trout can be considered a rich or high source of protein, omega-3 fatty acids, vitamin D, vitamin B_3, vitamin B_{12}, phosphorus and selenium.
- Trout is considered to be low in salt, whereas other fish such as pangasius, mackerel, canned tuna, prawns and langoustine have a higher salt content and are considered to have a medium salt content.
- Although trout is an oil-rich fish, when compared to other oil-rich fish it has a lower total fat and saturated fat content.
- There are some approved EC health claims relating to the long-chain PUFAs DHA and EPA found in oil-rich fish such as trout. However, there are conditions for their use that must be met.

Conclusion

The UK Department of Health recommendation is to eat at least two portions of fish (140g each) per week, of which should be oil-rich. However, few people (approximately 28% of adults) in the UK eat oil-rich fish. Trout is an oil-rich fish, which has relatively low total fat and saturated fat compared with other oil-rich fish. Depending on how trout is prepared, it is generally low in sugar, saturates and salt. Raw trout can be considered a source of vitamin B_1, vitamin B_6 and potassium and a rich or high source of protein, omega-3 fatty acids, vitamin D, vitamin B_3, vitamin B_{12}, phosphorus and selenium.

There is good evidence of beneficial health outcomes from fish consumption for reduction in risk of cardiac death and improved neurodevelopment in infants and young children when fish is consumed by the mother before and during pregnancy. Evidence also suggests that fish consumption is probably associated with a lower risk of stroke and possibly beneficial for mental health, for example to improve mood and help treat depression. The health attributes of fish are most likely to be long-chain PUFAs, although other nutrients in fish (*e.g.* protein, selenium, vitamin D) may also contribute to the health benefits.

The Marine Conservation Society currently rates farmed rainbow trout as a good choice of fish for consumers in terms of environmental sustainability.

In summary, trout is a healthy and sustainable oil-rich fish, and therefore may provide health benefits, such as reducing the risk of CVD deaths and improving cognitive development, when included in the diet.

References

Aquaculture Stewardship Council (2013) Responsible aquaculture. Available: http://www.asc-aqua.org/index.cfm?act=tekst.item&iid=3&lng=1 (accessed 29 July 2013).

Bates B, Lennox A, Prentice A *et al.* (2012) *National Diet and Nutrition Survey, Headline Results from Years 1, 2, and 3 (combined) of the Rolling Programme (2008/09-2010/11)*. Department of Health, and Food Standards Agency, London.

Bates B, Lennox A, Bates C *et al.* (2011) *National Diet and Nutrition Survey, Headline Results from Years 1 an 2 (combined) of the Rolling Programme (2008/2009-2009/10).* Department of Health, and Food Standards Agency, London.

Bates B, Lennox A and Swan G (2010) N*ational Diet and Nutrition Survey, Headline Results from Year 1 of the Rolling Programme (2008-2009).* Department of Health, and Food Standards Agency, London

Black P and Sharp S (1997) Dietary fat and asthma: is there a connection? *European Respiratory Journal* 10: 6-12.

BNF (British Nutrition Foundation) (2013) *Nutrition and Development: Short- and long-term consequences for health* Oxford, Wiley Blackwells.

Bord Iascaigh Mhara and Irish Sea fisheries Board (2006) *Nutritional aspects of fish.* Cited in: Weichselbaum E, Coe S, Buttriss J and Stanner S (2013) Fish in the diet: A review *Nutrition Bulletin* 38: 128-77.

Borzoei S, Neovius M, Barkeling B *et al.* (2006) A comparison of effects of fish and beef protein on satiety in normal weight men *European Journal of Clinical Nutrition* 60: 897-902.

Brunner EJ, Jones PJS, Friel S and Bartley M (2009) Fish, human health and marine ecosystem health: policies in collision. *International Journal of Epidemiology* 38: 93-100.

Brunsø K (2009) Trends in consumer attitudes and selection. *FAO Fisheries and Aquaculture Proceedings* 13: 115-21.

