Fish, Meat and Other Animal Protein Sources

7

Abstract

The Mediterranean dietary pattern is based on a reduced intake of foods of animal origin, which provide essential amino acids (those the human body is unable to synthesize), as well as certain minerals and vitamins that are difficult to find or have a reduced bioavailability in vegetables. In this regard, fish is preferable to meat as a protein source, since the associated fats are mainly long-chain polyunsaturated fatty acids, with a predominance of n-3, as in sardines, anchovies and codfish. The Mediterranean Sea is less rich in fish than the Atlantic Ocean. The Atlantic coast is important to Portugal, Spain and Morocco, and Portugal and Spain are among the largest consumers of fish and seafood in the world. It is noteworthy that the composition of meat is highly dependent on how the animal was fed and grown and on the butcher's cut. In this regard, a lean steak from cows raised in the open air via extensive systems can be less deleterious to health than a piece of broiler chicken raised under an intensive system. In certain cases, total fat can be lower in beef (e.g. lean steak) than in a piece of chicken. Ancient meat preservation methods have been developed mainly for pork and rely on seasoning, smoking, fermentation and drying steps, aiming at reducing pH and water activity, which, in combination with spices, restricts microbial growth. Nowadays, some preservatives are allowed, even in 'Protected Designation of Origin' products as *chorizo, salami* and *jamon iberico*. The intake of large portions of meat is viewed by many as related to a high socioeconomic status, but excess meat is deleterious to health because of the accumulation of acidic deamination products such as uric acid, which becomes more difficult to eliminate with age, leading to gout, urate kidney stones and other ailments. Moderation of animal protein consumption and an increase in the ratio of vegetables to animal proteins may confer health-protective effects and result in a balanced diet.

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7.1 Fish, Meat and Other Animal Protein Sources: An Introduction

Proteins are the primary structural components of cells, especially muscle. Along with peptides, they play a multitude of crucial functions in the human body, from enzymes to signalling molecules (many important neurotransmitters are primary or secondary amines, derived from amino acids). Moreover, the immune system mainly relies on protein interactions (e.g. immunoglobulins [Igs], surface cell proteins).

Body proteins are synthesised as needed, after the polymerisation of 20 standard amino acids, which in turn are obtained from food or synthesized *de novo*. Some non-standard amino acids (obtained by post-translational modifications) also have important functions and are incorporated into some proteins, such as collagen or myosin.

Humans do not have the complete pathways to synthesise nine amino acids (phenylalanine, valine, threonine, tryptophan, methionine, leucine, isoleucine, lysine and histidine). They are therefore essential or indispensable and must be supplied by the diet. Under some circumstances, the synthesis of some other amino acids can be limited.[1]

The inclusion of animal protein sources (fish, shellfish, seafood, meat, dairy and eggs) in the diet ensures that all the necessary amino acids are provided in balanced proportions; for this reason, proteins of animal origin are called 'complete proteins'. On the other hand, most vegetable protein sources (e.g. cereals, pulses and nuts) generally lack one or more of the indispensable amino acids (limiting amino acids); for this reason, they are called 'incomplete proteins'. In most food cultures, several traditional dishes combine, for instance, cereals and pulses, which result in a higher-quality protein intake as the limiting amino acids of these foods are different and therefore complement each other. Examples of such dishes combine maize and beans, wheat (such as pasta) and chickpeas, black beans and rice. Another way to overcome this issue is the introduction, in the diet of a large variety of vegetable foods supplemented with some animal protein sources.

In a balanced diet, it is then necessary to observe the requirements and bioavailability of indispensable amino acids (NAP 2015), as shown in Table 7.1 (percentage values). Animal proteins are a rich source of sulphur-containing amino acids, such as cysteine and methionine, the metabolism of which generates sulphuric acid, as well as lysine, arginine and histidine, the metabolism of which yields hydrochloric acid, increasing the acid load of the organism. On the other hand, the catabolism of vegetable foods generally originates bicarbonate and inorganic anions. The bicarbonate ion, a base with buffering capacity, can reduce the net rate of endogenous acid accumulation (Frassetto et al. 2000; Sellmeyer et al. 2001). In other words, vegetables contain significant amounts of base

[1] Further information on proteins and their functions in the human body can be found in chapters 5, 6, 7, 8 and 22 of Nelson DL, Cox MM. (2012) Lenhinger—Principles of Biochemistry. W. H. Freeman and Company, New York and Basingstoke.

Table 7.1 Estimated average requirements of indispensable amino acids, expressed as percentage values of the total recommended intake of dietary protein (NAP 2015)

Amino acid	Minimum % proportion
Histidine	6.27
Isoleucine	8.71
Leucine	19.16
Lysine	17.77
Methionine & cysteine	8.71
Phenylalanine & tyrosine	16.38
Threonine	9.41
Tryptophan	2.44
Valine	11.15

precursors that may help neutralise acidic metabolites in the body (e.g. from protein digestion).

With aging, the glomerular filtration rate is reduced and the kidney's ability to excrete this dietary acid load decreases. Thus, otherwise healthy individuals develop progressively increasing blood acidity and decreasing plasma bicarbonate as they age. Because urinary excretion of acid is insufficient, other homeostatic systems, such as bone, buffer the excess dietary acid load (Sellmeyer et al. 2001). Over decades, the magnitude of daily positive acid balance may be sufficient to induce osteoporosis, as bone is the only internal reservoir capable of supplying a base to the systemic circulation over the lifetime (Frassetto et al. 2000).

The accumulation of acidic metabolites has been correlated with health issues, namely the incidence of hip fracture in the elderly. Renal net acid excretion correlates positively with animal protein intake and negatively with vegetable protein intake (Frassetto et al. 2000; Sellmeyer et al. 2001).

Not all proteins are easily digested. In the human gut, most globular proteins from animal sources are almost completely hydrolysed to amino acids, but some fibrous proteins, such as keratin, are only partially digested. On the other hand, some proteins from plant foods are enclosed in cellulose husks, thus impairing their enzymatic breakdown.

In developed countries, protein availability exceeds average population requirements, and measured food intake also reveals that consumption, mainly from animal sources, is often much higher than internationally recommended intake levels. Excessive proteins are digested and converted into their amino acid residues, the carbon backbones of which are used to produce energy via the Krebs cycle. Some amino acids are converted into ketone bodies and others to glucose or both. The use of proteins to produce energy, instead of fats and carbohydrates, occurs in starvation (when body proteins are consumed), in untreated diabetes and in cases of excess protein in the diet.

The link between the Krebs and urea cycles ensures that the N-moieties (obtained by deamination) are converted to urea and uric acid and eventually eliminated. High blood concentrations of uric acid can lead to gout. Excess of urea and uric acid are also commonly associated with medical conditions such as diabetes and the formation of ammonium acid urate kidney stones. On the other hand, the accumulation of ketone bodies in the blood can alter blood pH (which can be life threatening) and may be related to an imbalanced lipid metabolism and/or diabetes.

In the case of the Mediterranean diet (MD), the daily pattern of animal protein consumption is generally low. Traditional Mediterranean dishes usually do not include animal foods as the main ingredient but instead as a source of taste.

The composition, health and nutritional aspects of the main sources of animal protein are reviewed. Animal sources of protein also contain fats. The drawbacks as well as the relevance of certain fats and vitamins of animal origin to a balanced diet are also discussed in this chapter.

7.2 Seafood

In the Mediterranean basin, particularly in the countries that this work refer to (Fig. 1.1), a large variety of fish is consumed, particularly pelagics but also shellfish, cephalopods and crustaceans. Since freshwater fish is not so commonly consumed in these countries, only marine fish and seafood are the objects of this review.

The large Atlantic coasts of Portugal, Spain and Morocco, and the richer variety of fishes found in the Atlantic Ocean, influence local patterns of fish consumption, although with common features. The most prominent species consumed in the above-mentioned countries (Fig. 1.1) are tuna (*Thunnus alalunga*), mackerel (*Scomber scombrus*), aquaculture produce such as gilt-head bream (*Sparus aurata*) and Mediterranean seabass (*Dicentrarchus labrax*), as well as smaller species such as sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*). Cod (*Gadus morhua*), a demersal fish, is very popular in all these areas, although it is captured in the North Sea. The intake of species such as eel (*Anguilla anguilla*), a migrating snake-like fish that is captured in fresh water, sole (and related flat fish species such as Dover sole), or cephalopods such as squid (*Loligo forbesii*, *Loligo vulgaris* and related species), cuttlefish (*Sepia officinalis*) and octopus (*Octopus vulgaris*) are noteworthy.

The most widely consumed species of shellfish, or bivalves, in the Mediterranean region are clams, mussels (*Mytilus edulis*, *M. galloprovincialis* and related species) and cockle (*Cerastoderma edule*), among many other species, such as razor clams and others for which the English name is hard to find, as in the case of 'tellina' or 'conquilha'.

Crustaceans, such as different types of crabs (*Cancer pagurus*) and shrimps (*Crangon crangon*, as well as *Penaeus* sp. and *Palaemon* sp.) have been also consumed in the area. Lobster is not so widely available in the area.

A larger variety of seafood is available in Portugal and Spain because of their Atlantic coastline. Both countries are at the top of the world ranking of countries of per capita seafood consumption (Banks 2012).

