MAY FOOD BECOME MEDICINE - DOES CARP MEAT HAVE A CHANCE TO BECOME A FUNCTIONAL FOOD FOR PEOPLE WITH CARDIOVASCULAR DISEASE?

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ABSTRACT

Fish consumption is associated with lower risk of cardiovascular disease mortality. The health benefits of fish consumption are attributed to high content of omega-3 polyunsaturated fatty acids (PUFA), especially eicosapentaenoic and docosahexaenoic acid. Animal and human studies have demonstrated that n-3 PUFAs improve the function of the normal and damaged endothelium. It is recommended to eat two servings of fish per week.
The aim of the review was to find publications about the nutritional value of carp meat and its possible uses as functional food for patients with cardiovascular disease.
A search for open–access original full texts sin PubMed, Google Scholar, Medline Complete database was performed in June 2022. A total of 490 results were found. Eventually 22 articles were included for systematic review.
Carp consumption improves plasma lipid profile and therefore it could be considered a functional food. Carp meat is rich in essential amino acids too. The carp culture systems decide about PUFA and protein content in the meat. Carp can be cooked as traditional dishes or carp powder can be added to other dishes to enrich their nutritional value. The recommended method of carp meat preparation to preserve its' nutritional value is oven baking. Carp meat or carp powder can be used as functional food for patients with cardiovascular diseases.
Keywords:. carp meat; functional food; nutritional value; omega-3 polyunsaturated fatty acids.

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INTRODUCTION

Fish intake is associated with lower risk of cardiovascular disease mortality [1]. The health benefits of fish consumption are attributed to their high content of omega-3 polyunsaturated fatty acids (n-3 PUFA), especially eicosapentaenoic (EPA) and docosahexaenoic acid (DHA). Animal and human studies have demonstrated that n-3 PUFAs improve the function of the normal and damaged endothelium as they increase nitric oxide availability and the metabolic pathways of cytochrome P450 oxygenases. Nitric oxide causes vasodilatation and reduces blood pressure. Moreover, the antioxidant, anti-inflammatory, and anti-thrombotic features of n-3 LC PUFAs stabilize the electrophysiological properties of cardiomyocytes [1,2]. The authorities in nutrition and public health recommend two servings of fish per week as part of a healthy balanced diet [2]. The recommended daily intake of EPA + DHA for adults is 250mg/day [3]. Despite recommendations, fish consumption in Central Europe remains very low, e.g. in the Czech Republic it amounts to only 5.5 kg of fish and fish products *per capita* per year [4]. In Serbia common carp is the most marketed fish and it accounts for more than 80% of the national aquaculture there [5]. The landlocked countries and many without fish-eating traditions do not meet the recommendations for fish nor n-3 PUFA consumption [6]. Compared to marine fish, freshwater fish which usually contain a lower content of n-3 PUFA, are often overlooked as its source. The advantage of carp compared to sea fish is its high selenium content and low mercury content in the meat. Selenium as a component of redox enzymes and cytochrome is involved in the metabolic processes of the cell. It is part of glutathione peroxidase, which is an enzyme that protects cell membranes against damage by free radicals. The recommended daily intake of selenium is 45 µg for women and 55 µg for men. Selenium in our diet comes from offal and fish. Selenium deficiency can cause endemic in China juvenile cardiomyopathy (Keshan disease) and articular cartilage dystrophy (Kashin-Back disease) [3].

According to Sea Fisheries Institute National Research Institute in Gdynia, Poland, 100g of carp meat contains on average 214mg of n-3 PUFA, trout 1804, and wild salmon 3800mg [7]. One serving of carp meat (220g) meets the daily requirements of an adult for protein and fat-soluble vitamins.

Majority of studies analysed marine fish or fish oil. There are few articles related to freshwater fish and cardiovascular health are available. Common carp (*Cyprinus carpio* L.) is one of the most widely cultured freshwater species. Fish is bred in purity-controlled ponds not absorbing harmful substances. In Central Europe it has been kept for over a thousand years. It can be considered a good alternative source of protein and n-3 PUFA. The annual carp production in the European Union is over 70 t, which constitutes 5% of the entire European aquaculture production. It is produced in 15 countries. Nearly 97% of common carp production comes from Poland, Czech Republic, Germany and Hungary [8]. In 2017, the production of carp in Poland amounted to 17.5 thousand tons. Poland imports carp from the Czech Republic, Hungary, Lithuania and Croatia. Imported carp accounts for 25% of the carp available on the market.

