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Contributions (in 2005) of marine and fresh water products (finfish and shellfish, seafood, wild and farmed) to the French dietary intakes of vitamins D and B12, selenium, iodine and docosahexaenoic acid: impact on public health

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Abstract

Primary objective To assess the contributions of seafood (finfish and shellfish, wild and farmed, freshwater and marine) to the French recommended daily intakes of dietary elements that are particularly abundant in these foods.

Methods and procedures We first calculated the concentrations of each of these elements by critical analysis of a large body of published data. We then determined the consumption of seafood in France (in 2005) using a modified version of the method of measuring dietary intake defined by the FAO.

Main outcomes and results The percentages of the French recommended daily intakes obtained from seafood species are: 44% for vitamin D, 65% for vitamin B12, 24% for selenium, 21% for iodine and 156% for an omega-3 fatty acid, docosahexaenoic acid (DHA) (159% referring to the French AFSSA seafood data).

Conclusions French people must increase their seafood consumption to counteract disorders arising due to the demonstrated low concentrations of these nutrients in their usual diets; this could help overcome a potentially major public health problem.

Keywords: *Seafood, iodine, selenium, vitamin D, cobalamine, docosahexaenoic acid, omega-3 polyunsaturated fatty acids*

Introduction

Seafood in France includes a wide range of species (Medale et al. 2003) that can be prepared in innumerable ways to suit people of all ages and lifestyles. An unbalanced diet is the cause of deficient intakes of certain nutrients, which could give rise to major public health problems. Finfish and shellfish, wild and farmed, freshwater and marine, are about the only foods that are major sources of the omega-3 polyunsaturated fatty acid docosahexaenoic acid (DHA), vitamin D (several finfish and shellfish) and vitamin B12 (most finfish and shellfish), iodine (all marine seafood) and selenium (almost all seafood). We have measured the consumption of the main forms of seafood in France, calculated the contents of these nutrients from published data, and used

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these figures to calculate the contribution of seafood to the percentage of the French recommended daily allowance (RDA).

Materials and methods

The production data were taken from the annual estimates of fisheries and farming production published by OFIMER and the Ministry of Agriculture and Fisheries. The data are given as live weights. The import and export data were taken from the annual report of international trade in fish and aquaculture products published by OFIMER based on data provided by the Director General of Customs and the Ministries of the French Economy, Finance and Industry. These import and export data are given in net weight and were converted to live weight. The actual consumption of the main species or groups of species of finfish and shellfish per French inhabitant was determined using the FAO method (FAO 2004). The determination involved an assessment of supplies for 2005 based on the quantities of primary products of fishing and farming destined for human consumption, plus data on imports and exports of these products, both primary and processed (Paquotte et al. 2002; Girard and Paquotte 2003). The real consumption (edible) was calculated (g/day) from various tables, mainly the French tables (Favier et al. 1995). The nutrients in seafood ('world mean' in Table I) were calculated using composition tables (Favier et al. 1995; Lamand et al. 1996; Souci et al. 2000; Bourre 2005a), the USDA Internet database, and laboratory nutrition data (McCance and Widdowson 2004). In addition, a total of 94 publications were analysed, some given in a previous publication (Bourre and Paquotte 2006). The French government (AFSSA 2006) recently published data on the DHA content in the main types of seafood sold in France. The tables compare the world mean values and with the French values from AFSSA. Our conclusions are based on the nutrient contents of unprocessed products.

Results and discussion

Table I shows that 20 species of finfish and shellfish provide 89% of the total seafood intake in France. These are tuna, cod, salmon, Alaskan pollock, sardine, saithe, shrimp, mussel, hake, herring, mackerel, monkfish, trout, scallop, squid, sprat, chinchar, anchovy, oyster and whiting (Table I). There is an average yearly consumption per inhabitant (Table I and II) of 34.9 kg live weight equivalents (95.5 g/day), corresponding to 37 g/day edible fish (Table II).