In general, fish is known to have a balanced essential amino acid composition, and it is recommended for a healthy diet. However, the free amino acid composition changes considerably during storage and subsequent processing (if any). A possible issue, involving fish proteins (but easily avoided with adequate preservation methods) is the accumulation of biogenic amines (organic bases derived from the degradation of free amino acids), including histamine. Histamine is produced from the decarboxylation of histidine (a common amino acid in fish) by the enzyme histidine decarboxylase. The reaction is favoured by temperature and by the release of cellular contents (which ensures the presence of the enzyme in sufficient amounts). Thus, correct processing and refrigeration prevents the formation of histamine, a potent allergen that can cause food poisoning.

Besides protein, fish and seafood also provide relevant amounts of long chain (n3) polyunsaturated fatty acids (PUFA) playing several important physiological roles in the body (DiLeone 2011; Galli and Calder 2009; Jump 2002; Mozaffarian and Wu 2012; Sanders 2009; Stark et al. 2008). These essential fatty acids include (Fig. 5.5) eicosapentaenoic acid (EPA: 20:5, n-3), docosapentaenoic acid (DPA: 22:5, n-3) and docosahexaenoic acid (DHA: 22:6, n-3).

Dietary patterns change over time, and a westernisation of the MD has been observed in the area. One concern is the increase of the ratio of n-6 to n-3 fatty acids in the diet. According to Stark and colleagues (2008), n-6 and n-3 fatty acids are metabolised by the same set of enzymes thus, competing for the same active sites. According to the same authors, metabolites of n-3 fatty acids are anti-inflammatory and anti-arrhythmic, while metabolites of n-6 fatty acids may result in the accumulation of pro-thrombotic and pro-inflammatory compounds (Galli and Calder 2009). The preference for fish may mitigate this issue, given its high n-3 PUFA content.

EPA and DHA are reported to modulate a variety of relevant biological pathways (Mozaffarian and Wu 2012). In human studies, both fatty acids lower triglyceride levels and collagen-stimulated platelet aggregation; they seem to favourably affect cardiac diastolic filling, arterial compliance and to have some effect against inflammation and oxidative stress (Mozaffarian and Wu 2012). Less is known about the effects of DPA on biological pathways or physiological risk factors; a few observational studies suggest potential benefits for inflammation.

Moreover, eicosanoids are chemical messengers derived from 20-carbon PUFA that play critical roles in immune and inflammatory responses. Both 20-carbon omega-6 fatty acids (arachidonic acid) and 20-carbon omega-3 fatty acids (EPA) can be found in cell membranes. DPA can be synthesised endogenously from EPA (Mozaffarian and Wu 2012).

EPA and DHA are metabolised by cytochrome P450 enzymes to generate mono-epoxides derived from (n-3) fatty acids (MEFA). An EPA-derived MEFA was referred to display potent anti-inflammatory activity, in human bronchi and MEFA derived from either EPA or DHA were similarly potent at achieving mesenteric microvessel dilation (Mozaffarian and Wu 2012).

Generally, dietary guidelines converge on a recommended minimum consumption of 250–500 mg/day of combined EPA+DHA for an average adult (Smit et al. 2009). Despite the alternative sources of essential fatty acids and protein, in the context of the MD, fish should be preferred to meat, with two or more servings per week (Bach-Faig et al. 2011).

7.2.1 Tuna (*Thunnus alalunga*)

Tuna or albacore is a pelagic fish that can be found in the open waters of all tropical and temperate oceans, including the Mediterranean Sea. It has migration habits and a lifespan of 11–12 years, reaching reproductive maturity at around 5–6 years. The increasing world demand for tuna, preserved and traded by the canning industry, are rapidly decreasing the population numbers of albacore tuna.

Like other fish captured in the wild, tuna accumulates methylmercury, a very toxic compound that undergoes biomagnification along the food chain. For safety reasons, a moderate consumption of tuna and similar predator fishes should be observed. Tuna is consumed primarily as canned food. Canned tuna is presented as cooked fish meat in vegetable oil, olive oil or in water. The proportion of salt may vary. Tuna is typically gutted by hand, and then pre-cooked for prescribed times. The fish is processed again to separate lateral dark meat, filleted and canned, usually in oil. Cans are sealed and heated for 2–4 h to ensure sterility.

The data presented below refer to the most commonly found commodity: canned tuna in vegetable oil with added salt.

Canned tuna supplies 186–214 kcal/100 g from: proteins (24.3–26.5 %) and fat (about 8–13 %). No carbohydrates or organic acids are found. Fat is mainly PUFA (7.1 %, mostly conjugated linoleic acid [CLA]), and monounsaturated fatty acids [MUFA: 3.8 %). Saturated fatty acids (SFA) account for 0.9–1.3 % of the global composition, trans-fatty acids account for 0.2 % and cholesterol for 31–41 mg/100 g (INSA 2015; USDA 2015).

Tuna is a source of the omega-3 fatty acids: EPA (0.07 g/100 g), DPA (0.005 %) and DHA (0.18 %), as well as the fat-soluble vitamins retinol (5–23 μg/100 g), α-tocopherol (1.9–2.3 mg/100 g) and vitamin D (0.4 μg/100 g). Most water-soluble vitamins are absent, except for some of B-complex vitamins such as niacin (9.8–11.7 mg/100 g), B_6 (0.23–0.43 mg/100 g) and B_{12} (2.2–2.4 μg/100 g). Tuna also contains relevant micronutrients such as phosphorus (P: 202 mg/100 g), manganese (Mn: 0.016 mg/100 g), selenium (Se: 60.1 μg/100 g) and fluorine (F: 31 μg/100 g) (INSA 2015; USDA 2015).

7.2.2 Sardine (*Sardina pilchardus*)

Sardines are small epipelagic fish that have a cylindrical shape, are about 10–20 cm long and sometimes migrate along the coast in shoals. Sardines are forage for large pelagic fish and present a lower risk of accumulating persistent pollutants such as mercury compounds because they are low in the food chain; thus, they are safer for human consumption. Sardine is an important fishery species, and the countries with the largest catches in 1999 were Morocco and Spain (FAO 2015b). Sardine is consumed fresh, frozen and canned.

7.2.2.1 Fresh Sardines

Fresh sardines are consumed all over the Mediterranean area and are most popular in Portugal, Spain, Italy and Greece. Sardines have been captured in coastal areas since ancient times and consumed during summer, mainly grilled or fried. Sardines that are not consumed fresh are canned, generally in a seasoned sauce containing olive oil and tomato paste. Canned sardines are exported and/or consumed during winter.

The fishing season for sardines usually starts in June, which in Portugal overlaps 'Santos Populares', a series of popular festivals that take place outdoors. Sardines are the symbol of Lisbon festivities, 'Santo António' (the city's patron saint). Sardines are grilled on charcoal in downtown streets, where eating and dancing takes place, attracting many tourists and artists that dare to face the strong smell and flavour. In early summer, sardines are at their best because the higher fat content contributes to their taste and flavour. The fresh sardine season ends with summer.

Consumption of sardines grilled on charcoal, served with boiled potatoes and salad (green pepper, onion, tomato and lettuce), generously seasoned with olive oil, in the evening at a terrace near the sea, is a pleasure shared mainly by Portuguese and Spanish populations, and is a good portrait of the MD and way of life.

Since fresh sardines are not commonly eaten worldwide, only the Portuguese Food Information Resource (PortFir) database (INSA 2015) could be used in this review. Data correspond to consumers' preferences for raw fresh high-fat sardines. Comparisons are made to the same category of grilled and fried fish.

Raw sardine supplies 221 kcal/100 g, whereas grilled sardines contain 211 kcal/100 g and fried sardines contain 247 kcal/100 g. Raw sardines have a total fat content of 16.4 %, slightly below the protein content of 18.4 %; no carbohydrates are referred. Total fats are 4.7 % SFA, 4.0 % MUFA, 5.6 % PUFA, 0.5 % trans-fatty acids (TFA), also including 0.5 % linoleic acid and 20 mg/100 g cholesterol. Sardines are a good source of fat-soluble vitamins, particularly vitamin A (47 μg/100 g of retinol eq.), vitamin D (21 μg/100 g), α-tocopherol (0.66 mg/100 g) and the water-soluble B vitamins niacin (4.4 mg/100 g), B_6 (0.57 mg/100 g) and B_{12} (10 μg/100 g). Sardines have a high P content (314 mg/100 g). When grilled, sardines lose water and fat. This cooking method results in a decrease of SFA, MUFA (the larger loss) and PUFA but slightly concentrates cholesterol, the level of which increases from 20 to 43 mg/100 g; vitamin levels may result a little higher too. In the case of fried sardines it should be noted that the raw fish is coated with batter (a mix of wheat flour with milk/water and eggs) before frying. Batter residues contribute to the frying oil degradation. Nowadays, olive oil is rarely used for frying, given its current high price; soy, sunflower or corn oils are often used instead, and thus, the accumulation of degradation products is more likely, and this cooking method should not be preferred.

In short, fresh sardines are a good source of protein, supplying a wide variety of amino acids and are a well-known fatty fish, containing essential fatty acids but low levels of cholesterol.

7.2.2.2 Canned Sardines

Canned sardines (in olive oil, drained) supply 186 kcal/100 g and a total fat content of 9 %, which is significantly less energy and fat than their fresh cooked counterparts. The quantity of protein is higher (26.3 %) and the SFA levels are much lower (1.5 %). The predominance of MUFA should be noted, as well as cholesterol levels that are higher (60 mg/100 g) than in (cooked) fresh sardines. Moreover, the industrial processing of sardines significantly reduces its vitamin content, with the exception of vitamin B_{12} (13 μg/100 g) (INSA 2015).