The breeding period in Europe is 3 years. For comparison, more than 4 million tons of carp are produced annually in Asia. The rearing is usually carried out in ponds or cages, and the climatic conditions allow for the production of commercial fish after 9-12 months.

The best range for the survival and growth of carp is pH 7.5-8.0 [9]. In the first year of breeding common carp, natural food (small water creatures) constitutes 60-100%. Up to 30% of carp's diet in the second and third years of breeding is natural food. The natural food increases the growth of 100-400 kg of carps per hectare of pond. With the abundance of natural food and feeding the carps with 'artificial' food, the increments are 1000-1500 kg per hectare of the pond [10]. There is also semi-extensive breeding. It is based on feeding the fish with natural feed without additional feeding. Low intensive carp breeding technology means that apart from the natural feed, fish receive cereals at the time of summer intensive feeding. The cereal food is the seeds of land plants: white lupine, blue lupine, yellow lupine, horse beans, beans, peas, soybeans, vetch, flax, rape, wheat, rye, barley, oats, buckwheat, millet, corn, sorghum, wheat, rye and barley bran. The content of natural feed is up to 50%. Such breeding system is used in 95–98% of pond farms in Poland, Czech Republic, Hungary and Germany [8].

High intensive carp breeding is conducted in warm power plant cooling water. Fish are kept in the warm ponds at great density. The feed is a high protein granulated material with a minimal content of natural feed [8].

Processed carp in modified atmosphere packaging is being sold more and more. On the other hand, sales of live carp are declining. The ecological production of this species of fish allows the carp brand to be established as a healthy food, and maybe even functional foods. "May food become medicine," said Hippocrates. Nowadays, such a wish becomes a goal due to the fact that cardiovascular diseases are civilization and social diseases and the most common causes of death, and their treatment involves high costs [11]. PUFAs cannot be synthesized in the human body, therefore omega 3 and omega 6 PUFAs must be supplied from the diet as essential fatty acids.

The first definition of functional food was developed in 1991 in Japan as a result of activities under the Foods For Specified Health Uses (FOSHU) program. Initially, functional food was considered a healthy ingredient of the diet. Dietary supplements were excluded [12]. According to the European Commission (Functional Food Science in Europe FUFOSE), functional food is food with a scientifically proven beneficial effect on one or more functions of the body, beyond the basic nutritional effects, and its use improves health and well-being or decreases the risk of disease. It is a food consumed as part of a conventional diet and is not "closed" in any known form of drugs or supplements (tablets, pills, capsules). In 2014, the Functional Food Center (FFC) introduced an improved version of the known definition, treating functional food as: "natural or processed food, containing known or unknown biologically active compounds, which in defined, effective, non-toxic amounts provide clinically proven and documented health benefits in prevention or treatment of chronic diseases. " [13]. It was noted for the first time that functional food can be both natural and processed, and bioactive compounds considered as the source of functionality are generally secondary metabolites which synergistically improve the well-being of the organism. In the US, there is no formal definition of functional food. They often use the terms nutraceuticals, medical food or dietary supplements that do not meet European or Japanese regulations. This is why functional food is regulated in the same way as other food products in the US market. In practice, it is assumed that functional food can be both natural food and food to which a health-promoting ingredient has been added or from which the ingredient has been removed, for special health reasons. These are products whose ingredient has been technologically or chemically modified, where the bioavailability of the active substance may also have been modified. It is therefore worth noting that functional food is one of the elements of a healthy lifestyle and is the perfect transition between classic food and medications [14]. The main advantage of functional food, as well as the challenge for its creators, is the possibility of using it in strictly defined cases. Prophylaxis and alleviating the symptoms of civilization diseases are the most desirable nowadays. Hence the amount of research on the effects of functional food in specific disease entities, including Alzheimer's disease and Parkinson's disease [15,16], cardiovascular diseases [17,18] neoplastic diseases [19] asthma [20], diabetes [21] and obesity [22].

The aim of the study was to find the most recent publications about the nutritional value of carp meat depending on the animal diet used during breeding, storage methods and culinary processing and its possible uses as afunctional food.

