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Freshwater Fish – Wholesome Foodstuffs

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Abstract

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Fish production by aquaculture is growing considerably and freshwater fish species are increasingly interesting for human nutrition. Freshwater fish are an excellent source of high quality animal protein. The protein content of flesh comes to 15 - 20% of wet weight and the protein is characterized by a balanced amino acid composition. The lipid content of freshwater fish varies dependent on species, size and nutrition. The lipid contains substantial concentrations of essential fatty acids of the n-3 and n-6 series. Since the polyunsaturated n-3 fatty acids have antiatherosclerotic efficacy freshwater fish can be used for preventing cardiovascular diseases. The flesh of freshwater fish species is also a source for meeting the mineral requirement of humans. Freshwater fish contain higher portions of potassium and phosphorus as well as of the trace mineral iron. Last not least freshwater fish comprise several vitamins. Therefore, freshwater fish can be recommended as wholesome foodstuffs.
Key words: freshwater fish, protein content, lipid content and quality, mineral and vitamin content

Introduction

World aquaculture production is growing continuously since years. In 2000 the global aquaculture production was more than 45 million t. That means increasing quantities of fish and other aquatic organisms are reared while on the other hand the portion of fish which is caught in the oceans is stagnating or even decreasing. Table 1 show that about 10 million t of the total aquaculture production are algae, and 35 million t are fish, crustaceans and molluscan. The most important fish group are cyprinids, however, also large quantities of salmonids and tilapias are produced in aquaculture. Therefore, freshwater fish make up an important portion of aquatic organisms which are used as human foodstuffs.

In many regions of the world freshwater fish are a significant source of animal protein. But freshwater fish contain also considerable quantities of valuable lipids as well as minerals and vitamins. The following presentation summarizes some results about the importance of freshwater fish for human nutrition.

Table 1

World aquaculture production (million t) in 2000 (FAO, 2002)

Algae	10.1
Fish, Crustaceans and Molluscan	35.6
- Cyprinids	15.7
- Salmonids	1.5
- Tilapias	1.2
- *Other fish species*	*3.8*
- Shrimps and prawns	1.1
- Molluscan	10.7
Total	45.7

Protein content

Like most vegetable and animal organisms freshwater fish mainly consist of water. The water content varies between 65 and 80%. Accordingly dry matter comes to 20 - 35%. There are considerable differences between various tissues. In the dry matter of muscle or flesh protein is the main component (Table 2). The protein content generally amounts to 15-20% of wet weight in the muscle. In lipid rich fish species the protein level is lower than in species with poor lipid content in their flesh (Steffens and Wirth, 1999).

The amino acid composition of the protein in different freshwater fish species is similar (Table 3). It can be stated, that the fish protein is of high nutritive value. This is especially true in case of eating just caught fish without longer storing time. The digestibility of fish protein is high, the flesh contains only small portions of connective tissue.

Lipid content

Depending on species, size and nutrition the lipid level of the flesh in freshwater fish can vary considerably (Table 4). There are freshwater fish species like pike (*Esox lucius*), perch (*Perca fluviatilis*) and pike-perch (*Sander lucioperca*) with exceptionally lean meat while other species are characterized by medium or even high lipid levels in their muscle, e.g. eel (*Anguilla anguilla*). Lipid content varies between less than 5% and more than 50% in the dry matter of muscle.

With growing fish size lipid level in the muscle generally increases (Table 5). The lipid content of large rainbow trout (*Oncorhynchus mykiss*) weighing more than 1000 g frequently is about 10% of wet weight (Maaß et al., 1999).

Nutrition has a significant influence on

Table 2

Protein content of the meat in different freshwater fish species (Steffens, 1964; Scherz and Senser, 1994; Steffens et al., 1999)

Fish species	Protein, % of wet weight	Protein, % of dry matter
Esox lucius	18.4	90
Sander lucioperca	19.2	89
Oncorhynchus mykiss	19.5	74
Silurus glanis	15.3	55
Cyprinus carpio	16.1	54
Anguilla anguilla	15	37

Table 3

Essential amino acid composition (g/16g N) of the protein in different freshwater fish species (Wunsche and Steffens, 1968; Steffens, 1979)

Amino acids	*Esox lucius*	*Oncorhynchus mykiss*	*Coregonus albula*	*Cyprinus carpio*	*Anguilla anguilla*
Arginine	7.4	5.3	5.6	5.9	9.4
Histidine	2.1	3.4	1.9	2.6	2.7
Isoleucine	5.3	4.4	5.3	5.3	5.3
Leucine	8.2	7.7	6.9	8.0	7.8
Lysin	9.2	8.6	8.9	9.2	8.8
Methionine	3.2	3.3	3.1	3.7	3.1
Phenylalanine	4.2	4.1	3.5	4.0	4.0
Threonine	5.0	4.6	5.0	4.7	4.9
Tryptophan	0.9	1.1	1.0	1.1	0.9
Valine	5.6	5.2	5.9	6.2	5.6