Vitamin D

Table I shows that the 10 finfish and shellfish with the highest vitamin D contents are: eel (20 µg/100 g edible), herring (17 µg/100 g edible), salmon (15 µg/100 g edible), sardine (11 µg/100 g edible), mackerel (10 µg/100 g edible), trout (8.0 µg/100 g edible), oysters (8.0 µg/100 g edible), anchovy (7.0 µg/100 g edible), tuna (5.0 µg/100 g edible), and halibut (4.3 µg/100 g edible). The greatest contributors to the vitamin D requirements that are part of the present French diet are salmon (0.57 µg/day/person), tuna (0.24 µg/day/person), sardine (0.23 µg/day/person), herring (0.22 µg/day/person), mackerel (0.11 µg/day/person), monkfish and trout (0.1 µg/day/person), cod (0.05 µg/day/person), and oysters and anchovy (0.04 µg/day/person).

Table I. Finfish and shellfish presented in decreasing order of edible (eatable) quantities.

Species	Total[a] (kg) in 2005	Total[a] (g/day)	Edible[b] (g/day)	Vitamin D, world mean (μg/100 g edible)	Vitamin D (μg/day)	Vitamin B12, world mean (μg/100 g edible)	Vitamin B12 (μg/day)	Selenium, world mean (μg/100 g edible)	Selenium (μg/day)	Iodine, world mean (μg/100 g edible)	Iodine (μg/day)	DHA, world mean[c] (mg/100 g edible)	DHA, world mean[d] (mg/day)	DHA, France AFSSA[e] (mg/100 g edible)	DHA, France AFSSA[e,f] (mg/day)
Tuna	3.90	10.69	4.81	5.0	0.24	6.40	0.31	56	2.69	45	2.16	420	20.20	131	6.3
Cod	1.74	4.77	4.05	1.3	0.05	1.10	0.05	35	1.42	160	6.48	170	6.88	75	3.04
Salmon	1.95	5.35	3.85	15.0	0.58	4.00	0.15	33	1.27	26	1.01	1247	48.00	2164	83.31
Alaskan pollock	1.84	5.04	3.28	1.1	0.04	1.20	0.04	20	0.66	103	3.38	259	8.49	173	5.67
Sardine	1.05	2.88	2.02	11.0	0.22	3.00	0.06	51	1.03	32	0.65	1350	27.27	1269	25.63
Saithe	0.98	2.69	1.75	0.8	0.01	3.50	0.06	31	0.54	200	3.50	259	4.53	173	3.03
Shrimp	1.60	4.37	1.74	1.3	0.02	1.30	0.02	40	0.70	80	1.39	160	2.78	66	1.15
Mussel	2.60	7.12	1.42	2.4	0.03	10.00	0.14	57	0.81	365	5.18	178	3.52	151	2.14