METHODS

A search for open–access original full texts sin PubMed, Google Scholar, Medline Complete database was performed in June 2022. The databases were searched with the phrases: 'carp meat quality and functional food', 'omega-3 polyunsaturated fatty acids in carp meat' and 'nutritional value of carp meat' published between 2005 and 2021. A total of 490 results were found. The 40 non duplicate citations were screened. Then 18 articles were excluded after abstract screen. After that 22 articles were retrieved. Eventually 22 articles were included for systematic review.

RESULTS AND DISCUSSION

Czech scientists showed that a diet enriched with 400 g of carp meat per week improved plasma lipids in patients after aortocoronary bypass [23]. Scientists compared two methods of carp breeding: using their patented technology of pond production of carp with increased content of n-3 fatty acids *vs* carp from traditional pond culture using supplemental cereal feeding. There were significantly higher amounts of PUFA and n-3 long chain PUFA in omega-3 carp meat, while the cereal carp meat contained a higher proportion of MUFA - mostly oleic acid. Moreover, omega-3 carp had a content of beneficial EPA+DHA five times higher than that of cereal carp (53 vs. 262 mg of EPA+DHA per 100 g fillet) [23].

Bušová et al. compared the lipid, protein water and ash content in common carp and rainbow trout. The MUFA and PUFA content did not significantly differ among trout and carp meat samples [24].
breeding which was 17-19% and was similar to other fresh fish. There was no significant differences among groups fed with natural and artificial nor mixed feeds. The total content of exogenous amino acids: histidine, threonine, lysine, leucine, isoleucine, phenylalanine, methionine, and valine was 43.8 g/100 g carp protein which is higher than the value for the standard protein (26.5 g/100 g protein). In carp meat originating from intensive production a slightly higher content of histidine and arginine was recorded [8].

El-Beltagi et al. compared two additives to pizza: dried carp powder and chickpea flour. The dried carp fish powder significantly increased protein, fat and zinc content in pizza. Interestingly, chickpea and dried carp fish (up to 7.50%) had no effect on any sensorial parameters except for odour in the pizza [25].

Mahboob et al. published a report of assessment of carp meat quality after 6 week storage at -21°C or 4°C when compared to the fresh fish. After storage there was a significant decrease in crude protein and lipid contents. In fish stored at -21 °C water content significantly decreased but the quality of fish stored at 4 °C deteriorated faster than that of the -21 °C [26].

Hussain et al. analysed the impact of habitat degradation on proximate composition and amino acid profile of Indian major carps from different habitats. Researchers compared *Catla catla, Labeo rohita* and *Cirrhinus mrigala* collected from polluted, non-polluted area and a carp from a commercial fish farm. They found that fishes from the polluted areas indicated a significantly higher lipid content and lower protein content. The highest concentration of moisture was found in farm fish [27].

Ljubojević et al. tested four diets for carp rapeseed oil-high protein (ROHP), fish oil-high protein (FOHP); rapeseed oil-low protein (ROLP) and fish oil-low protein (FOLP) for 75 days. An enhanced protein sparing effect was observed in fish receiving lower protein diets. At the same time significant accumulation of crude lipid was observed in carp meat. Scientists showed that diets supplemented with rapeseed oil can be used successfully in common carp cage production [28].

In the study of Sobczak et al. an n-3 PUFA-enriched feed (*Schizochytrium* sp. meal or salmon oil) for carp was tested. Carp meat after use of the experimental feed contained less protein and more crude fat and had larger muscle fibres than controls. It contained more PUFA, n-3 PUFA, total EPA and DHA, and a smaller share of total MUFA were observed compared with control fish. Authors concluded that *Schizochytrium* sp. meal as a source of EPA and DHA gave much better results than salmon oil [29].

Trbović et al. investigated the influence of two feeds: maize and extruded feed on the proximate and fatty acid composition of carp. It was found that protein, lipid, and ash contents were significantly higher in the extruded feed group compared with maize. The carp fed extruded feed showed higher protein and moisture contents. However total lipid content was significantly higher in carp fed with maize. The saturated fatty acid (SFA) content in carp fed with maize was lower than that in carp fed with extruded feed. The MUFA content in carp fed maize was 61.83% and it was significantly higher than in carp fed extruded feed (41.95%) . The PUFA content in carp fed with maize was 13.66% and it was lower than that in carp fed with extruded feed (30.91%) [5].