Burr M (2007) Secondary prevention of CHD in UK men: the Diet and Reinfarction Trial and its sequel *Proceedings of the Nutrition Society* 66: 9-15.

Chowdhury R, Stevens S, Gormon D *et al.* (2012) Association between fish consumption, long-chain omega 3 fatty acids, and risk of cerebrovascular disease: systematic review and meta-analysis *British Medical Journal* 345: e6698.

Datta S, Alfaham M, Appleby P *et al.* (2002) Vitamin D deficiency in pregnant women from a non-European ethnic minority population – an intervention study *British Journal of Obstetrics and Gynaecology* 109: 250-3.

Defra (Department for Environment, Food and Rural Affairs) (2011) *Family Food 2010*. Defra, London.

Department of Health (DH) (2013) Nutrient analysis of fish and fish products. Department of Health, London. Available: https://www.gov.uk/government/publications/nutrient-analysis-of-fish (accessed 4 September 2013).

Department of Health (DH) (2011) Nutrition and health claims. Guidance to compliance with Regulation (EC) 1924/2006 on nutrition and health claims made on foods. Version 2, November 2011. Department of Health, London. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/204320/Nutrition_and_health_claims_guidance_November_2011.pdf (accessed 4 September).

Department of Health (DH) (1994) *Nutritional aspects of cardiovascular disease*. HMSO, London.

European Parliament and Council (2012) Regulation (EC) No 1924/2006 of the European Parliament and of the council of 20 December 2006 on nutrition and health claims made on foods. *Official Journal of the European Union* L12: 3-18. Available: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2006R1924:20121129:EN:PDF (accessed 29 July 2013).

EC (European Commission) (2008) Council Directive 90/496/EEC on nutrition labeling for foodstuffs as regards recommended daily allowances, energy conversion factors and definitions *Official Journal of the European Union 285: 9-12.*

EFSA (European Food Safety Authority) (2010) Scientific Opinion in Dietary Reference Values for fats, including saturated fatty acids, polyunsaturated fatty acids, monounsaturated fatty acids, trans fatty acids, and cholesterol *EFSA Journal* 8: 1461.

Elmadfa I, Meyer A, Nowak V *et al.* (2009) *European Nutrition and Health Report 2009*. Karger, London.

FAO (Food and Agriculture Organisation) (2008) *Food and Nutrition paper: Fats and fatty acids in human health.* FAO, Geneva.

FAO GLOBEFISH (2011) *Globefish highlights: A quarterly update on world seafood markets.* Issue 2/2011. Available: http://www.globefish.org/upl/Publications/files/GSH_April_2011.pdf (accessed 22 July 2013).

FAO GLOBEFISH (2013) *Market reports* Available: http://globefish.org/market-reports.html (accessed 6 August 2013).

Fernandes A Smith F, Petch R *et al.* (2009) *Investigation into the levels of environmental contaminants in Scottish marine and freshwater fin fish and shellfish* Food and Environment Research Agency, York.

FSA (Food Standards Agency) (2002) *McCance and Widdowson's the composition of foods. Summary Edition (6th Edition)*. Royal Society of Chemistry, London.

FSA (Food Standards Agency) (2008) *Consumer attitudes to food standards, wave 8.* Food Standards Agency, London.

Fujuhira E, Takahashi H and Nakazwa M (1970) Effect of long-term feeding of taurine in hereditary hyperglycemic obese mice. *Chemical and Pharmaceutical Bulletin* 18: 1636-42.

Ginsberg GL and Toal BF (2009) Quantitative approach for incorporating methylmercury risks and omega-3 fatty acid benefits in developing species-specific fish consumption advice *Environmental Health Perspective* 117: 267-75.

Gregory J, Lowe S, Bates CJ *et al.* (2000) National Diet and Nutrition Survey: Young People Aged 4 to 18 years, vol. 1: Report of the Diet and Nutrition Survey. The Stationary Office, London.