Hake	0.87	2.39	1.39	1.5	0.02	0.70	0.01	43	0.60	23	0.32	338	4.69	123	1.71
Herring	0.82	2.26	1.35	17.0	0.23	10.20	0.14	34	0.46	38	0.51	937	12.64	937	12.64
Mackerel	0.61	1.68	1.17	10.0	0.12	9.00	0.11	43	0.50	64	0.76	1493	17.46	1404	16.43
Monkfish	0.48	1.32	1.12	1.2	0.01	9.00	0.10	36	0.40	23		126	1.41	37	0.41
Trout	0.64	1.75	1.05	8.0	0.08	2.30	0.02	26	0.27	6	0.06	543	5.70	543	5.7
Scallop	2.01	5.50	0.99	[g]		1.60	0.02	28	0.28	10	0.10	144	1.43	105	1.04
Squid	0.29	0.79	0.71			1.30	0.01	57	0.41	21	0.15	491	3.48	167	1.19
Sprat+Atlantic horse mackerel	0.40	1.09	0.60												
Anchovy	0.29	0.80	0.58	7.0	0.04	0.62	0.00	36	0.21	51	0.29	600	3.48	1365	7.92
Oyster	1.81	4.97	0.55	8.0	0.04	15.00	0.08	55	0.30	125	0.69	107	0.58	64	0.35
Whiting	0.31	0.86	0.52			2.30	0.01	32	0.17			107	0.56	69	0.36
Redfish	0.25	0.68	0.48	2.3	0.01	3.80	0.02			99		70	0.36	70	0.36
Sharks (spotted dogfish)	0.23	0.62	0.40			0.60	0.00	47	0.19			660	2.64	66	0.26
Ling	0.17	0.48	0.34			0.55	0.00	36	0.12					65	
Haddock	0.18	0.49	0.33			0.74	0.00	35	0.12	338	1.11	139	0.46	60	0.2
Nephrops	0.30	0.82	0.30			25.00	0.08								
Sole	0.16	0.43	0.26					24	0.06	17	0.04	141	0.37	72	0.19
Cuttlefish	0.12	0.33	0.26			3.00	0.01	55	0.14			66	0.17	156	0.41
Sea bass	0.13	0.35	0.24			3.80	0.01					434	1.04	617	1.48
Crab	0.44	1.19	0.23									113	0.26	714	1.64
Sea bream	0.11	0.30	0.21												
Pollack	0.11	0.29	0.18	0.7	0.00	1.20	0.00	20	0.04	103	0.18	259	0.47	76	0.14
Place	0.07	0.19	0.15	1.6	0.02	1.50	0.00	28	0.04	32	0.05	193	0.29	41	0.06
Halibut	0.06	0.16	0.13	4.3	0.01	1.00	0.00	70	0.09	23	0.03	318	0.41	1400	1.82
Carp	0.08	0.22	0.13							2	0.03	108	0.14	108	0.14
Octopus	0.05	0.14	0.13			20.00	0.03	29	0.04			81	0.10	56	0.07
Spiny lobster	0.08	0.22	0.10			25.00	0.03	99	0.10			80	0.08	72	0.07
Lobster	0.11	0.30	0.09	1.2	0.00	2.30	0.00	115	0.10	515	0.46	142	0.13	178	0.16
Roe end lever	0.03	0.08	0.07												