Scientists aim for patenting formulas that would allow maximal growth of body mass, high n-3 long chain

PUFA and protein content in carp meat. Montenegro et al publish a report about it. A 120-d feeding trial was conducted to determine the effect of patented feeding containing *Medicago sativa* on growth and chemical composition, fatty acid content, and nutritional and lipid indices of the meat of grass carp when compared to regular grain feed. Carp meat protein content was significantly greater in the group fed with *Medicago sativa*, while the lipid and cholesterol contents were significantly greater in the grain diet group. Their results show that feeding with *Medicago sativa* decreases the growth of carp, but improves the quality of meat by increasing the protein, EPA, and DHA contents. It reduces cholesterol content and improves nutritional indices of the carp meat [30].

Fish depend on dietary fatty acids (FA). The FA support their physiological condition and health. Böhm et al. investigated diet effects on the composition of polar and neutral lipid FA (PLFA and NLFA, respectively) in eight different tissues (dorsal and ventral muscle, heart, kidney, intestine, eyes, liver and adipose tissue) of common carp. Two-year old carp were fed with three diet sources (zooplankton, zooplankton plus supplementary feeds containing vegetable, or fish oil) with different FA composition. After 210 days of feeding on different diets the PLFA and NLFA response was clearly tissue-specific. PLFA were generally rich in omega-3 polyunsaturated FA and only marginally influenced by dietary FA, whereas the NLFA composition strongly reflected dietary FA profiles. However, the NLFA composition in carp tissues varied considerably at low NLFA mass ratios, suggesting that carp is able to regulate the NLFA composition and thus FA quality in its tissues when NLFA contents are low. The study shows that NLFA accumulate in muscle tissues, which indicates that higher nutritional quality feeds are selectively allocated into tissues and thus available for human consumption [31].

Zajic et al. studied the effect of carp purging period of up to 70 days on lipid content and quality of its flesh. Purging is a very important part of the rearing process for common carp and is conducted between October and December. Fish are kept in clear water without feeding. They are intended to empty the gut and eliminate possible tainted flavour. This causes weight loss and stored fat mobilisation. The experiment investigated the effect of a purging of 70 days on lipid content and quality of common carp flesh. Four-year-old carp weighing 1700–2600g from three different production systems (C: supplemented with cereal; P: with pellet made of linseed/rapeseed; N: fed with a natural feed) were sampled every 14 days for weight, fillet yield and analysis of lipid content. Fillet yield was highest after 14 days and decreased after the time point. During all the experiment, fillet fat content decreased continuously in groups C and P, but remained stable in group N. Initially, carp from groups C and P mainly metabolised MUFAs, but after prolonged starvation all groups metabolised more PUFAs. After 70 days all groups showed similar saturated FA (SFA), MUFA and PUFA values. Authors' conclusion was that carp are able to metabolise selected FA for their energy needs when they are in good condition and have surplus fat stores. If body fat content is low, carp may metabolise all FA types equally to sustain metabolic functions [32].

The same group of scientists from Czech Republic investigated fatty acid composition of freshwater fish species marketed in their country. Authors selected three species from extensive culture systems: rainbow trout, tench, and common carp, eight species from semi-intensive culture systems: common carp, northern pike, pikeperch, grass carp, European perch, tench, silver carp, and catfish, and seven species from intensive farming: African catfish, rainbow trout, Wels catfish, Nile tilapia, brook trout, northern whitefish, and pikeperch. The fat content and FA composition were influenced by the culture systems. A significant dependence of FA composition on the fat content was observed. The content of SFA was below 34% in all analysed fish. Northern pike, pikeperch, and European perch contained with over 50% the highest proportion of PUFA. The cultured fish reached the highest content of eicosapentaenoic and docosahexaenoic fatty acid. The nutritional quality of the selected species was measured by atherogenic and thrombogenic indexes. The indexes ranged from 0.27 to 0.63 and 0.20 to 0.61 and PUFA/SFA ratios ranged from 0.67 to 2.01. The results obtained demonstrated that the flesh of all analysed species were of high nutritional quality [33].

Another scientific team from Central Europe analysed FA composition and fat content in common carp fillet origination from five different fish farms in Hungary. Lipid peroxidation parameters were determined in fish muscle. The data on FA composition of common carp showed that different methods of rearing and feeding cause significant differences in the proportions of n-6 and n-3 PUFA of this species. Authors concluded that the feeding practice of the last month before capture determined the FA profile of fillet. The scientists propose to divide carp nutrition into two main periods: growth and weight gain period; second - improving the nutritional quality of the fillet composition [34].

