Nutritional characteristics of animal products

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Lecture notes for students of MSc courses of Nutrition and Feed Safety and Animal Science

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Chapter 1. Introduction

Everyone knows that a good diet is essential for life and health. Food supplies the raw materials for the growth from a single cell to a full-grown adult and to maintain the body: there is no other source of the substances we need.

All the cells of the body need a supply of chemical energy (in the form of glucose or fatty acids) which comes ultimately from food. Structural proteins, fats and mineral compounds (as in bone) are formed from the raw materials provided by the diet. Enzymes and their cofactors contain vitamins and mineral elements.

Today, although life expectancy in the well developed countries is greater than ever before, many people are anxious and confused about what they should eat and, judging from the media, one would think our diet is very poor.

What has happened is that, during this century, we have moved from a position where many were under-nourished to a state of general over-nutrition. Today most of us eat enough to supply all the protein, minerals and vitamins we need, but many eat too much in relation to energy used and we consume a diet high in fats and sugar. The old problems of rickets, poor growth in children, iron-deficiency anaemia have largely gone but they have been replaced with disability or premature death from coronary heart disease, stroke and cancers. In all these, diet plays a role.

Thus, the major causes of death have changed dramatically. There are many reasons for this and nutrition is one of them.

The consequences of nutrient deficiency, like iron-deficiency anaemia, can be quickly and dramatically reversed by improving the diet. This is not the case for coronary heart disease, high blood pressure and atherosclerosis. Diet is implicated in these conditions and in some cancers, but it is not the sole cause. Diet accounts for about 30% of the risk of coronary heart disease. In spite of huge amounts of research, we are much less certain about the role of diet in these conditions.

As people become more affluent they choose different foods and consequently their nutrient intakes change. Compared with the early part of the 20th century, people now eat more sugar and less starch, more fat and less fibre, more meat and less vegetable protein and more alcohol, and often more food energy than they use up. These changes occur in all societies as they become more prosperous. Such a diet, in which 60% of food energy may come from fat and sugar, along with a sedentary life-style, appears to be less healthy than a more plain diet and contributes to the development of obesity, coronary (ischaemic) heart disease, hypertension and stroke, atherosclerosis, dental caries and some kinds of cancers.

Chapter 2. The contribution of animal products to human requirements

The contribution of animal products to world food supplies is summarized in Table 1. In total, animal products provide about one-sixth of energy supplies and one-third of protein supplies; meat is the major contributor, followed by milk and milk products. The figures for individual countries and world regions differ considerably from the world averages (Table 2). In Europe and North America, meat consumption is 30-40 times greater than in the countries of the Indian subcontinent, although the discrepancy for milk consumption is not as great.

Table 1. Contribution of various food groups to world food supplies (FAO)

Food group	Energy (%)	Protein (%)
Cereals	49	43
Roots, tubers and pulses	10	10
Nuts, oils, vegetable fats	8	4
Sugars and sugar products	9	2
Vegetables and fruits	8	7
All plant products	84	66
Meat	7	15
Eggs	1	2
Fish	1	5
Milk	5	11
Other	2	1
All animal products	16	34

Table 2. Meat and milk consumption in selected countries and world regions (kg/head/year) (FAO)

Country and region	Meat	Milk
USA	115.5	247.0
Argentina	91.1	179.5
Europe	83.1	228.7
UK	71.6	232.7
Burundi	3.7	7.8
Bangladesh	2.4	11.9
India	3.6	54.2
Sri Lanka	2.4	31.3

When the figures in the tables are translated into nutrient intakes they show, first, that over the world as a whole, foods derived from animals provide each person with about 1.9 MJ of energy and 28 g of protein per day (Table 3). These quantities are equivalent to about 16 per cent of an adult’s energy intake and 34 per cent of protein intake. In India, animal products supply only 7 per cent of man's energy intake and 15 per cent of protein, whereas in the USA the corresponding figures are 28 and 64 per cent. The most important contribution of animal products to man's requirements is that of protein. In Europe, this contribution rises from the world average figure of 28 g/day to just over 50 g/day; in Africa, it falls to slightly less than 10 g/day. For individual countries, the range is even greater, from 3.4 g/day in Burundi and Mozambique to 75.1 g/day in France.