Table I (*Continued*)

Species	Total[a] (kg) in 2005	Total[a] (g/day)	Edible[b] (g/day)	Vitamin D, world mean (µg/100 g edible)	Vitamin D (µg/day)	Vitamin B12, world mean (µg/100 g edible)	Vitamin B12 (µg/day)	Selenium, world mean (µg/100 g edible)	Selenium (µg/day)	Iodine, world mean (µg/100 g edible)	Iodine (µg/day)	DHA, world mean[c] (mg/ 100 g edible)	DHA, world mean[d] (mg/day)	DHA, France AFSSA[e] (mg/ 100 g edible)	DHA, France AFSSA[e,f] (mg/day)
Crayfish	0.02	0.05	0.01	0.3	0.00	2.40	0.00					12	0.00	12	0
Eel	0.00	0.00	0.00	20.0	0.00			50	0.00	7	0.00	430	0.00	716	0
Other flatfish[h]	0.27	0.70													
Other whole groundfish[h]	1.78	4.88													
Other whole goundfish in fillets[h]	3.97	10.87													
Other freshwater fish	0.72	1.98													
Molluscs and invertebrates	1.22	3.34													
Other crustacean	0.03	0.10													

Notes: [a]Wet weight of the whole fish, including the head, viscera, shell and skeleton etc. Total intake per year or per day is the whole animal, kg or g live weight equivalents (bones, head, viscera, shell, etc.). [b]Only the eatable part that is sold, and hence assumed to be consumed. [c]Mean values from the published data referred to in Materials and methods. [d]French consumption based upon the mean concentration of DHA around the world. [e]Data from AFSSA (2006). [f]Calculated from the previous column. AFSSA (2006) provided data for all seafood, except herring, redfish, carp, trout and crayfish sold in the main French ports on the Atlantic and Mediterranean coasts; thus, the mean world values for these seafood species were used to calculate the last column. The AFSSA data differ from international mean values in term of the DHA content: two times more for salmon and anchovy (but similar amounts for the other fatty fish such as sardine and mackerel), more than three times less for tuna, two times more for sharks (however, 10 times less for spotted dogfish, not shown). However, the total amount of DHA consumed in France is similar when calculated by the two methods. The DHA content of salmon according to AFSSA (2,164 mg/100 g) is very different from the mean world value (1,247 mg/100 g). The content may be dramatically different from one country to another, or the part of the muscle used for measurements. The lipid distribution within Atlantic salmon fillets varies from 2.4% to 18.5%, depending on the anatomical origin of the fillet (Katitou et al. 2001). Moreover, farmed Atlantic salmon from Norway usually sold in France had 2,000 $\pm$ 190 mg/100 g, while the wild salmon from Scotland, Ireland and Norway had only 900–1,400 mg/100 g (Bourre et al. 2006), in agreement with AFSSA. [g]Data not specified, not available for seafood consumed in France or in Europe (including Canadian and US data for Atlantic seafood). Values for wild salmon (DHA, 600 mg/100 g) and wild trout (DHA, 100 mg/100 g) have not been taken into account, as these fish are rarely consumed. Only Atlantic salmon is taken into account (Pacific salmon is not consumed in France). Relatively little fresh tuna is purchased by French families—most of the fresh fish is prepared by restaurants and canteens, while the rest is canned. The canned tuna sold in France is 70% albacore, 28% listao and 2% germon. [h]Includes, according to the Finance Ministry and Customs, various species that are poorly declared or not specified (swordfish, red mullet, ray, turbot, mullet, etc.). Perch and pike are not listed individually. These three unknowns account for 23% of the weight of finfish and shellfish consumed and cannot be taken into account in the final calculations of the various nutrients.

Table II.

Species	Total (kg/2005)	Total (g/day)	Edible (g/day)	Vitamin D (RDA = 5 µg/day)	Vitamin B12 (RDA = 2.4 µg/day)	Selenium (RDA = 60 µg/day)	Iodine (RDA = 150 µg/day)	DHA (RDA = 120 mg/day)	DHA AFSSA
Total for tested species[a] (mg/day)	34.88	95.53	36.99	1.79	1.50	13.75	28.53	180.02	185.02
% French RDA				36	63	23	19	150	154
Total estimated for all individual species[b] (mg/day)				2.20	1.55	14.69	32.26	187.04	191.5
% French RDA estimated				44	65	24	21	156	159

Notes: French RDAs listed are those for an adult man, because the way that age and sex influence the Seafood absorption are not yet known. [a]Values for known species or parameters; 40 species for amounts consumed daily, 34 species for the DHA, 32 species for vitamin B12, 22 species for vitamin D, 24 species for iodine, and 30 species for selenium. [b]Wet weight of 73.58 g/day/person, the total being 95.53 g/day/person. This does not include the last six rows of Table I ('others', 21% of the fresh weight consumed), but implies an extrapolation to individual species, for which the value of a specific parameter is not known. The calculations are based on the fresh weight consumed (second column). Species for which the value of a specific parameter is not known account for 5.4% of DHA, 4.7% of vitamin B12, 18.9% of vitamin D, 13.1% of iodine, and 6.9% of selenium. These last data were used to calculate the% French RDA estimated for all individual species, the last row in the table.

The 22 species of finfish and shellfish whose vitamin D contents are known account for 36% of the French RDA of this vitamin (Table II). Taking all the species individually, and extrapolating to include those whose vitamin D contents are not known, provides 44% of the RDA. The results of the SU.VI.MAX study showed that the diets of about 70% of the population provided less than 33% of the RDA (Deschamps et al. 2005). Seafood is one of the dietary elements that contribute most to the vitamin D intake, quite apart from being an excellent source of high-quality protein.