7.2.3 Anchovy (*Engraulis encrasicolus*)

The European anchovy is a fish with a slender elongated body, oval in cross-section and common in the coastal areas of Europe and the Mediterranean basin. It is a pelagic coastland fish forming large schools, similar to sardines. It has a tendency to extend into more northern waters in the summer, generally moving into the surface layers, retreating and descending in winter. Anchovies feed on planktonic organisms and reach about 12–15 cm (FAO 2015c). They are consumed as fresh or canned foods or after traditional preservation involving brining and maturation. Anchovies have been brined since the times of the Roman Empire, when they formed the base of a very popular fermented fish sauce called ‘garum’. The traditional method of preserving anchovies involves evisceration, followed by brining and a maturation stage until fish flesh turns deep grey, after which anchovies are industrially canned or preserved in olive oil and capers (*Capparis spinosa*) in small jars. This results in a characteristically strong flavour for many dishes, although anchovies became world famous because of their use in pizza. No data on composition for this type of preserve were available in the food databases used in the current publication.

7.2.3.1 Fresh Anchovies

Fresh anchovies supply 131 kcal/100 g from: proteins (20.35 %) and total fat (4.84 %). SFA, MUFA and PUFA proportions are quite close, with a slight predominance of PUFA (USDA 2015).[2] Anchovies contain 1.3 % SFA (mainly 16:0, 14:0 and 18:0), 1.2 % MUFA (mainly 18:1 and 16:1) and 1.6 % PUFA, mainly the essential fatty acids EPA (0.54 %), DHA (0.91 %) and DPA (0.029 g/100 g), and also include cholesterol (60 mg/100 g). Fresh anchovies are also a good source of fat-soluble

[2] Report 15001: fish, anchovy, European, raw (*Engraulis encrasicholus*).

vitamins, particularly vitamin A (15 μg/100 g of retinol) and α-tocopherol (0.57 mg/100 g), as well as water-soluble B vitamins: niacin (14.0 mg/100 g), B_6 (0.14 mg/100 g) and B_{12} (0.62 μg/100 g). Anchovies have high levels of Ca (147 mg/100 g) and P (174 mg/100 g), as well as the micronutrients Mn and Se.

7.2.3.2 Canned Anchovies

Compared with fresh anchovies, processed anchovies supply more energy (210 kcal/100 g) from a slightly higher concentration of proteins (28.9 %) and total lipids (9.71 %). The relative proportions of SFA, MUFA and PUFA are similar, resulting in an increased concentration of every component, including EPA (0.76 %), DPA (0.04 %), DHA (1.29 %) and cholesterol (85 mg/100 g). Processing affects vitamin content by decreasing vitamin A and E, while concentrating niacin (19.9 mg/100 g), vitamin B_6 (0.2 mg/100 g) and vitamins B_{12} and D_3 (cholecalciferol). In particular, vitamin D_3 can reach 0.62 μg/100 g, whereas it was most likely below the detection level in fresh anchovies. Concentration of Ca (232 mg/100 g) and P (252 mg/100 g) seems to increase with processing but not in the same proportions (USDA 2015).[3]

7.2.4 Codfish (*Gadus morhua*)

Cod is a demersal, voracious fish, feeding largely on other fish and various invertebrates. The species *Gadus morhua* is found on both sides of the North Atlantic. Although some groups of small cod are relatively stationary, individuals or groups may undertake astonishingly long migrations. For some reason, larger fish are found in colder waters, at 0–5 °C (FAO 2015d). A North Pacific species of cod, *G. macrocephalus*, is very similar in appearance to the Atlantic form but does not have the same economic value. *Gadus morhua* is captured in Norway, dried, salted and, ideally, exposed to the sun.

Cod livers are processed to make cod liver oil, used as a food supplement as a source of fat-soluble vitamins (A, D, E) and essential n-3 fatty acids (EPA and DHA).

Cod has been an important economic commodity in international markets since the Viking period, as Vikings travelled with dried cod and soon developed a dried cod market in southern Europe, enduring the black plague of the fourteenth century, wars and crisis. By the fifteenth century, Portuguese and Spanish peoples started sailing to Norway to fish for cod. Dry salted cod is still an important Norwegian trade commodity, although ecological organizations (World Wildlife Fund and Greenpeace) have placed *Gadus morhua* on the list of endangered species. Efforts have been directed towards the development of effective and sustainable cod farming systems (FAO 2015d).

[3] Report 15002: fish, anchovy, European, canned in oil, drained solids (*Engraulis encrasicholus*).

Dry salted codfish is consumed in all countries referred in the present review, from Portugal to Croatia. It is locally known as ‘bacalhau’ (Portugal), ‘bacalao’ (Spain), ‘baccalá’ (Italy), ‘bakaliáros’ (Greece) or ‘bakalar’ (Croatia). It is cooked in many different ways after being desalted in water, and is appreciated for its succulent white and flaky meat. In Portugal, its presence is mandatory in both Christmas Eve and Christmas lunch meals. Unlike sardines, which are known as a fat fish, codfish has a low fat content.

Merged data from the Portuguese National Institute of Health (Instituto Nacional de Saúde Doutor Ricardo Jorge [INSA]) and the US Department of Agriculture (USDA) food composition databases are discussed below, although records diverge at the desalting step. The INSA database refers to dry salted Atlantic cod (*Gadus morhua*) at the stage it is normally cooked in South Europe (after being desalted in water and with 76.2 % water content), while the USDA database (2015) refers to the same fish but not ready for consumption (16.1 % water, and with the salt added for preservation). Thus, the primary composition data were retrieved from INSA and complemented with relevant information from the USDA database (mainly in a qualitative way).

Thus, uncooked codfish supplies 80 kcal/100 g from: proteins (19 %) and total lipids (0.4 %; equal fractions of SFA [16:0, 18:0, 14:0], MUFA [mainly 18:1] and PUFA [18:2, 20:4, traces of 18:3 and 18:4, and relevant quantities of EPA, DPA and DHA]), as well as cholesterol (52 mg/100 g). Fat-soluble vitamins are present in fair amounts (retinol [4 μg/100 g], vitamins $D_2 + D_3$ [4.5 μg] and α-tocopherol [0.28 mg/100 g]), as are the water-soluble B vitamins thiamine (0.047 mg/100 g), riboflavin (0.068 mg/100 g), niacin (0.76 mg/100 g), B_6 (0.072 mg/100 g) and B_{12} (0.95 μg/100 g). Relevant minerals are Ca (33 mg/100 g), P (116 mg/100 g), Mg (23 mg/100 g) and Mn and Se (INSA 2015; USDA 2015).

7.2.5 Cephalopods

Cephalopods (squid, cuttlefish and octopus) are members of the molluscan class *Cephalopoda*. These exclusively marine animals are characterised by bilateral body symmetry, a prominent head and a set of arms or tentacles (muscular hydrostats) modified from the primitive molluscan foot. They are called inkfish because of their ability to squirt ink (with the exception of a few species). Cephalopods play a major role in the trophic web of all marine ecosystems, both as predators and as prey. Cephalopods are found in oceans worldwide (except the polar seas), and they cannot tolerate fresh water (only one species was detected in brackish waters). Like most molluscs, cephalopods use haemocyanin—a copper-containing protein—rather than haemoglobin to transport oxygen. As a result, their blood is colourless when deoxygenated and turns blue when exposed to air (Jereb and Roper 2010). Cephalopods are balanced food protein sources (containing all the essential amino acids). Its flesh contains lower amounts of essential fatty acids than most fishes. It is also lower in some vitamins than the so-called fat fishes, and cholesterol and sodium levels are generally higher.

Cephalopods are mainly fished by Southeast Asian and Mediterranean countries, which are also traditionally the major consumers (Jereb and Roper 2010), with Portugal, Spain and Italy registering the highest per capita intake values in 2011 (FAO 2015e).[4]

7.2.5.1 Squid (*Loligo forbesii*, *L. vulgaris*, and Related Species)

Loligo spp. includes a large variety of edible species, and this neritic cephalopod genus is distributed worldwide, particularly in western Atlantic and Mediterranean areas (Jereb and Roper 2010). According to the same authors, adults undergo vertical migrations, living close to the bottom during the day, and ascending towards the surface at night. Squids grow rapidly and may significantly vary in size. *Loligo* spp. is a voracious and opportunistic predator, feeding on a wide spectrum of prey only limited by size. Mature squids are encountered almost throughout the year, but two peak spawning periods are generally observed: the first and more important in spring, and the second, less intense, in late summer and fall (Jereb and Roper 2010). Squid is commonly known in Portugal, Spain and Italy as 'lula' or 'calamar/calamari' and marketed either fresh, frozen, or processed into canned or pre-cooked dishes. Squids are cooked in a variety of ways (stuffed with tentacles and 'chouriço/chorizo'[5] and cooked in tomato sauce, grilled, cooked with vegetables, etc.), although the most popular form is in rings previously seasoned, battered, and fried.