Hallund J, Overgaard Madsen B, Bugel SH *et al.* (2010) The effect of farmed trout on cardiovascular risk markers in healthy men *British Journal of Nutrition* 104; 1528-36.

He K, Song Y, Daviglus M *et al.* (2004a) Fish consumption and incidence of stroke. A meta-analysis of cohort studies *Stroke* 35: 1538-42.

He K, Song Y, Daviglus M *et al.* (2004b) Accumulated evidence on fish consumption and coronary heart disease mortality. A meta-analysis of cohort studies *Circulation* 109: 2705-11.

Henderson L, Gregory J, Irving K *et al.* (2003) National Diet and Nutrition Survey: Adults Aged 19 to 64 years, vol. 2: Energy, protein, carbohydrate, fat and alcohol intake. The Stationery Office, London.

Huang TL, Zandi PP, Tucker KL (2005) Benefits of fatty fish on dementia risk are stronger for those without APOE epsilon4 *Neurology* 65: 1409-14.

Karapanagiotidis IT, Bell MV, Little DC *et al* (2006) Polyunsaturated fatty acid content of wild and farmed tilapias in Thailand: Effect of aquaculture practices and implications for human nutrition *Journal of Agriculture and Food Chemistry* 54: 4304-10.

Laerum BN, Wentzel-Larsen T, Gulsvik A *et al*. (2007) Relationship of fish and cod oil intake with adult asthma *Clinical & Experimental Allergy* 37: 1616-23.

Lanham-New S, Buttriss J, Miles L *et al.* (2011) Proceedings of the rank forum on vitamin D *British Journal of Nutrition* 105: 144-56.

Lanham-New S, Thompson R, More J *et al.* (2007) Importance of vitamin D, calcium and exercise to bone health with specific reference to children and adolescents *Nutrition Bulletin* 32: 364-77.

Lin Pao-Yen, Huang S-Y, Su K-P (2010) A meta-analytic review of polyunsaturated fatty acid compositions in patients with depression *Biol Psychiatry* 68: 140-7.

Mental Health Foundation (2013) Mental health statistics. Available: http://www.mentalhealth.org.uk/help-information/mental-health-statistics/ (accessed 22 July 2013).

Miles EA, Aston L and Calder PC (2003) In vitro effects of eicosanoids derived from 20-carbon fatty acids on T helper type 1 and T helper type 2 cytokine production in human whole-blood cultures. *Clinical and Experimental Allergy* 33: 624-32.

Miles E and Calder P (2012) Influence of marine *n*-3 polyunsaturated fatty acids on immune function and a systematic review of their health effects on clinical outcomes in rheumatoid arthritis *British Journal of Nutrition* 107: S171-S84.

Morris M, Evens D, Tangney C *et al.* (2005) Fish consumption and cognitive decline with age in a large community study *Archives of Neurology* 62: 1849-53.

Mozaffarian D and Rimm EB (2006) Fish intake, contaminants and human health. Evaluating the risks and benefits. *JAMA* 296: 1885-99.

O'Callaghan J (2010) A pilot study to validate non-invasive methods of assessing the dietary intakes of long-chain omega-3 fatty acids in an adult sample population. *MSc Public Health Nutrition, QMU*

Oken E, Wright RO, Kleinman KP *et al.* (2005) Maternal fish consumption, hair mercury and infant cognition in a US cohort. *Environmental Health Perspective* 113: 1376-80.

Oken E, Radesky JS, Wright RO *et al.* (2008) Maternal fish intake during pregnancy, blood mercury levels and child cognition at age 3 years in a US cohort *American Journal of Epidemiology* 167: 1171-81.

Orchard T, Pan X, Cheek F *et al*. (2012) A systematic review of omega-3 fatty acids and osteoporosis *British Journal of Nutrition* 107; S253-S60.