Vitamin B12

The 10 finfish and shellfish with the highest vitamin B12 contents are (Table I): lobster and spiny lobster (25 μg/100 g edible), octopus (20 μg/100 g edible), oysters (15 μg/100 g edible), herring and mussels (10 μg/100 g edible), mackerel and monkfish (9 μg/100 g edible), tuna (6 μg/100 g edible) and salmon (4 μg/100 g edible). The greatest contributors to the vitamin B12 requirements that are part of the present diet are: tuna (0.31 μg/day/person), salmon (0.15 μg/day/person), mussels and herring (0.14 μg/day/person), mackerel (0.09 μg/day/person), oysters and monkfish (0.08 μg/day/person), nephrops (0.05 μg/day/person), and sardine and saithe (0.06 μg/day/person). The 31 species of finfish and shellfish whose vitamin B12 contents are known account for 63% of the RDA of this vitamin. Taking all the species individually, and extrapolating to include those whose DHA contents are not known, provides 65% of the RDA (Table II). This explains the good dietary intake of the vitamin in France, despite a reduced beef consumption and the almost complete disappearance of offal (liver) from the diet.

Selenium

The 10 finfish and shellfish with the highest selenium contents are (Table I): lobster (115 μg/100 g edible), spiny lobster (99 μg/100 g edible), halibut (70 μg/100 g edible), mussels and squid (57 μg/100 g edible), tuna, oysters and cuttlefish (55 μg/100 g edible), and sardine and eel (50 μg/100 g edible). The greatest contributors to the selenium requirements that are part of the present diet are: tuna (2.7 μg/day/person), cod (1.4 μg/day/person), salmon (1.3 μg/day/person), sardine (1.1 μg/day/person), mussels (0.8 μg/day/person), Alaskan pollock (0.7 μg/day/person), shrimp, hake and saithe (0.6 μg/day/person), and herring, mackerel and squid (0.4 μg/day/person). The 30 species of finfish and shellfish, whose selenium contents are known, account for 23% of the French RDA of this trace element. Taking all the species individually, and extrapolating to include those whose selenium contents are not known, provides 24% of the RDA (Table II). This could be linked to the observation that most of the volunteers who took part in the French SU.VI.MAX study (adults aged younger than 60 years) had serum concentrations below the values considered optimal for glutathione peroxidase activity, preserving adequate cognitive and immune function and for protection against cancer (Arnaud et al. 2006).

Iodine

The 10 finfish and shellfish with the highest iodine contents are (Table I): lobster (515 μg/100 g edible), mussels (365 μg/100 g edible), haddock (338 μg/100 g edible), saithe (200 µg/100 g edible), cod (160 µg/100 g edible), oysters (125 µg/100 g edible), Alaskan pollock and pollack (103 µg/100 g edible), redfish (99 µg/100 g edible) and shrimp (80 µg/100 g edible). The greatest contributors to the iodine requirements that are part of the present diet are cod (6.5 µg/person/day), mussels (5.1 µg/person/day), Alaskan pollock and saithe (3.5 µg/person/day), tuna (2.1 µg/person/day), shrimp (1.2 µg/person/day), salmon (1.0 µg/person/day), haddock (0.9 µg/person/day), sardine and redfish (0.7 µg/person/day). The 26 species of finfish and shellfish whose iodine contents are known account for 19% of the French RDA of this omega-3 fatty acid. Taking all the species individually, and extrapolating to include those whose iodine contents are not known, provides 21% of the RDA (Table II). Increasing seafood consumption would reduce the deficit demonstrated in a number of epidemiological studies. Quite a large percentage of French people (12.3% of men and 13.9% of women) (Valeix et al. 1999) suffer from thyroid hypertrophy. This could be a problem for women of child-bearing age (Delange 2001). Most marine fish provide 30% of the RDA in a 100 g edible portion, and are thus classified as rich in iodine. Several other seafood species are good sources of iodine, providing at least 15% of the RDA. Freshwater fish contain less iodine, while the iodine content of marine fish varies somewhat with the water salinity.