Komprda and his scientific team from Czech Republic analysed arachidonic acid (AA) content, long-chain n−3 polyunsaturated fatty acid (PUFA), and PUFA n−6/PUFA n−3 ratio in meat of chickens, turkeys, common carp, and rainbow trout, fed either commercial diet or diets with manipulated PUFA n−3 and PUFA n−6 contents. AA content was within the range of 20 mg/100 g in rainbow trout fed the diet with linseed oil to 138 mg/100 g in chickens fed the diet based on maize to the age of 90 days. AA content in turkeys fed the diet with lineseed oil or fish oil did not differ from that of rainbow trout. Long-chain polyunsaturated fatty acid (LCE) was in the range of 16 mg/100 g of turkeys fed a commercial feed mixture to 681 mg/100 g in of rainbow trout fed a commercial feed mixture. Only turkeys fed the diet with lineseed oil deposited more LCE (71 mg/100 g) when compared to all other poultry sets except turkeys fed the diet with fish oil (123 mg/100 g). Apart from all fish samples, also turkeys fed the diet with either lineseed oil or fish oil met the recommended value of the PUFA n−6/PUFA n−3 ratio which should be <4. AA content in chicken and turkey decreased significantly with increasing live weight reached at the slaughter age [35].

Wang with a team of researchers from USA analysed wild freshwater fish characteristics as a human food source for several classes of FA, particularly branched chain fatty acids (BCFA). The BCFA are a major bioactive dietary component entering the food supply primarily *via* dairy and beef. Authors evaluated the FA content of 27 freshwater fish species available in the north-eastern USA. They focused on the BCFA and bioactive PUFA, specifically n-3 (omega-3),EPA and DHA. The mean (± SD) BCFA content in all analysed fish species was 1.0 ± 0.5% of total FA in edible muscle. The rainbow smelt (*Osmerus mordax*) and pumpkinseed (*Lepomis* *gibbosus*) had the highest percentage of BCFA(>2%). EPA + DHA constituted 28% of total FA. In all the fish species, the dominating BCFA were *iso*-15:0, *anteiso*-15:0, *iso*-16:0, *iso*-17:0 and *anteiso*-17:0. Fish skin had much higher BCFA content than muscle, but lower EPA and DHA. Total BCFA in fish skins was positively related with that in muscle. The authors concluded that consuming a standardized portion, 70 g of wild freshwater fish contributes only small amounts of BCFA, 2.5–24.2 mg, to the American diet, while it adds high amounts of EPA + DHA (107 mg to 558 mg) [36].

Fish readily accumulates toxic mercury (Hg) and microcystins (MC) in eutrophic aquatic systems. In China, farmed fish is widely consumed. Many freshwater lakes are eutrophic, which results in the increasing accumulation of MC in fish tissue. Authors from China analysed 205 fish samples of 10 primary species collected from the eutrophic Wujiangdu Reservoir, China. The contents of Hg, MC and PUFA in fish were measured. The results showed that Hg and Methyl-Hg concentrations in all fish samples were below the safety limit (500 ng/g w.w) established by the Standardization Administration of China. The MC concentrations in fish were significantly higher in silver carp and black carp than in perch and catfish. In nutritional terms, average concentrations of n-3 PUFA and EPA + DHA of fish were 2.0 ± 2.5 and 1.4 ± 0.5 mg/g w.w., respectively. The risk-benefit assessment suggests that the n-3 PUFA benefits from consuming all farmed fish species in the reservoir outweigh the adverse effects of Hg [37].

A team of Brazilian scientists analysed the chemical composition of commercially important in their country freshwater fish species (Nile tilapia, bighead carp, grass carp, common carp and silver carp). They determined the moisture, ash, protein and lipid contents and the FA composition, as well as the nutritional quality of the lipids in fillets of these five freshwater fish species. Moisture was 74.7%-81.7% of the fillets, protein 15.8%-18.8%, lipids 0.4%-8.2%. The major FA in all the fish species were: saturated palmitic acid (90-1740 mg/100 g) and monounsaturated oleic acid (70-2260 mg/100 g). The grass and common carps and Nile tilapia had high contents of γ-linolenic acid (GLA) of 536 mg/100 g. Bighead carp was the richest source of omega-3 PUFA, mainly EPA (400 mg/100 g) and DHA (620 mg/100 g), and had the highest omega-3/omega-6 ratio of 6.11. The nutritional evaluation of the FA profile indicated that average values were: atherogenicity index ∼0.59, thrombogenicity index ∼0.82, hypocholesterolemic/hypercholesterolemic ratio ∼1.98, polyunsaturated/saturated ratio ∼0.43 and ω-3/ω-6 ratio ∼2.18, values suggesting that the consumption of these freshwater fish species is of benefit to human health [38].