According to the INSA and USDA databases (accessed in 2015), raw squid, mixed species,[6] supplies 92 kcal/100 g, mainly from proteins (15.6 %) and total lipids (1.38 %; the sum of SFA [0.2–0.4 %; mostly 16:0 and traces of 14:0 and 18:0], MUFA [0.1 %; mainly 18:1 and 20:1] and PUFA [0.4–0.52 %; mainly EPA and DHA] as well as cholesterol [140–233 mg/100 g]). According to the INSA database (2015) no trans-fatty acids or linoleic acid were found. When merging data from the INSA and USDA databases, it can be noted that the fat-soluble vitamins retinol (10 μg/100 g) and α-tocopherol (1.2 mg/100 g) are present in fair and constant amounts, whereas the levels of vitamins $D_2 + D_3$ (0–3.5 μg/100 g) vary widely. Water-soluble B vitamins are thiamine (0.047–0.071 mg/100 g), riboflavin (0.016–0.068 mg/100 g), niacin (0.76–1.0 mg/100 g), B_6 (0.053–0.072 mg/100 g) and B_{12} (0.95–1.1 μg/100 g). Ascorbic acid can be detected in highly variable amounts (0–4.7 mg/100 g). Relevant minerals are Ca (18–32 mg/100 g), P (221–261 mg/100 g) and Mg (33–49 mg/100 g) (INSA 2015; USDA 2015). The following minerals are also worth mentioning: copper (Cu: 1.9 mg/100 g), Mn (0.035 mg/100 g) and Se (44.8 μg/100 g) (USDA 2015).

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[4] Food supply quantity (from food balance sheets, 2011 statistical data), referring to the total amount of the commodity available for human consumption during 1 calendar year (FAO 2015d, 2015e).

[5] Dry fermented sausage: a traditionally processed pork meat that is seasoned and fermented prior to a smoking 'cure'.

[6] Analysed species may differ between databases. It is probable that PortFir (INSA 2015) includes just *Loligo* sp. while the USDA database specifically notes that *Ommastrephidae* sp. is also included.

7.2.5.2 Cuttlefish (*Sepia officinalis*)

Cuttlefish are found predominantly on sandy to muddy bottoms of the coastline to about 200 m in depth; larger individuals are encountered in the deeper part of the range. In the western Mediterranean, in early spring, large individuals leave the deeper water, where they have spent the winter, to migrate into shallower water (males precede females by about a week). The maximum mantle length is 45 cm, weighing up to 4 kg in temperate waters. This group is followed by a succession of smaller cuttlefish, arriving in shallow waters throughout the summer. In fall/autumn, the gradual descent begins. Common cuttlefish is usually marketed fresh and frozen, and is a highly valued food item, particularly in Italy and Spain (FAO 2015f). Cuttlefish is similarly cooked in Portugal and North Spain, e.g. in its own ink, with beans and 'chouriço' ('feijoada de choco') or seasoned and fried, resembling fish fingers.

According to the INSA and USDA databases, raw cuttlefish, mixed species (*Sepiidae* sp.) supplies 79 kcal/100 g from: proteins (16.2 %) and total lipids (0.7 %; being the sum of SFA 0.12–0.4 %, mostly16:0 and traces of 18:0; MUFA 0.08 %, mainly 18:1 and 20:1; and PUFA 0.13–0.52 %, mainly 20:4, EPA and DHA), as well as cholesterol (112–233 mg/100 g). No trans-fatty acids or linoleic acid are found (INSA 2015). Fat-soluble vitamins are present in fair and constant amounts: retinol (10 μg/100 g) and α-tocopherol (1.2 mg/100 g). Vitamin $D_2 + D_3$ content varies widely (0–3.5 μg/100 g). Water-soluble B vitamins are also found: thiamine (0.047–0.071 mg/100 g), riboflavin (0.016–0.068 mg/100 g), niacin (0.76–1.0 mg/100 g), B_6 (0.053–0.072 mg/100 g) and B_{12} (0.95–1.1 μg/100 g). Ascorbic acid can be found at highly variable levels (0–4.7 mg/100 g). Relevant minerals are Ca (18–32 mg/100 g), P (221–261 mg/100 g) and Mg (33–49 mg/100 g) (INSA 2015; USDA 2015). In addition, the following minerals are also detected: Cu (1.9 mg/100 g), Mn (0.035 mg/100 g) and Se (44.8 μg/100 g) (USDA 2015).

7.2.5.3 Octopus (*Octopus vulgaris*)

Octopus is found worldwide, mostly in temperate and tropical waters as it becomes inactive below 7 °C. It is a medium- to large-sized animal, chunky in appearance and commonly found in shallow waters in a variety of habitats (e.g. rocks, coral reefs and grass beds) (FAO 2015g). The pattern of octopus consumption is similar to that of other cephalopods: it is consumed in all countries of the present study, with the most probable exception of Morocco. Small- and medium-size animals are preferred for the softness of the meat. Octopus can be cooked in a variety of ways: as a stew, baked, grilled, fried, incorporated in rice dishes (e.g. the portuguese 'arroz de polvo') or as an appetiser salad, consisting of cooked and sliced pieces of octopus immersed in a mixture of olive oil, vinegar, onion and aromatic herbs. Octopus is most popular in Portugal and in Spain.

According to the INSA and USDA databases (accessed in 2015), raw octopus, *Octopus vulgaris*, supplies 73–82 kcal/100 g from: proteins (14.9–15.6 %) and total lipids (1.04–1.20 %, being the sum of SFA 0.23–0.3 %, 14:0, 16:0 and 18:0; MUFA 0.10–0.16 %, mainly 16:1 and 18:1; and PUFA 0.24–0.60 %, mainly 18:4, 20:4, EPA and DHA), as well as cholesterol (48–64 mg/100 g). No trans-fatty acids or linoleic acid are registered in the PortFir database (INSA 2015). α-tocopherol (0.73–1.2 mg/100 g), and retinol (3.0–4.5 μg/100 g), which is present in variable amounts. Vitamin D is absent, and vitamin K is present only in very small amounts (0.1 μg/100 g). Water-soluble B vitamins are thiamine (0.02–0.03 mg/100 g), riboflavin (0.04 mg/100 g) and niacin (1.3–2.1 mg/100 g). Again, divergent values for some vitamins and minerals are found when merging data from the INSA and USDA databases, as is the case of vitamins B_6 (0.07–0.36 mg/100 g), B_{12} (1.3–2.0 μg/100 g), ascorbic acid (0–5.0 mg/100 g), Ca (32–53 mg/100 g), and P (186–261 mg/100 g); also relevant are Mg (30–49 mg/100 g), Fe (5.3 mg/100 g), Cu (0.43 mg/100 g), Mn (0.025 mg/100 g) and Se (44.8 μg/100 g) (USDA 2015).

When compared with other cephalopods, octopus provides a higher vitamin content and less cholesterol for the same edible portion.

7.2.6 Bivalves

Bivalves have been consumed by humans at least since the time of the Roman Empire judging by the empty shells found in archaeological sites.

The circulatory system relies on haemoglobin as the oxygen-carrying protein, with iron (Fe) in its active centre instead of Cu, as in the case of cephalopods and crustaceans. Bivalves are filter feeders, passing large quantities of water through their gills and filtering out organic particles, including chemical pollutants and microbial pathogens. These are retained in tissues and become concentrated in their liver-like digestive glands. Another issue, closely monitored by health authorities, is the presence of biotoxins produced by microalgae ingested by bivalves. To address the growing trend of consumption and to reduce food safety issues, aquaculture systems have been improving cultivation techniques that take advantage of bivalves' sedentary habits, and contributing to the lowering of market prices. Generally, juveniles are transferred from hatcheries (in controlled tanks) and reared off the seabed in suspended rafts, on floating trays or cemented to ropes. Here, they are largely free from bottom-dwelling predators (such as starfish and crabs), are less exposed to contaminated debris, and can be harvested by hand when they reach a suitable size.

Oysters, scallops, clams, ark clams, mussels and cockles are the most commonly consumed bivalves, and are included as ingredients in main courses (such as 'carne de porco à alentejana', with clams and pork) or appetisers (generally cooked with wine and herbs) accompanied with bread that is dipped in sauce.

None of the food databases accessed in the current work provided adequate information about the species of clams consumed in the area (namely blue mussel, Mediterranean mussel, Atlantic surf clam and common cockle). For this reason, no detailed food composition is provided, but no major differences from other bivalves are expected.

7.2.6.1 Mussels (*Mytilus edulis*, *M. galloprovincialis* and Related Species)

Mytilus edulis and *M. galloprovincialis* are two closely related species, commonly known simply as mussels. Mussels have a solid shell and are approximately triangular in outline. The shell exhibits fine concentric lines, of different tones of purple, blue and brown on an almost black periostracum. The interior is pearl-white with a wide border of purple or dark blue. Mussels, in general, are common in Europe and in the Mediterranean basin, living on all coasts attached to rocks and piers from intertidal areas to 40 m deep, sometimes building large groups of individuals. The diet of mussels consists of phytoplankton and detritus filtered from the surrounding water. The species dimensions are greatly influenced by its biotope: intertidal shells often remain smaller (5–6 cm long) than deep-water shells, which easily measure 9 cm (FAO 2015h, 2015i).

Mussels (raw, *Mytilus* sp.) supply 69–86 kcal/100 g: protein (11.9–12.1 %), starch (2 %) and total lipids (1.50–2.24 %, being the sum of SFA 0.3–0.42 %, 14:0, 16:0 and 18:0; MUFA 0.3–0.51 %, mainly 16:1, 18:1 and 20:1; and PUFA 0.50–0.61 %, mainly 20:4, EPA and DHA) as well as cholesterol (28–40 mg/100 g) (INSA 2015; USDA 2015). No trans-fatty acids or linoleic acid have been registered (INSA 2015).