Omega-3 fatty acids

The mean world data indicate that the 10 finfish and shellfish with the highest DHA contents are (Table I): mackerel (1,490 mg/100 g edible), sardine (1,350 mg/100 g edible), salmon (1,247 mg/100 g edible), herring (937 mg/100 g edible), shark (660 mg/100 g edible), anchovy (600 mg/100 g edible), trout (540 mg/100 g edible), squid (490 mg/100 g edible), sea bass (430 mg/100 g edible), eel and tuna (430 mg/100 g edible). The greatest contributors to the DHA requirements that are part of the present diet are: salmon (47.6 mg/day/person), sardine (28.4 mg/day/person), tuna (20.5 mg/day/person), mackerel (15.7 mg/day/person), herring (12.4 mg/day/person), Alaskan pollock (8.9 mg/day/person), cod (6.9 mg/day/person), trout (6.5 mg/day/person), hake (4.7 mg/day/person), and saithe (4.6 mg/day/person). The 34 species of finfish and shellfish whose DHA contents are known account for 150% of the RDA of this omega-3 fatty acid. Taking all the species individually, and extrapolating to include those whose DHA contents are not known, provides 156% of the RDA (Legrand et al. 2000) (Table II). The six species of oily fish (salmon, sardine, tuna, mackerel, herring and Alaskan pollock) provide 72% of the seafood DHA in France, and thus approximately 112% of the French RDA.

The French AFSSA data indicate that the 10 finfish and shellfish with the highest DHA contents are (Table I): salmon (2,164 mg/100 g edible), swordfish (1,750 mg/100 g edible), mackerel (1,404 mg/100 g edible), halibut (1,400 mg/100 g edible), anchovy (1,365 mg/100 g edible), sardine (1,269 mg/100 g edible), herring (937 mg/100 g edible), eel and crab (716 mg/100 g edible) and sea bass (607 mg/100 g edible). The greatest contributors to the DHA requirements that are part of the present diet are: salmon (83.3 mg/day/person), sardine (25.6 mg/day/person), mackerel (16.4 mg/day/person), herring (12.6 mg/day/person), anchovy (7.9 mg/day/person), tuna (6.3 mg/day/person), trout and Alaskan pollock (5.7 mg/day/person), and cod and saithe (3.0 mg/day/person). Salmon alone provides 44% of the DHA intake from seafood in France, while six species of oily fish (salmon, sardine, mackerel, herring, anchovy and tuna) provide 79% of the seafood DHA, and thus 159% of the French RDA (Table II).

Omega-3 fatty acids are important components of the human diet, as they help prevent and treat several disorders. Cardiovascular authorities worldwide recommend eating two servings of fish per week, at least one of which should be oily fish. If those who eat little fish were to increase their consumption of seafood by 20 g/day, it would reduce their risk of dying from cardiovascular disease by 7% (He et al. 2004). There is an inverse association between the consumption of fish and the risk of certain cancers, particularly colon cancer (Norat et al. 2005), and breast and prostate cancers (Chajes and Bougnoux 2003). Omega-3 fatty acids are also anti-inflammatory; they may be important for counteracting rheumatological and dermatological (psoriasis) disorders, in addition to cardiovascular disease. Omega-3 fatty acids are essential nutrients that are incorporated into the brain, where they influence several functions, including cognition (Bourre, 2006a,b). It was shown recently that there is an inverse association reviewed between fish consumption and the prevention of psychiatric disorders such as depression, manic-depressive psychosis and dementia (Bourre 2005b).