Table 4

Lipid content of the meat in different freshwater fish species (Steffens, 1964; Scherz and Senser, 1994; Steffens et al., 1998, 1999)

Fish species	Lipid, % of wet weight	Lipid, % of dry matter
Esox lucius	0.9	4
Perca fluviatilis	0.8	4
Sander lucioperca	0.7	3
Oncorhynchus mykiss [1]	4.9	19
Silurus glanis	11.3	41
Cyprinus carpio [2]	12.7	42
Tinca tinca [1]	10.2	38
Anguilla anguilla	24.5	60

[1] Feeding with pellets; [2] Supplementary feeding with grain

the lipid content of muscle especially in aquaculture fish species. Common carp (*Cyprinus carpio*) which were reared in ponds on the basis of natural food or fed supplementary grain differ in the lipid content of the meat (Tables 6 and 7). In most cases supplementary feeding of carbohydrate-rich vegetables results in higher lipid levels of the fish. However, the lipid content in fish muscle also depends on the intensity of feeding.

In feeding experiments tench (*Tinca tinca*) exhibited the highest fat content after intensive feeding of pellets in compari-

Table 5
Lipid content of the muscle (incl. skin) in male rainbow trout of different size (Steffens, 1979)

Average fish weight, g	Lipid, % of wet weight	Lipid, % of dry matter
213	4.6	17.4
342	5.4	20.2
442	6.4	22.9
558	6.9	24
695	8.5	28

Table 6
Lipid content of the muscle (incl. skin) in common carp reared on the basis of natural food or fed supplementary wheat in ponds (Wirth and Steffens, 1996)

	Carp reared on the basis of natural food in pond	Carp fed supplementary wheat in pond
Average fish weight, g	1497	1681
Lipid, % of wet weight	3.1	5.5
Lipid, % of dry matter	14.7	24.6

son to rearing only on the basis of natural food or on feeding supplementary wheat (Table 8).

European catfish (*Silurus glanis*) which were reared with fish as food in ponds had a much lower lipid level in their filet than catfish fed intensively with pellets (Table 9).

Lipid quality

Lipids of freshwater fish are characterized by high levels of n-3 polyunsaturated fatty acids, e.g. eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). But they also contain considerable amounts of n-6 fatty acids, especially linoleic acid and arachidonic acid (Steffens et al., 1993, 1997). While the essential fatty acid ratio (n-3/ n-6) of marine fish generally varies between 5 and 10, the essential fatty acid ratio of freshwater fish is 1 to 4 (Table 10). This seems appropriate for human nutrition.

Because of its favourable fatty acid composition the lipids of freshwater fish are of outstanding nutritional significance. It is well known that not only the n-6 fatty acids are essential for human nutrition. The n-3 fatty acids are just as necessary and must be also supplied in the diet. Both series of essential fatty acids cannot be synthesized by animals or humans.

Since the fatty acid composition depends on the ingested food freshwater fish feeding on phyto- and zooplankton are abundant in n-3 polyunsaturated fatty acids (Steffens and Wirth, 1997). In cultured fish the fatty acid composition reflects, to a large extent, that of the delivered diets (Table 11). It is, therefore, possible to produce fish with a ratio of n-3/n-6 polyunsaturated fatty acids that is optimal for human nutrition (Steffens, 1997; Steffens and Wirth, 1999).

Clinical tests with hypertensive patients in Hungary and Germany proved the effectiveness of eating freshwater fish in lowering blood pressure and plasma lipids (Steffens et al., 1993; Steffens and Wirthk, 2005). Hypertensive patients were put on a two-week diet of 100 g silver carp meat (*Hypophthalmichthys molitrix*) per day. This resulted in a significant drop in

Table 7
Lipid content of the fillet (without skin) in common carp reared under different nutritional conditions (Oberle et al., 1997)

	Suppl. Wheat feeding	Suppl. Rye feeding	Suppl. Corn feeding	Suppl. lupine feeding	Zooplankton feeding
Average fish weight, g	994	915	979	979	659
Lipid, % of wet weight	8.1	7.5	8.8	6.6	4.6
Lipid, % of dry matter	28.3	27.1	29.9	24.3	18.9

Table 8
Lipid content of the muscle (incl. skin) in tench reared under different nutritional conditions (Steffens et al., 1998)

	Tench reared on the basis of natural food in pond	Tench fed suppl. Wheat in pond	Tench fed pellets in pond
Average fish weight, g	255	390	429
Lipid, % of wet weight	1.1	2.0	10.1

Table 9
Lipid content of the fillet in European catfish fed fish or pellets in ponds (Fullner and Wirth, 1996)

	Catfish fed fish in pond	Catfish fed pellets in pond
Average fish weight, g	1208	1314
Lipid, % of wet weight	2.9	11.8
Lipid, % of dry matter	13.2	40.0