α-Tocopherol (0.55–0.74 mg/100 g) and γ-tocopherol (0.02 mg/100 g) are present in fairly stable amounts, when merging data from INSA and USDA databases, whereas the concentration of retinol (48–360 μg/100 g) and ascorbic acid (0–8.0 mg/100 g) vary widely. Vitamin D is absent, and vitamin K is present only in very small amounts (0.1 μg/100 g). Mussels contain the B vitamins thiamine (0.10–0.16 mg/100 g), riboflavin (0.14–0.21 mg/100 g), niacin (1.2–1.6 mg/100 g), B_6 (0.05–0.08 mg/100 g) and B_{12} (12.0–19.0 μg/100 g). Relevant minerals are Ca (26–56 mg/100 g), P (197–240 mg/100 g), Mg (34–36 mg/100 g), Mn (3.4 mg/100 g) and Se (44.8 μg/100 g). Like other molluscs, mussels provide quite a high level of sodium (290 mg/100 g) (INSA 2015; USDA 2015).

7.2.6.2 Cockle (*Cerastoderma edule*)

Cockle is a common designation for bivalves that have an almost globular very thick shell with radiating ribs and very fine irregular concentric lines. Growth stages are prominent, and may include other species related to *Cerastoderma edule* (the most common in the area). The shell is dirt white or pale yellow and white inside. Cockles can jump by bending and straightening their foot, although (like other molluscs) they are quite sedentary. Preferred habitats are sandy bays that are intertidal to only a few meters deep, with some arrival of fresh water, where they live just under the bottom surface on sand, mud or gravel. They are relatively common along the Atlantic coast but quite rare in the Mediterranean. Consequently, they are more commonly consumed in Portugal and Spain, particularly the small subspecies (3–4 cm) (FAO 2015j).

Cockle shell *(on scallop shells). Shellfish or bivalves, like other fish, provide a protein with the correct balance in amino acids and are simultaneously an important source of unsaturated long-chain fatty acids n-3, which play important physiological roles in the organism. Photo reprinted with kind permission from T. N. Wassermann*

Cockles (raw, mixed species) supply 60–79 kcal/100 g from: proteins (10.5–13.5 %), some available carbohydrates (2.7 % of starch) and total lipids (0.7 %, being the sum of SFA 0.1–0.3 %, MUFA 0.1–0.3 % and PUFA 0.3–0.50 %) (INSA 2015; USDA 2015). No trans-fatty acids or linoleic acid are registered (INSA 2015).

Cockles have an average content of 30 mg/100 g cholesterol. Fat-soluble vitamins are absent but water-soluble B vitamins are found in variable amounts: thiamine (0.005–0.16 mg/100 g), riboflavin (0.11–0.20 mg/100 g), niacin (1.7–3.2 mg/100 g), B_6 (0.04 mg/100 g) and B_{12} (41.0 μg/100 g). Relevant minerals are Ca (30–56 mg/100 g), P (159 mg/100 g) and Mg (58 mg/100 g). Like other molluscs, cockles have a relatively high sodium content (376 mg/100 g) (INSA 2015; USDA 2015).

7.2.7 Crustaceans

Crustaceans are highly valued worldwide and moderately consumed in the countries that have been mentioned throughout this text. Crustaceans include species of crab, shrimp and lobster belonging to the class *Malacostraca*. Besides an exoskeleton, crustaceans have an open circulatory system, with haemocyanin as the oxygen-carrying metal-protein.

The most popular crustaceans are crabs and shrimps, consumed as appetisers or as main course ingredients (as in the well-known 'paella'). As opposed to lobsters, crabs and shrimps are farmed on a large scale, which makes them more easily available and cheaper. Lobster is still consumed, in the area, as a delicacy.

Crabs are gathered in the wild but are mostly cultured. They are benthic organisms, living on a wide range of sand, gravel and rocky bottoms, usually at a depth of 6–40 m. The species *Cancer pagurus* is found from the Eastern Atlantic (northern Morocco) extending along to the north coast of the Mediterranean (Marseille, Napoli). It is the most common edible species in the area. Its body is broadly oval, with large and smooth pincers, without spinules and four pairs of similar legs. The carapace exhibits a homogenous reddish brown pale colour and is about 20 cm long.

No detailed information is available from databases on the crab species normally found and consumed in the area. Therefore, the discussion on crustaceans is only based on data for shrimp/prawn, raw, mixed species, mostly from the family *Penaeidae*. The most common shrimp in the area is *Crangon crangon*, which is distributed along the Atlantic coast of Europe, including Portugal and Morocco, as well as in the Mediterranean. Like other shrimps, *C. crangon* prefer shallow coastal, marine or slightly brackish waters (0–20 m), where it lives near the bottom. A larger quantity of edible species is available in the Atlantic coast than in the Mediterranean Sea. Nowadays, farmed prawns (mainly of genus *Penaeus*) are usually preferred for their low prices (FAO 2015k).

Thus, shrimp, raw, mixed species (including those from aquaculture) supply 77–83 kcal/100 g from: proteins (13.6–17.6 %), starch (0.3–0.9 %) and total fat (0.6–1.0 %, being the sum of SFA 0.1 %, mostly 16:0), MUFA 0.1 %, conjugated *cis–trans* isomers of 16:1 and 18:1; and PUFA 0.3 %, mainly 18:2, n-6; 20:4; EPA, DHA and some DPA). Shrimps also contain cholesterol (126–154 mg/100 g) (INSA 2015; USDA 2015). According to INSA (2015), *Penaeus* sp. contain linoleic acid (0.1 %) and no trans-fatty acids, while the USDA database (2015) registers trans isomers (0.018 g/100 g, of which 0.011 g corresponds to *trans*-monoenoic acids). By overlapping data from both databases, it can be deduced that *trans*-monoenoic acids most probably account for CLA.

Fat-soluble vitamins found in shrimp are retinol (0–54 μg/100 g), α-tocopherol (0.70–1.32 mg/100 g), γ-tocopherol (0.12 mg/100 g) and δ-tocopherol (0.03 mg/100 g). Shrimps also contain water-soluble B vitamins: thiamine (0.02–0.03 mg/100 g), riboflavin (0.010–0.015 mg/100 g), niacin (1.78–2.0 mg/100 g), pantothenic acid (0.31 mg/100 g), B_6 (0.05–0.16 mg/100 g) and B_{12} (1.1–2.1 μg/100 g). Relevant minerals are Ca (54–87 mg/100 g), P (150–244 mg/100 g) and Mg (22–30 mg/100 g).

In short, fish and seafood provide a balanced source of animal protein (containing all essential amino acids) with low energy. Fat content is variable but generally rich in essential fatty acids, namely omega-3, and a wide range of vitamins. With the exception of some cephalopods (squid and cuttlefish) and crustaceans, fish and seafood is low in cholesterol and contains no TFA.

7.3 Meat

Meat has been part of the food habits of humankind since the origin of the species, as a protein and energy source, and providing the essential amino acids (Table 7.1), vitamins and minerals. Meat is generally a good source of iron present in a haemoglobin centre and a major source of vitamin B_{12}, essential fatty acids (EPA, DHA and DPA) and other bioactive fats such as CLA. Meat is a very satiating food, which may compel an individual to eat larger portions than necessary. Excess animal protein consumption is deleterious to health, as mentioned above and further explained below.

Roughly, 'red meat' includes all meat from mammals (beef, lamb, pork, veal and goat), whereas 'white meat' refers mainly to poultry (turkey, duck, goose, chicken and rabbit). Animals with 'white' meat have muscles with fast-twitch fibres that enable quick bursts of activity (such as fleeing from predators) at the expense of locally stored glycogen. On the other hand, 'red meat animals' have muscles with slow-twitch fibres. These muscles are used for extended periods of activity such as standing or walking, and need a consistent energy source such as fat reserves. As the muscles of red meat animals perform aerobic respiration, the concentration of myoglobin is higher than in the muscles of white meat animals, which mainly work under anaerobiosis (breaking glycogen down to lactic acid). International organisations have been advising consumers to reduce the intake of red meat, particularly processed meats, due to the risk of coronary disease and bowel cancer (American Heart Association 2015; NHS 2015). Red meat can be part of a healthy diet, if lean parts and small portions are preferred and consumed with vegetables. In the context of the MD, Bach-Faig and colleagues (2011) recommend, in increasing order of preference, lower intakes of processed red meat, such as 'jamon' (<1 serving/week), red meat (<2 servings/week), white meat (about 2 servings/week) and 2–4 eggs/week.

On average, white meat contains less saturated fat and less cholesterol than red meat, but this only applies to the average of whole carcasses, as in fact such content depends on the type of each piece of meat. Both total fat and the composition of the lipid fraction depend on many factors, from the feed and breed of the animals to the butcher's cut, even the cooking method.

Table 7.2 shows the lipid profile of different types of raw meat, referring to the portion ready to be cooked (the figures should be regarded only as a guidance; data were obtained from different sources and correspond to commonly consumed butcher cuts). Roughly, total fat and saturated fat are commonly within the same range of values for white and red meats. However, in commonly consumed butcher cuts, total fat tends to be lower in the case of beef and higher in chicken and in pork. Cholesterol levels are in the same range (INSA 2015; USDA 2015) but slightly higher in chicken (the skin is probably the main contributor). According to Table 7.2, chicken and pork generally contain a lower concentration of TFA than beef (even the lean cuts). Nevertheless, TFA of ruminant origin may include *trans*-

Table 7.2 Lipid profile for the main types of consumed meat (chicken [poultry], beef [ruminants], pork). Mean values from distinct breeds and geographical locations (EU and USA) expressed as percentage of edible portion

Type of fat	Chicken (a)	Beef (fat trimmed) (b)	Pork (fat trimmed) (c)
Total fat, %	14.4	4.0	10.2
SFA	3.6	1.8	3.51
MUFA	5.9	2.2	3.9
PUFA	2.7	0.33	1.65
Cholesterol	0.009	0.006	0.007
TFA	0.1	0.2	0.1
Linoleic acid/ALA	2.5	0.1	0.36
EPA	0.01	0.002	$<10^{-4}$
DPA	0.01	0.012	$<10^{-4}$
DHA	0.03	0.001	$<10^{-4}$

Displayed results have been calculated by the elaboration of single data points from different sources (Alfaia et al. 2007; INSA 2015; Martins et al. 2007; Marušić et al. 2013; USDA 2015). Total fat includes SFA, MUFA, PUFA, cholesterol, and TFA; PUFA includes ALA, EPA, DPA and DHA; (a) whole carcass, meat and skin, without gizzards; (b) Beef, grass-fed, lean only, raw; (c) pork ribs with bone, raw

isomers of CLA and other compounds potentially beneficial to human health (Alfaia et al. 2007).