As shown in Table II, the French requirement for DHA could be met from seafood alone, as this source provides 159% of the French RDA, in agreement with the SU.VI.MAX findings (Astorg et al. 2004). But there are major caveats. First, the RDA is designed to provide a good diet, while the omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and DHA, have true pharmacological actions when given at much higher doses (approximately 1,000 mg EPA+DHA). This is most clearly seen by their cardiovascular action. The French diet does not provide enough DHA and EPA for this purpose. The group whose diet provides the most DHA (1,472 mg/day) according to SU.VI.MAX eat amounts similar to that eaten by the average Inuit of the same age (1,596 mg/day) (Dewailly et al. 2001), and the diet of the modern Inuit provides much less than did the diet of their parents. Thus, even the highest intakes of seafood in France provide too little omega-3 fatty acids for them to have a pharmacological action, especially on the cardiovascular system. Secondly, the French RDAs are lower than those of other countries or authorities. For example, the international committee, the ISFFAL, recommends a minimum of 220 mg DHA, which is about twice the French RDA. The SU.VI.MAX survey found that fish and seafood provides 162 mg/day, not far from the 180 mg/day (world mean values for DHA in seafood) or the 185 mg/day (French AFSSA data) shown in Table II, even though it is calculated quite differently. But these mean values mask wide variations from one individual to another, from less than one-twelfth of the RDA to 12 times the RDA. Thus, efforts should be made to identify those whose diets provide little DHA and persuade them to eat more seafood. A study carried out on a relatively small number of men and women living in Brittany who were asked not to eat seafood found that their intake was less than one-half the RDA (Weill et al. 2002). The third point is that all the data used in this study are based on unprocessed products. Preparation, particularly frying, probably results in a considerable loss of omega-3 fatty acids into the oil. Finally, while salmon provides about 27% of the dietary DHA in France, this figure was obtained using data for farmed salmon fed fish oil. Farmed salmon account for 92% for the salmon eaten in France. The DHA supply would be much lower if the salmon were wild rather than farmed (wild fish contains only about one-half of the DHA), or if the farmed fish were fed a diet containing less fish oil.

Conclusions

The data in the tables do not include 23% of the seafood consumed because they are not included in the official statistics. The reason for this is that they are not major contributors to overall consumption or that they are eaten in very restricted areas. Hence the data are underestimates. The data also assume that all portions are in fact eaten, which is not so. Similarly, the losses that occur during preparation and cooking have not been taken into account as they vary greatly, and are not well defined. This leads to overestimation. But the overestimations and underestimations probably cancel each other out, so the conclusions are still pertinent. All the calculations were performed using data for unprocessed products, although these products are rarely eaten as such. Some nutrients are temperature sensitive. The only omega-3 fatty acids listed here are EPA and DHA, but fish and seafood contains measurable amounts of alpha-linolenic acid (ALA), and this fatty acid can be very high in farmed fish fed rapeseed or linseed products (Regost et al. 2003; Bell et al. 2004; Menoyo et al. 2005). The overall bioavailability of omega-3 fatty acids in fish is better than omega-3 fatty acid ethyl esters in capsules; the difference is nine-fold for DHA (Visioli et al. 2003). In addition, seafood contains significant amounts of monounsaturated fatty acids in addition to omega-3 fatty acids, particularly omega-9 fatty acids such as oleic acid and nervonic acid.

Fish farming not only counteracts the losses due to overfishing, it also ensures a balanced lipid content, so that the composition of farmed fish can remain constant, in contrast to the geographic, sexual and seasonal variations that occur in wild fish. Moreover, feeding any animal, including seafood, a diet enriched in omega-3 fatty acids increases the nutritional value of derived products for humans (Bourre 2005c). Aquaculture, together with new agricultural techniques, may improve or exacerbate disorders by altering the nutritional value. Clearly, the food production system must be recognized as a factor influencing the decrease (or increase) in disorders and chronic diseases.

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