There is data that different heat treatments (pan-frying, oven-baking, and grilling) influence the contents of PUFA in fish tissue. Czech scientists examined four fish species: pike, carp, cod, and herring. Mostly non-polar lipids (triacylglycerols) were present in the fish tissue, the PUFA were present mainly in the phospholipid fraction. Omnivorous fish species (carp, herring) contained more triacylglycerols than predatory ones (pike, cod). Higher amounts of PUFAs were detected in the marine species than in the freshwater ones. The impact of heat treatments on the lipid composition in the fish tissue is species-specific: herring tissue is most heat-stable, and the mildest heat treatment for PUFA preservation was oven-baking [39].

The sensory properties apart from the nutritional value are also very important for fish manufacturers and consumers. These features were assessed by a team of Polish scientists in 2021.They tested the meat of common carp fed for 116 days with two blends: the control feed contained 5% of fishmeal and vegetable oils (rapeseed and soybean) and in the experimental diet half of the fishmeal was replaced with a blendofmicroalgae (*Spirulina* sp., *Chlorella* sp.), macroalga e (*Laminaria digitata*) and vegetable oil was replaced with salmon oil. The energy value, FA profile of carp meat, nutritional characteristics of fat and protein, and culinary properties of fillets were assessed. Fillets of carp fed experimental diet contained more protein, less fat and were characterized with lower energy value. Intramuscular fat of fish fed with the experimental diet had a better quality parameters. Protein in both groups was high quality comparing to the protein standard. The study showed that meat of carp fed with the feed enriched with sustainable and natural feed ingredients can be a sensorily attractive source of nutritious ingredients in the human diet [40].

The FA composition of the fillets of dwarf common carp from Lake Hévíz in Hungary may be a surprise for researchers. The fish was collected in winter. Fillet FA profile of the thermally adapted (28 °C) Hévíz carps differed from profiles from divergent culture and feeding conditions in the overall level of saturation. Fillet myristic acid proportions largely exceeded all literature data. Fillet FA assessment results indicate the effects of thermal adaptation (high saturation level) and the correlative effects of feed components rich in omega-3 fatty acids, with special respect to DHA [41].

The genetic background of nutritional properties of carp flesh was also studied. A Polish study evaluated the influence of finishing diets on the activity of 21 genes involved in hepatic lipid metabolism and intestinal homeostasis, liver and intestine histology, and the level of EPA and DHA in common carp fillets. Authors compared two experimental diets: control diet mimicking a commercial feed and a test diet fortified with EPA and DHA retrieved from salmon by-products. An additional control from extensively cultured carps was investigated. The experiment revealed that the expression of seven hepatic genes: *lipoprotein lipase* and *fatty acid synthase*, and six intestinal genes: *claudin-3c* and *γ-glutamyl transpeptidase*, was influenced specifically by the experimental diets and farming type. Fish from the additional control group had the smallest hepatocytes and the largest nuclei compared with the control group and the group fed with the experimental diet. No pathology was found in intestine samples. The levels of EPA and DHA in fillets were significantly higher in fish receiving the diet enriched with EPA and DHA compared with controls. Authors conclude that the use of fortified diets is a promising solution to produce freshwater species with enhanced nutritional value without compromising the safety of fillets [42].

DISCUSSION

In total 6 (27%) out of reviewed articles originate from Czech Republic,4 (18%) from Poland, 2 (9%) from Serbia, 2 (9%) from Hungary and 1 (4.5%) from each: Argentina, Brazil. China, Egypt, Germany, Pakistan, Saudi Arabia and USA. Regarding the continents:

15 (68%) come from Europe, 3 (14%) from Asia, 2 (9%) from South America and 1 (4.5%) from Africa and North America. This is in line with the culinary customs of these countries. Carp dishes are constantly present in Jewish cuisine, and on the occasion of the Christmas Eve they are consumed in Poland. Czechs, Hungarians, Germans and Serbs also eat carp dishes. Carp is eaten in China too. And so in Europe common carp is produced mainly in Poland, Czech Republic, Germany and Hungary [8]. Hungary has no access to the sea, therefore seafood is not easily available there. Landlocked countries produce and consume more freshwater fish because marine fish are much more expensive for them. Buying frozen or smoked fish instead of fresh means extending the shelf life, but also changes the nutritional value. Frozen fish lose a small part of their nutritional value [26]. When steaming, baking or stewing, fish lose the least omega-3 FA. Frying destroys them and creates harmful acrolein.