Table 3. Contribution of animal products to human diets (FAO, 1998)

	Energy (MJ/day)			Protein (g/day)		
	Meat	Milk	Total*	Meat	Milk	Total*
World	0.87	0.59	1.90	12.6	7.0	27.6
Developed countries	1.41	1.40	3.62	25.9	17.3	55.5
Developing countries	0.72	0.37	1.41	8.8	4.2	19.7
Africa	0.30	0.29	0.74	5.6	3.6	12.5
Ghana	0.13	0.01	0.36	3.5	0.2	11.4
India	0.08	0.60	0.76	1.7	6.2	10.0
Europe	1.45	1.51	3.83	24.1	18.2	53.8
UK	1.94	1.61	4.38	26.3	19.3	54.9
USA	1.86	1.77	4.33	40.5	22.8	72.8

* includes eggs and fish

The main factor determining the intake of animal protein is the wealth of the human population, but this factor is modulated by additional factors, especially the availability of alternative sources of protein and the religious beliefs and social customs of consumers. Thus there are parts of the world, such as arctic and desert areas, where crop production is not feasible, and the human population is largely dependent on animals for a protein supply. In arctic areas, Eskimos eat fish and eat animals that also live on fish. In desert areas, nomadic people survive on the products of animals such as the camel, which can live on the sparse natural vegetation.

The consumption of pig meat is prohibited by several of the major religious groups. However, sheep meat and chicken are not commonly proscribed, except by people who choose to be vegetarians. The consumption of milk, milk products and eggs is subject to fewer religious and social restrictions, although the extreme vegetarians, known as vegans, exclude these from their diets. In many parts of the world fresh milk is not consumed by adults, who then lose the ability to secrete the digestive enzyme lactase and hence to digest lactose. They are said to be “lactose intolerant”, and if they subsequently ingest foods containing lactose it is fermented in the large intestine and causes a digestive upset.

These restrictions clearly influence global and national patterns of consumption of animal products. For example, in India, where pig meat and beef are generally not eaten, meat consumption is very low and milk, milk products and eggs supply a high proportion of animal protein intake. In the USA, which has a wealthy population whose eating habits are not so much determined by religious beliefs, both meat and milk are consumed in large amounts. Meat consumption is high also in countries with a well-developed pastoral agriculture, such as Australia and Argentina. European countries follow close behind.

Within the world’s poorer, developing countries, there is a close relationship between social class and the consumption of animal products, with the consumption patterns of richer people approaching those of the developed countries. In the developed countries, however, this relationship is much less marked, as even poorer people can afford meat and milk products. The type of meat consumed may vary between social classes, however, with richer people eating more steaks and fewer hamburgers, hence more protein and less fat. Milk consumption shows no systematic change with social class.

In developed countries, the patterns of consumption of animal products are liable to become even more confused by the growing awareness of consumers of moral objections to, and possible health risks from, such foods. Beside vegetarians there are additional categories of people who claim to eat only a little meat, or to eat only “white” meats (chicken and pork) and not “red” meat (beef). Others reject the white meats because they dislike the intensive farming methods used to produce them. The increasing ratio of alternative and free range farming systems can offer alternative for those people.

Concern for human health, which is discussed later, centres on the avoidance of the saturated fats found in many animal products.

Consumer preference for animal products may be partly based on their supposed superior nutritional value, but is probably more strongly determined by their organoleptic characteristics (i.e. their taste and texture). Wholly vegetable diets tend to be bland and unexciting, and meat and the other animal products are used to add variety. Improved methods of preservation of animal products, such as refrigeration, heat processing and canning or vacuum sealing, have made it easier for people to enjoy a continuous supply of these products.

The phrase “need or desire animal products” introduces the question of their essentiality in human nutrition. Do we really need these foods or do we just like or prefer them? The continuing successful existence of the vegetarians, and - more particularly - the vegans, among us demonstrates the non-essentiality of animal products for man; all the nutrients required by man can be met by foods not of animal origin. There are, however, several major nutritional advantages in meeting man's requirements partly from animal, rather than entirely from plant, sources. The first is that animal products supply nutrients in proportions closer to those required by man. Thus animal proteins are valuable for supplementing the proteins of staple foods such as cereals by supplying lysine and other essential amino acids, and this is particularly important for growing children, for whom amino acid requirements are most critical. If lysine requirements have to be met with cereal proteins, protein intake has to be high and much of it is wasted.