Pieniak Z, Verbeke W and Scholderer J (2010) health-related beliefs and consumer knowledge as determinants of fish consumption *Journal of Human Nutrition and Dietetics* 23: 480-8.

Prentice A (2008) Vitamin D deficiency: A global perspective *Nutrition Reviews* 66, S153-S64.

Ramel A, Martinez JA, Kiely M *et al.* (2010) Effects on weight loss and seafodd consumption on inflammation parameters in young, overweight and obese European men and women during 8 weeks of energy restriction *European Journal Clinical Nutrition* 64: 987-93.

Russo GL (2009) Dietary *n*-6 and *n*-3 polyunsaturated fatty acids: from biochemistry to clinical implications in cardiovascular prevention *Biochemical Pharmacology* 71: 937-46.

Ruxton CHS (2011) The benefits of fish consumption *Nutrition Bulletin* 36: 6-19.

Ruxton CHS, Reed SC, Simpson JA and Millington KJ (2004) The health benefits of omega-3 polyunsaturated fatty acids: a review of the evidence. *Journal of Human Nutrition and Dietetics* 17: 449-59.

Ryan K (2011) Fish consumption in women of child-bearing age: current intakes, motivations, barriers and awareness of advisories. *MSc Dietetics, QMU*

Sadler K, Nicholson S, Steer T *et al*. (2011). National Diet and Nutrition Survey – Assessment of dietary sodium in adults (aged 19-64 years) in England, 2011. Department of Health, London. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/213420/Sodium-Survey-England-2011_Text_to-DH_FINAL1.pdf (accessed 29 July 2013).

Sala-Vila A, Miles E and Calder P (2008) Fatty acid composition abnormalities in atopic disease: evidence explored and role in the disease process examined *Clinical and Experimental Allergy* 38: 1432-50.

SACN (Scientific Advisory Committee on Nutrition) (2004) *Advice on fish consumption: Benefits and risks.* The Stationary Office, London.

Scottish Centre for Social Research (2011) A survey of 24 hour urinary sodium excretion in a representative sample of the Scottish population as a measure of salt intake. Available; http://www.foodbase.org.uk/results.php?f_category_id=&f_report_id=681 (accessed 29 July 2013).

Shahar E, Folsom A, Melnick S *et al.* (1994) Dietary *n*-3 polyunsaturated fatty acids and smoking-related chronic obstructive pulmonary disease. *New England Journal of Medicine* 331: 228-33.

Skeaff C and Miller J (2009) Dietary fat and coronary heart disease: summary of evidence from prospective cohort and randomized controlled trials *Annals of Nutrition and Metabolism* 55: 173-201.

Tabak C, Smit H, Heederik D *et al.* (2001) Diet and chronic obstructive pulmonary disease: independent beneficial effects of fruits, whole grains and alcohol (the MORGEN study) *Clinical and Experimental Allergy* 31: 747-55.

Verbeke W, Sioen I, Pieniak Z *et al.* (2005) Consumer perception versus scientific evidence about health benefits and safety risks from fish consumption *Public Health Nutrition* 8(4): 422-9.

Walda I, Tabak C, Smith H *et al* (2002) Diet and 20-year chronic obstructive pulmonary disease mortality in middle-aged men from three European countries *European Journal of Clinical Nutrition* 56: 638-43.

Weaver KL, Ivester P, Chilton JA *et al.* (2008) The content of favorable and unfavorable polyunsaturated fatty acids found in commonly eaten fish *Journal of the American Dietetic Association* 108: 1178-85.

Weichselbaum E, Coe S, Buttriss J and Stanner S (2013) Fish in the diet: A review *Nutrition Bulletin* 38: 128-77.

Whelton S, He J, Whelton P *et al.* (2004) Meta-analysis of observational studies on fish intake and coronary heart disease *The American Journal of Cardiology* 93: 1119-23. *Cochrane Database of Systematic Reviews Cochrane Database of Systematic Reviews*