Oven baking is recommended method of thermal treatment in preparation of healthy fish dishes [39]. Smoking even increases the content of EPA and DHA in fish meat, but it increases the concentration of heavy metals [43].

For humans, seafood is the primary source of long-chain PUFA (LC-PUFA). Historically, capture fisheries were able to meet the demand. Unfortunately at present we experience a “sea change” in how we feed a seafood- and LC-PUFA-hungry world. The Food and Agriculture Organization of the United Nations published data that 53% of marine fisheries are fully exploited, 28% are over exploited, and 4% are depleted or recovering from depletion. Only 15% are under exploited and capable of sustaining more intense harvest pressure. Concurrently with the collapse of many fisheries, the global demand for fish continues to grow. The annual fish consumption has grown by more than 70% since the 1960s, reaching 17 kg *per capita* in 2007 in some countries [44]. For this reason, catch of freshwater fish is of interest to landlocked countries, the ones with very few coastlines or by highly polluted seas.

Although carp meat contains less PUFA than seafood, its’ composition is similar to trout. Less mercury than in seafish and high selenium content are carp’s advantages too [37].

The variation in protein and fat content of fish muscle may be due to habitat variation, water quality, used artificial feed and availability of plankton [27]. The decrease in protein contents in fish under toxic stress is due to diversification of energy to accomplish impending energy demands [45]. Carp breeding can be improved by use of new experimental feeds, which results if better FA and protein characteristics of carp meat [5,8,28,29,30,31,35,40,42].

Carp breeding requires knowledge of the epizootic situation. The koi herpes virus (KHV), carp edema virus (CEV), carp spring viremia (SVC) infections pose a problem for European carp fish farming. The priority action in the case of viral diseases is the frequent drying and liming of the ponds. Bacterial diseases of carp are caused by bacteria of the genus *Aeromonas* and *Pseudomonas*. The carp parasites are Myxozoa. Invasion of myxosporididae can have a significant negative effect on the health of the fish and can potentially cause high losses. Importantly, a strong invasion of *Myxobolus cyprini* disqualifies commercial fish as a salable product. In Germany, like in Poland, cormorants are a huge problem for pond users. The continuous increase in the population of the birds means fish stock losses [46].

Since the publication of data on the Minamata disease (human and animal poisoning with dimethyl mercury), consumers have been concerned about consuming oily marine fish [47].

According to the US Food & Drug Administration (FDA) [48] fish are part of a healthy eating pattern and provide key nutrients during pregnancy, breastfeeding, and early childhood. Fish is rich in omega-3 FA (DHA and EPA) and omega-6 FA, iron, iodine, choline, which supports development of the baby’s spinal cord. Fish provide iron and zinc to support immune system. Fish are a source of other nutrients like protein, vitamin B12, vitamin D, and selenium too. While it is important to limit mercury in the diets of those who are pregnant or breastfeeding and children, many types of fish are both nutritious and lower in mercury. The FDA considers king mackerel, marlin, shark, swordfish, tilefish and tuna as high in mercury. Carp is considered a good fish by FDA (FDA).

Out of the 22 analysed publications only one can be considered as testing carp with increased content of n-3 fatty acids for patients after aortocoronary bypass as a functional food [23]. More human studies are needed. Best would be to have a variety of case-control human studies with assessment of carp meat consumption on heart health. There is more publications on minerals and vitamins, dietary fiber and omega-3 acids as functional foods [49].

CONCLUSIONS

1. Carp consumption improves plasma lipid profile and therefore it could be considered a functional food for people with cardiovascular disease if there was more publications available.
2. The carp culture systems decide about PUFA and protein content in carp meat.
3. Carp can be cooked as traditional dishes or carp powder can be added to other dishes to enrich their nutritional value. The recommended method of carp meat preparation to preserve its’ nutritional value is oven baking.

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