Chicken contains about ten times more essential fatty acids (ALA, EPA, DPA and DHA) than beef and far more than pork's meat. On the other hand, pork does not contain EPA or DHA but is richer than beef, in linoleic acid.

Although marginal, some uncommon types of meat are consumed in the area, such as rabbit, frog, snail and small birds (quail, pheasant). Horse meat seems to be poorly accepted by many consumers in the Mediterranean area and for that reason it is not discussed in the current work. Farmed animals intended for meat consumption are regularly inspected by a veterinarian to ensure not only their health but also hygiene and comfort. When slaughtered, every carcass is again inspected for compliance with requirements for human consumption.

7.3.1 Poultry (Chicken, Turkey, Duck)

Although chicken and turkey are categorised as white meat animals, their legs, which support their body weight, rely on muscles that provide endurance work. Consequently, they contain larger amounts of myoglobin than breast meat; this enables leg muscles to use oxygen more efficiently for respiration. Ducks, which use chest muscles for long flights, have dark meat all over the body. Chicken and turkeys are categorised as white meat because most muscles perform anaerobically and hence contain low concentrations of myoglobin, which is responsible for the meat pigmentation. Thus, both types of meat—white and dark (or red)—can be found within poultry.

The chicken (*Gallus gallus domesticus*) is one of the most common and widespread domestic animals. Since ancient times, humans have kept chickens close to their homes as a source of food, consuming both their meat and their eggs. Chickens are omnivores, eating seeds, insects, small lizards and even small snakes or young mice. Chickens are gregarious birds with a communal approach to the incubation of eggs and raising of young; they may live for 5–10 years, depending on the breed.

However, the majority of poultry for human consumption is raised using intensive-farming techniques; a smaller proportion is raised with an organic approach, relying on different feed and keeping the animals in the open air for some periods of time. Chickens intensively farmed for meat take less than 6 weeks to reach slaughter size, while organic meat chicken will usually be slaughtered at about 14 weeks of age. Chicken farmed for their eggs can produce more than 300 eggs/year. After 12 months of laying, egg-laying ability usually starts to decline, and the animals are then slaughtered and used in processed foods or as pet food ingredients.

Thus, broiler chicken, meat and skin, raw, supplies 201–215 kcal/100 g from: proteins (18.6–19.6 %) and total fat (13.6–15.1 %) (INSA 2015; USDA 2015).

Chicken contains all fat-soluble vitamins in fair amounts: retinol (20–41 μg/100 g), α-tocopherol (0.20–0.30 mg/100 g), vitamins $D_2 + D_3$ (0.20–0.62 μg/100 g) and K (1.5 μg/100 g). The water-soluble vitamins are ascorbic acid (0–1.6 mg/100 g), folates (6–9.4 mg/100 g), thiamine (0.06–0.12 mg/100 g), riboflavin (0.120–0.25 mg/100 g), niacin (6.6–6.8 mg/100 g), pantothenic acid (0.91 mg/100 g), B_6 (0.30–0.35 mg/100 g) and B_{12} (0.31–0.80 μg). Relevant minerals are P (147–176 mg/100 g) and Mg (20–23 mg/100 g) (INSA 2015; USDA 2015), Mn (0.019 mg/100 g) and Se (14.4 μg/100 g) (USDA 2015).

Another detected substance in chicken meat is betaine[7] (7.8 mg/100 g), a non-protein amino acid and a compatible solute that protects cells against osmotic stress and may promote water retention. Betaine is ubiquitous in nature, occurring in plant foods as well as in animal foods and there are no reported toxic effects associated to it (NCBI 2015). Duck and turkey meat share most of the characteristics of chicken meat.

7.3.2 Ruminants (Bovine, Lamb and Goat)

Cattle (*Bos taurus*) is raised for milk or meat production. Domestic cows naturally feed on grasses, stems and other herbaceous plant material. An average cow can

[7] Also named 2-(trimethylazaniumyl)acetate.

consume about 70 kg of grass in an 8-h day and may reach a body mass of more than 600 kg. The lifespan of domestic cows may exceed 20 years (EOL 2015).

Cows, like lambs (*Ovis aries*) and goats (*Capra hircus*) are herbivorous ruminants, meaning that their digestive system breaks down cellulose and other relatively indigestible plant material. Ruminants have a four-chambered stomach, including a rumen where specialised bacteria take part in digestion. The process of digestion is very slow (taking 70–100 h in cows), and therefore extracts the most nutrients from plant materials (EOL 2015).

The meat of young cows is known as veal, and that of adults is called beef. Cattle may be raised by intensive or extensive systems, which have an impact on the lifespan, feeding, handling and the final quality of the meat. In extensive systems, cows are kept outdoors most of the time, feeding on pasture but with access to shelter. Alternatively cattle can be confined in intensive systems, although in the observance of international guidelines for minimising stress and improving the wellbeing of animals. In intensive farming systems, cattle for meat are raised to slaughter in about 3–16 months, thus significantly reducing their lifespan. Extensive systems are less productive in the short-term but produce the best-quality meat while providing an increased lifespan and animal welfare. These systems are more adequate in mild climates, as in the Mediterranean basin, where they are common for small ruminants.

Domestic sheep (*Ovis aries*) are extremely versatile and exist in a wide variety of habitats worldwide, ranging from temperate mountain forests to desert conditions. Their natural life expectancy is about 22–23 years, and their average weight is about 35–40 kg (Reavill 2000).

Domestic goats (*Capra hircus*) have similar habits to sheep but a slight higher body mass and shorter life expectancy of 15 years (Mileski 2004). Roughly, the meat composition of large and small ruminants has an identical balance of compounds, but contents may significantly differ according to breed, climate, breeding systems, etc. Data on the composition of beef from two distinct databases are presented below as an example.

Thus, regarding meat composition (INSA 2015; USDA 2015), Beef, grass-fed, strip steaks, lean only, raw, supply 117–122 kcal/100 g from: proteins (20.9–23.1 %) and total fat (2.7–4.3 %).

Beef does not contain retinol; other fat-soluble vitamins are α-tocopherol (0.04–0.22 mg/100 g), vitamins $D_2 + D_3$ (0.10–0.40 μg/100 g) and vitamin K (0.9 μg/100 g). Regarding water-soluble vitamins, ascorbic acid is absent, but beef contains folates (13–16 μg/100 g), thiamine (0.05–0.10 mg/100 g), riboflavin (0.12–0.16 mg/100 g), niacin (4.6–6.7 mg/100 g), pantothenic acid (0.68 mg/100 g) and vitamins B_6 (0.51–0.65 mg/100 g) and B_{12} (1.18–2.0 μg/100 g). Relevant minerals are P (169–212 mg/100 g) as well as the microelements Mn (0.009 mg/100 g), Se (21.1 μg/100 g) (INSA 2015; USDA 2015). Betaine is quantified at a concentration of 7.6 mg/100 g (USDA 2015).

Martins and co-workers (2007) determined the average contents of CLA isomers in the most consumed ruminant meats in Portugal. Regarding the most relevant isomers, the concentration of the well-recognized beneficial isomer c9,t11 CLA was found to be significantly higher in extensively produced beef (78.4 ± 6.3 mg/g) and lamb meat (77.3 ± 6.3 mg/g) than in intensively produced beef (59.9 ± 13.7 mg/g). On the other hand, the meat concentration of t10,c12 CLA (which is not so desirable, as explained in Sect. 6.2) is generally higher in intensively produced beef than in beef from extensive systems (Martins et al. 2007), and it is also significantly lower in lamb meat (extensive system).

7.3.3 Pork

Pork is the name of the meat from the domestic pig (*Sus domesticus*), a voracious omnivore animal of which many subspecies exist, ranging from 1 to 2 m in length and 50 to 350 kg in weight. The colour of its skin may vary from pale pink to black, depending on the breed. Domestic pigs are farmed primarily for their meat, which is consumed fresh or processed (e.g. bacon, ham, etc.). Pork has been a very popular meat in the western world, including southern Europe, particularly due to the diversity of end products that can be obtained: smoked ham, chorizo, salami, mortadella, etc. Consumption of pork is forbidden for both Muslim and Jewish people for religious reasons.

Breeds from northern European countries, of large size and of white pinky skin, are generally exploited in intensive husbandries, whereas others, such as ‘cerdo iberico’ (of dark skin), are preferably raised by extensive systems. This is the way to obtain meat of the proper quality to use in the production of ‘chorizo’, smoked ham (‘jamon’) and other valuable ‘Protected Designation of Origin’ (PDO) products. The natural lifespan of pigs (in the wild) is about 15 years, but an adult may reach the necessary size and weight to slaughter in less than a year in intensive farming systems. Juveniles (suckling pigs) are slaughtered a few weeks after birth, when the tender meat (called ‘leitão’) is most appreciated.