There is one essential nutrient, vitamin B12, which is synthesised by gut microorganisms and also present in animal products but virtually absent from plant-derived foods. Animal products are also good sources of other vitamins, especially vitamin A, thiamin, riboflavin and niacin.

Another advantage of animal-derived foods for man is that their nutrients are more digestible than those of plant-derived foods. Plant cell walls impede digestion in the stomach and small intestine and, although they may be digested in the large intestine, the consequent release of nutrients may be too late to allow efficient absorption. Some minerals in plant tissues are bound in compounds that resist digestion, an example being phosphorus in phytates. Animal products are good sources of the minerals such as iron, copper and zinc.

1. Ethical and environmental objections to the use of animal products

The primary argument, in brief, is that man has no right to exploit other animal species. The objections to using animals are lessened if they are not killed (i.e. kept for milk or egg production), and increased if they are kept under unnatural and perhaps stressful conditions. A second type of ethical argument is that plant-derived foods should not be diverted to animal feeding when they could be used directly to feed human populations that may be short of food. In developed countries, other than those with a predominantly pastoral agriculture, around 70 per cent of the cereals grown are used to feed livestock, and even in developing countries (including those with food shortages) considerable areas of land are used to grow crops for animal feeding. Over the world as a whole, cereal usage as animal feed amounts to 115 kg per person per year; the range across countries is from 4 kg in India and sub-Saharan Africa to 600 kg in the USA.

Objections to the use of animals to provide human food are also made on environmental grounds. Over-grazing can destroy plant communities; demand for additional grazing can cause deforestation; the excreta of intensively kept livestock cause environmental pollution problems; methane emission from ruminants contributes to global warming.

The direct, nutritional objections to animal-derived foods arise mainly from two sources. First, farm animals may harbour organisms such as pathogenic bacteria and intestinal parasites that may be transmissible to man through the consumption of animal products. Second, some of the supposedly valuable nutrients in animal products - fats, in particular - have been implicated in the causation of certain diseases of man.

Chapter 3. Characteristics of foods of animal origin

1. Meats and meat products

The composition of all meats is dependent on the ratio of fat to lean, which determines the energy value and the concentrations of virtually all nutrients, because the nutrients are present in different concentrations in the fat and the lean. It is consequently difficult to give a mean or typical value for meats as a whole without specifying the fat: lean ratio. At the present time the nutritional advice to reduce saturated fatty acid intake has intensified consumer demand for leaner retail cuts of meats, and this demand is reflected back to the producer in a demand for leaner carcass, because the fat has increasingly less commercial value. Most countries operate grading schemes for carcass which determine the payments to producer: these have usually been based on carcass composition and fat content, and have discriminated against very fat and very lean carcass. There is pressure from nutritional and public health bodies to make these grading schemes more responsive to nutritional and medical opinion, which means that in future, as a result of breeding and selection to reduce the fat in carcass, one should expect the fat to lean ratio to fall.

This has important nutritional implications for those involved in dietary surveys because it makes it more difficult to estimate the fat intake from meats unless the lean and fat are measured separately, or the fat to lean ratio is estimated. This is possible, but not easy, with meats served as such, but the same caveats apply to meat products, where unless the product carries a nutritional label, the fat content can vary widely.

Table 4. gives the compositions of the separable lean and fat of the more important meats. However, the separation was made by home-type procedures, not by careful dissection. The table shows that the lean of the three major carcass meats is similar in gross composition, which should not be unexpected because they are in effect mammalian muscle; the poultry muscles have less intramuscular fat and most of the fat is associated with the skin, although it is not subcutaneous as seen in mammals.

The ratio of lean to fat varies between the different retail cuts of meat, depending on the anatomical position of the cut and also on the extent to which the joint has been trimmed.

In the case of beef the leanest cuts were silverside and rump steak, and the fattest forerib; for lamb they were leg and chops, and for pork, leg and belly respectively.

Information on the composition of the less common meats and those eaten in the developing countries is very much less extensive, but some examples for the proximate composition of a selection are given in Table 5. with the caveat that the fat to lean ratios will also vary in these species.