Table 10
Content of n-3 and n-6 fatty acids (%) in the lipids of different freshwater fish species (Vacha and Tvrzicka, 1994; Steffens and Wirth, 1995; Wirth and Steffens, 1998)

Fish species	Σ n-3	Σn-6	n-3/n-6
Hypophthalmichthys molitrix	21.6	11.0	2.0
Aristichthys nobilis	30.5	9.7	3.1
Tinca tinca	24.5	8.8	2.8
Coregonus albula	32.4	10.5	3.1
Silurus glanis	20.1	11.1	1.8
Esox lucius	18.6	13.3	1.4

Table 11

Content of n-3 and n-6 fatty acids (%) in the diet and in the lipids of rainbow trout and common carp fed this diet (Steffens and Wirth, 1995)

	Σ n-3	Σn-6	n-3/n-6
Diet	39.7	16.3	2.4
Oncorhynchus mykiss	36.9	15.7	2.4
Cyprinus carpio	30.8	13.6	2.3

systolic blood pressure by 15 mm Hg and diastolic pressure by 9 mm Hg (Table 12). In blood plasma, the level of triacylglycerols was reduced by 0.6 mmol/l, the HDL-cholesterol increased by 0.26 mmol/l, while the phospholipid concentration remained constant.

Mineral and vitamin content

Freshwater fish are a good source for several minerals and vitamins in human nutrition. Their meat is rich in potassium and phosphorus, but sodium, magnesium and calcium are present, too (Table 13). The flesh of freshwater fish contains also

Table 12

Effect of daily administration of 100 g of silver carp meat for two weeks to hypertensive patients on blood pressure and plasma lipids (Wirth et al., 1990)

	Pre	Post
Systolic blood pressure, mm Hg	151 ± 9	136 ± 7
Diastolic blood pressure, mm Hg	94 ± 7	85 ± 7
Triacylglycerols, mmol/l	1.82 ± 0.86	1.21 ± 0.53
HDL-cholesterol, mmol/l	1.52 ± 0.39	1.78 ± 0.44
Phospholipids, mg/dl	223 ± 35	226 ± 40

Table 13

Content of major elements in the muscle (mg/100 g) of different freshwater fish species (Scherz and Senser, 1994)

Fish species	Na	K	Mg	Ca	P
Esox lucius	75	304	28	20	215
Perca fluviatilis	47	330	20	20	198
Sander lucioperca	24	377	50	49	191
Oncorhynchus mykiss (*Salmo trutta*)	63	413	26	12	245
Silurus glanis	20	421	55	27	151
Cyprinus carpio	30	387	51	63	247
Tinca tinca	33	369	51	58	207
Anguilla anguilla	65	217	21	17	223

Table 14
Content of trace elements in the muscle (µg/100 g) of different freshwater fish species (Scherz and Senser, 1994)

Fish species	Fe	Mn	Se
Esox lucius	615	43	18
Perca fluviatilis	1000		24
Sander lucioperca	754	90	26
Oncorhynchus mykiss (*Salmo trutta*)	441	30	25
Silurus glanis	600	79	
Cyprinus carpio	700	55	
Tinca tinca	843	95	
Anguilla anguilla	600	25	31

Table 15
Content of vitamin A and several B vitamins in the muscle (µg/100 g) of different freshwater fish species (Scherz and Senser, 1994)

Fish species	A	B_1	B_2	B_6
Esox lucius	14	85	55	150
Perca fluviatilis	7	175	120	
Sander lucioperca		160	250	
Oncorhynchus mykiss (*Salmo trutta*)	32	84	76	
Cyprinus carpio	44	68	53	150
Tinca tinca	1	75	180	

some trace elements, e.g. iron and manganese (Table 14). Contrary to marine fish freshwater fish species are poor in iodine, since there are only very small portions of this trace element in fresh water. The iodine level in the muscle of cultured freshwater fish species may be enriched by adding marine brown algae (*Ascophyllum nodosum*, *Laminaria digitata*) to the fish feed (Reiter et al., 2002). By this means it is possible to enhance the iodine level in rainbow trout and other salmonids within 8 weeks from 10 to 50 µg/100 g filet (incl. skin).

Freshwater fish can also support meeting the demand for several vitamins such as vitamin A and some B vitamins (Table 15).

Conclusions

Freshwater fish are wholesome foodstuffs of high nutritive value. They are a good source for animal protein and especially for essential polyunsaturated fatty acids in human nutrition. Regular eating of fish (freshwater as well as marine fish species) can support preventing cardiovascular diseases. Freshwater fish are also in a position to meet the requirement for several minerals and vitamins. Moreover fish flesh has a good digestibility. For that

reason it is well suited as a healthy diet for children and seniors. The high nutritive value of freshwater fish should be, therefore, used for advertising and improving the market.

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