Pork, if fat trimmed, can be leaner than chicken although higher in cholesterol and SFA than other meats, whereas it is higher in thiamine (vitamin B_1).

Thus, for example, pork ribs with bone, fat trimmed, raw (about 9 % separable fat), supply 172–221 kcal/100 g from: protein (19.8–20.9 %) and total fat (9.8 %) (INSA 2015; USDA 2015).

Pork meat contains negligible amounts of retinol (0–3 μg/100 g), and vitamin K is absent, but other fat-soluble vitamins are provided in fair amounts: α-tocopherol (0.11–0.2 mg/100 g) and cholecalciferol (0.7–0.9 μg/100 g). Regarding water-soluble vitamins, ascorbic acid is absent as are folates, but pork meat is generally richer in thiamine (0.50–0.74 mg/100 g) and riboflavin (0.20–0.33 mg/100 g) than meat from other animals; the concentration of the other B vitamins is as follows: niacin (3.5–6.5 mg/100 g), pantothenic acid (0.86 mg/100 g), B_6 (0.40–0.46 mg/100 g) and B_{12} (0.54–1.0 μg/100 g). Relevant minerals are P (165–193 mg/100 g) and Se (33.3 μg/100 g) (INSA 2015; USDA 2015). Betaine, which may be correlated with water retention in meat, is quantified at a concentration of 2.8 mg/100 g (USDA 2015), lower than typical values from broiler chicken and beef.

7.3.4 Traditionally Processed Meat

Meat-preserving methods aim to decrease water activity and pH and may additionally avoid microbial growth by adding spices and compounds from wood fumes (in large-scale production, synthetic food preservatives may be added, within the allowed limits). In the Mediterranean basin, techniques for preparing cured sausages (chorizo) and dry smoked meat (jamon) have been developed locally, resulting in distinctive regional products. The technique for producing cured sausages evolved from ancient recipes involving filling pig intestines with meat by-products and drying with smoke. The manufacture and preservation methods were most probably improved by Roman legions to obtain an easily transported food resource with extended shelf-life at room temperature. The Romans also made other types of sausage products, 'circelli', 'tomacinae', 'butuli', which were eaten during annual orgiastic festivals and sacrifices.

Preservation methods include curing (by adding salt and spices), drying and (in many cases) smoking; these systems give the best results in mild climates. Meat is a complex raw material in which an alteration in a single factor results in a series of interrelated changes and processes. Traditional know-how and scientific knowledge together are determinant to quality and safety, and hence the creation of successful products. Nowadays, industries also include preservatives such nitrites and benzoates, as happens with cooked ham and bacon.

Pork is more often used in meat preserves, although beef sausages have been produced in Muslim countries such as Egypt (Rabie et al. 2010; Rabie and Toliba 2013).

Maturation of pork meat (e.g. ham and 'chorizo') involves lipolysis and proteolysis processes, conducted by endogenous enzymes or enzymes of microbial origin. The biochemical reactions that take place during the maturation of many of these traditional products is far from being understood from a scientific viewpoint, with quality and safety mostly relying on local knowledge. The extent of proteolytic and lipolytic reactions depends on the breed and feeding system of pigs (impacting the patterns of muscle proteolytic and lipolytic enzymes), processing techniques and, ultimately, the temperature of chambers (Alfaia et al. 2004; Cava et al. 1999).

However, many aspects of modern meat technology, combined with traditional processing practices, have been implemented, particularly in the smoked ham and sausage-producing segment of the meat industry. Current dry sausage and smoked ham production methods are continuously evolving, and changes based on technological advances are in sight.

7.3.4.1 'Chouriço/Chorizo' (Dry Fermented Sausages) and Similar Products

'Chouriço/chorizo' (dry fermented sausages) and similar products are fermented and cured spicy and smoked pork sausages, stuffed into dried and pre-treated intestines or bladder of the pork. Many different types of this kind of 'sausage' exist, depending on the ingredients and spices, which affect the cure and smoking periods. Fermented pork sausages of different sizes and flavours are most popular in Portugal, Spain and Italy. The spices included in the sausage are a particular feature that distinguishes them from other meat derivatives. They not only contribute to the aroma but also play a key role in the selection of adequate microbial communities responsible for the fermentation step. Salt, garlic, paprika and 'pimento' are spices commonly used in these products.

These sausages have traditionally been produced in the autumn and matured (by exposure to smoke) over the winter. The right firmness and flavour were normally attained after 2–3 months. The flavour of dry fermented sausages results from chemical, biochemical and microbiological reactions that take place alongside ripening, as well as compounds contributed by the smoke in products that undergo this step.

With reference to 'chorizo', a microbial fermentation step is relevant to quality, as opposed to the desirable low microbial activity in cured ham.

Lactic acid bacteria (LAB) are well known for their fastidious nutritional requirements but wide tolerance to environmental factors, contributing to the aroma and safety of many fermented foods. They play a key role in the first maturation step of 'chorizo' by producing lactic and acetic acids and later contributing to proteolysis and lipolysis. Species of genera *Lactobacillus* and *Pediococcus* are predominant (Santos et al. 1997).

Ansorena and colleagues (2000) registered a stepwise increase in acids as a consequence of LAB activity, followed by the accumulation of long-chain fatty acids (C16 and C18), resulting from the hydrolysis of triglycerides by both microbial and endogenous lipases. The next phase (after 21 days of maturation) is the accumulation of short-chain fatty acids ($C < 6$), which contribute to the typical organoleptic characteristics (Ansorena et al. 2000) and were noted as playing a relevant role in maintaining a healthy gut microbiota (Sect. 6.1). Esters and aldehydes were also reported by the same authors, as maturation products, some of which have been detected in red pepper (e.g. 2,4-decadienal and pentadecanal).

Bacterial proteolysis causes the accumulation of benzeneacetaldehyde (2-phenyl-acetaldehyde) from the oxidation of phenylalanine, as well as 2-methylbutanoic acid and 3-methylbutanoic acid, which result from microbial degradation of the amino acids, isoleucine and leucine, respectively. Thus, 2-phenyl-acetaldehyde communicates a green odour and sweet, floral taste with a spicy nuance. On the other hand, 2-methyl- and 3-methylbutanoic acid communicate a sweaty odour to the 'chorizo de Pamplona' (Ansorena et al. 2000).

In Portuguese 'chouriço' from Alentejo, the primary group of volatiles by the end of maturation are hydrocarbons, alcohols and sulphur compounds (Partidário et al. 2011). At least some of these sulphur compounds may be organosulphur compounds from garlic (most of them are under investigation for their potential health-promoting properties).

Many of these traditional products have been granted PDO or similar status by the EC. This status implies the mandatory use of specific techniques, with meat from local pork breeds raised in extensive farming systems and fed on pasture and acorn. Procedures, bags (intestine and bladder) and their treatments prior to use, temperatures of the maturation chambers and the type of wood used to produce fumes, are all regulated and stated in each PDO or similar EU-issued protocol. Industrial processes have been developed to shorten the maturation period, aiming to retain its uniqueness while allowing small sausages to be ready to market in about 4–6 weeks.

Among many examples of such products are 'chouriço de carne de Estremoz e Borba' (PT/PGI/0005/0159), 'chosco de Tineo' (ES-PGI-0005-0696) and 'salama da sugo' with IT-PGI-0005-01114 (EC 2002, 2010, 2014).

Fuet jamon. *Fuet jamon is a thin dry-cured sausage from Catalonia, Spain, obtained from minced pork meat and usually seasoned with garlic and black pepper. Unlike other Spanish sausage varieties such as chorizo, paprika is not used for fuet production. According to experts, this product may be defined as similar to Italian salami. Photo reprinted with kind permission from M. Barone*

7.3.4.2 'Jamón/Presunto' (Smoked Ham)

High-quality smoked hams are manufactured from Iberian pigs that are raised in an extensive system in the regions near the south border between Portugal and Spain (Alentejo, Andalucia and Granada) and mainly fed on pasture and acorn. A second (mountainous) region near the north border between Tràs-os-Montes and Castilla-Leon is also relevant (jamón serrano).

Relevant products within this category, holding PDO or similar status, are as follows (EC 1996, 2000, 2005, 2007, 2010, 2014):

(a) 'Jamón de Huelva' (ES/PDO/0005/0009)
(b) 'Jamón de Trevélez' (ES/PGI/0005/0309)
(c) 'Jamón de Serón' (ES/PGI/0005/01052), from the southern Iberian Peninsula
(d) 'Presunto de Vinhais/Presunto bísaro de Vinhais' (PT/PGI/0005/0456) and 'Lacón Gallego' (ES/PGI/0005/0104), both from the northern region of the Iberian Peninsula

The smoked ham preparation method follows some common steps, with specificities according to traditional recipes and the microclimate of the region. According to the methodology described in PDO documentation (ES/PDO/0005/0009) for 'Jamón de Huelva' (commonly known as 'jamón ibérico'), only the rear extremities larger than 7 kg are used. The first step is the salting with sodium chloride (NaCl) and nitrates, followed by a curing step at 0–5 °C and 70–90 % relative humidity for a variable time depending on the size of the piece (about 1 day/kg weight). The excess salt on the surface is washed out with water, and the hams are kept in chambers at 3–7 °C and 70–90 % relative humidity for 30–60 days to equilibrate salt content inside the piece to about 1 % and are then hung to dry for about 6 months followed by maturation in 'bodegas' until obtaining the correct sensory characteristics. The external aspect is determined by typical moulds, which give ham a white to blue-greyish colour. The meat in the interior is purple rose, non-fibrous, elastic, and of greasy consistency, with thin adipose veins distributed in the muscle.[8]

Iberian ham ripening involves little microbial activity, with the predominance of *Micrococcaceae*, which is well adapted to the salty environment (Alfaia et al. 2004). Similar to what was described for cheese, these proteolytic reactions yield peptides and free amino acids, which are correlated with flavour development in aged dry-cured ham, e.g. by contributing to the formation of aromatic compounds through pathways such as Strecker degradation or Maillard reaction (Alfaia et al. 2004). Free amino acids can also be decarboxylated into biogenic amines; although this should be avoided as they spoil the aroma and are dangerous to public health if maximum legal levels are approached.

Proteolysis also releases short peptides and non-protein amino acids, such as creatine, creatinine, glutathione, carnosine, carnitine and taurine (Marušić et al. 2013). The antioxidant and anti-hypertensive functions of short bioactive peptides have been described in Sect. 6.5. Moreover, Marušić et al. (2013) observed that carnosine, creatinine and serine were associated with antioxidant activity, while cysteine, glutathione and carnosine were associated with anti-hypertensive activity; all of them are present in dry cured ham.

[8] Adapted from ES/PDO/0005/0009-27.01.1998, available at: http://ec.europa.eu/agriculture/quality/door.

Lipolytic reactions are important phenomena that occur during ripening. Triglycerides are broken down, and some fatty acids may undergo several types of reactions. Thus, long-chain saturated aldehydes (C4–C10) can be formed, negatively affecting aroma and hence ham quality. These compounds were found to decrease with ripening in the case of Iberian pigs fed on acorn and pasture (Cava et al. 1999), but that is not the case in pigs confined and fed on industrial food. On the other hand, and according to the same authors, volatile aldehydes, such as pentanal and acetaldehyde are only predominant in 'jamón ibérico de bolota'.

Prolonged ageing does not always result in an improved taste with dry cured hams (Cava et al. 1999; Alfaia et al. 2004).

7.4 Eggs

The term 'eggs' generally means chicken eggs; however, quail eggs are also consumed, mostly as a delicacy. Eggs comprise an egg white (mostly albumin) and an egg yellow (yolk), of more complex composition.

Fresh raw eggs supply 143–149 kcal/100 g from: proteins (12.6–13.0 %), glucose (0.37 %) and total fat (9.51–10.0 %, being the sum of SFA 2.7–3.1 %, predominantly 16:0 and 18:0; MUFA 3.7–3.9 %, predominantly 16:1c and 18:1c; PUFA 1.9–2.1 %; TFA 0.04 %) and cholesterol (372 mg/100 g) (INSA 2015; USDA 2015).

Eggs are important sources of Ca and P and are rich in B vitamins, including B_{12} (0.89–1.0 μg/100 g), also containing retinol (160 μg/100 g), carotenoids (503 μg/100 g of lutein + zeaxanthin) and tocopherols (α-, β-, δ- and γ- in the concentrations of 1.05, 0.01, 0.06 and 0.5 mg/100 g, respectively). Eggs also supply cholecalciferol (1.7–2.0 μg/100 g) and vitamin K (0.3 μg/100 g) (INSA 2015; USDA 2015).

Nowadays, eggs are used in the dry or pasteurised liquid form for most industrial applications. These heating and drying processes somehow affect the flavour and texture of the final product also altering its nutritional value. Thus, the bioavailability of some vitamins seems to be reduced, as is the case of retinol and tocopherols (only α-tocopherol remains after the drying process). The lipid fraction also suffers some alterations (mainly in the concentrations of essential fatty acids) but the proportions of SFA/MUFA/PUFA do not significantly change.

We have drawn statistical data on total protein availability for human consumption from the United Nations (UN) Food and Agriculture Organization 'Food Balance Sheet' (FBS[9]) (FAO 2015e) for the countries on the UN Educational, Scientific and Cultural Organization (UNESCO) MD representative list (Portugal, Spain, Morocco, Italy, Greece, Cyprus and Croatia), and carried out some simple calculations. Results are presented in Table 7.3; the explanation about the FBS (Sect. 1.2) should also be noted. In the year 2011, the lowest value for total protein availability was registered in Cyprus (78.9 g/capita/day) while the highest value

[9] See Sect. 1.2 for information on FBS methodologies and meanings.

Table 7.3 Most relevant protein sources (g protein/capita/day) for the countries that integrate the representative list of UNESCO for the Mediterranean diet in the year 2011

Country	Fish and seafood	Meat	Dairy (except butter)	Eggs	Pulses	Total[a]
Portugal	15.2	31.2	16.8	2.8	2.0	111.2
Spain	12.9	30.8	15.4	4.3	5.2	103.3
Morocco	4.1	12.3	5.0	1.9	4.6	95.6
Italy	7.0	29.7	17.9	3.6	2.9	109.9
Greece	5.3	26.1	26.2	2.8	2.8	111.4
Cyprus	6.2	25.0	12.5	2.2	1.9	78.9
Croatia	6.0	17.5	18.5	2.8	0.6	82.4

Values were collected and/or calculated from the United Nations Food and Agriculture Organization Food Balance Sheets (accessed 2015) and refer to the year 2011. Food consumption per person is the amount of food, in terms of quantity, of each commodity and its derived products for each individual in the total population. Figures are shown for food items

[a]The difference in the values between total available protein (last column) and the sum of protein from discriminated items (previous columns) accounts for miscellaneous sources (not shown)

(111.4 g/capita/day) was registered in Greece. The main source of protein (in this representative list of countries) is meat, despite the almost threefold variation in its availability (from 12.3 g/capita/day in Morocco to 31.2 g/capita/day in Portugal). Dairy products are the second source of proteins (Table 7.3). The availability of fish varies as much as that of meat, and it is not necessarily associated with total protein intake. It is noteworthy that Portugal and Spain were amongst the world's largest consumers of fish and seafood in 2011 (FAO 2015a), showing total protein intakes of 111.2 g/capita/day (Portugal) and 103.3 g/capita/day (Spain), for which fish and seafood account for 14 and 12 % of total protein intake, respectively. In the remaining countries in our work, the contribution of fish to total protein intakes ranges from 4 to 7 % (Table 7.3). Nowadays, pulses seem to play a much less important role as a protein source than in the early 1960s, particularly in Croatia, where the availability of pulses is marginal (0.6 g/capita/day).

As can be deduced from that set of statistical data, there has been a remarkable increase in per capita meat consumption in all countries that make up the UNESCO representative list for 'Mediterranean Diet'.

By closely comparing data from the FBS over time (FAO 2015e), it can be observed that pork was the first choice in Spain and Portugal in 1961, closely followed by bovine meat. It should be recalled that pork meat can be more easily preserved via traditional methods such as smoking and curing than other types of meat. This pattern was not reflected in the other countries. In 1961, bovine was the most available type of meat in Italy. It can be deduced from market availability figures that Greeks consumed mostly the meat of small ruminants (lamb and goat), followed by bovine. In the same decade, bovine was preferred in Cyprus and Morocco, followed by the meat of small ruminants; no data for the 1960s are available from Croatia, thus impairing comparisons.

The equivalent dataset from 2011 (FAO 2015e) indicates that pork now seems to be the preferred meat in all countries, (highlighted in Fig. 1.1) with the exception of Morocco, the reasons for which are probably religious. Italy, Greece and Croatia show similar patterns of availability for consumption (data from 2011), with pork as the preferred meat, followed by bovine and poultry at quite similar proportions (FAO 2015e). Moreover, and still according to the same source, the availability of poultry for consumption has significantly increased. In 2011, poultry was the first choice in Morocco, followed by ruminant meat, in similar proportions. In Portugal and Spain, poultry displaced bovine meat as the second choice. Poultry is also the second choice in Cyprus.

These trends may indicate alterations in the pattern of meat consumption in the region.

With the development of agriculture and the increasing industrialisation of their products, intensive poultry breeding has turned out to be a good investment, mainly due to the short life cycle of the intensively farmed animals (about 1 month from egg to slaughter). The 'bovine spongiform encephalopathy' crisis may have discouraged the consumption of ruminant meat, while the economic crisis (quite severe in south Europe since 2009) may have triggered a demand for cheaper meats.

On the other hand, as can be observed in Table 7.3, pulses are currently far from counterbalancing animal protein intake, but the increase of public awareness about their health benefits may alter this deleterious increasing trend in meat consumption. One of the objectives of the International Year of Pulses (FAO 2015l).

In short, whether 'excess' dietary protein intake adversely affects bone in humans is currently a controversial subject in nutrition. Although not entirely conclusive, studies by both Frassetto and colleagues (2000) and Sellmeyer and co-workers (2001) support the hypothesis that "excessive dietary protein from foods with high potential renal acid load (e.g. animal foods) adversely affects bone, unless buffered by the consumption of alkali-rich foods (e.g. vegetable foods)." In other words, moderating animal protein intake and increasing the vegetable-to-animal protein ratio may confer a protective effect against osteoporosis, among other ailments (Frassetto et al. 2000; Sellmeyer et al. 2001).

Within animal protein sources, fish is known to have a balanced essential amino acid composition, and a desirable lipid profile, which is why it is recommended within a balanced healthy diet. Nevertheless, it should be noted that the characteristics of each type of meat, and consequently their potential benefits and deleterious effects will always strongly depend on the frequency and quantity of consumed meat, and is not dissociable from the other components of the MD.

Pulses may partially or totally substitute meat when combined with other protein sources, providing satiety and improving gut's health, along with other benefits.

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