Table 4. Typical composition of some raw meats (g/100 g)

Meat	Separable components	Water (g)	Protein (g)	Fat (g)	Energy (kJ)
Beef	Lean	74.0	20.3	4.6	515
	Fat	24.0	8.8	66.9	2,665
Lamb	Lean	70.1	20.8	8.8	678
	Fat	21.2	6.2	71.8	2,807
Pork	Lean	71.5	20.7	7.1	625
	Fat	21.1	6.8	71.4	2,803
Veal fillet		74.9	21.1	2.7	456
Chicken meat		74.4	20.5	4.3	506
meat and skin		64.4	17.6	17.7	962
Turkey meat		75.5	21.9	2.2	448
meat and skin		72.0	20.6	6.9	607

Table 5. shows that it is possible to make some generalizations about meats. First, as one would expect, the water content declines as the fat increases; second, the protein contents are around 20% in most fresh meats; and third, the fat content of wild animals is usually lower than comparable domesticated species. Domesticated species have been selected for growth rate, and until recently the ideal animal was a fat one; the use of the terms

“fatstock prices” in the marketing of animals, and “fattening livestock” during finishing reflects this preference. In mediaeval times fat breeding stock had advantages in maintaining condition over the winter, and even now, the survival of hill cattle and sheep under extreme conditions may depend on an adequate covering of subcutaneous fat. The fat content of retail joint is an important factor in the development of flavour during cooking, and there is a widely held view in the meat trade that adequate fat levels are required to produce acceptable eating quality.

The composition of the organs which are collectively described as offal shows much smaller variations; kidneys and hearts often have adhering fat, but the organs themselves have characteristic compositions and more constant lean to fat ratios. Table 6. gives the ranges of compositions for heart, kidney and liver in the major meat-producing farm animal species. These values are for trimmed organs taken from young animals; the fat content of the heart of matured animals may be over 17 g/100 g. Brain is exceptional in having a fat content of the same order as protein; in brain, however, a large proportion of the fat is made up of complex phospholipids and glycolipids. Brain tissues contain high ratio of polyunsaturated fatty acids, among them docosahexaenoic acid (DHA), which is an important m-3 fatty acid and plays an important role in different brain functions.

Table 5. Composition of some other raw meats (g/100 g)

Meat	Energy (kJ)	Water (g)	Protein (g)	Fat (g)
Camel	1117	59.1	19.6	20.3
Frog	285	83.6	15.3	0.3
Goat				
lean	749	69.2	18.0	11.3
medium	1494	51.6	15.2	32.4
Hare	480	75.0	21.5	3.1
Horse	713	70.0	19.0	10.0
Moose, lean	420	76.0	22.0	1.2
Rabbit	529	74.6	22.2	4.0
Reindeer	490	74.0	21.0	3.6
Roe deer	500	74.0	21.0	4.0
Snake	393	75.0	14.4	3.3
Water buffalo	502	76.5	17.7	4.9

The very wide range of meat products available is a testimony to human ingenuity in using as much as possible of the whole animal. It is therefore impossible to make generalizations about their proximate composition. Many contain substantial concentrations of fat but this is very variable, and there is a tendency for the cheaper products to contain more fat and connective tissue because these are cheaper ingredients than steak. Meat products often contain cereals as technological additives, and statistics on meat consumption are very slightly distorted if the amounts of meat products eaten are taken as being entirely meat.

Table 6. Ranges of composition in organs (g/100g raw tissue)

	Heart	Kidney	Liver
Energy (kJ)	363-629	363-380	567-683
Water	73.2-79.2	78.8-79.8	67.3-72.9
Protein	15.2-17.1	15.7-16.5	19.1-21.3
Fat	2.6-9.3	2.6-2.7	6.3-10.3

2. Nutrients in meat and meat products

Meats are conventionally acceptable as protein foods, and this is true for the lean, which contains substantial amounts of high biological value protein. The amino acid composition shows that when compared with the amino acid requirements of man, and the ideal reference protein, the balance of amino acids is very close to the reference. The concept of first-class proteins has, however, been superseded as information on amino acid composition has become available. The major proteins of connective tissue, collagen and elastin, have imbalanced and inadequate amino acid compositions and will not support growth.

Meats as a whole are important sources of fat in the diet. A range of different classes of lipids are present in animal tissues: triglycerides, which form the fat stores in adipose tissues in subcutaneous fat; the abdominal fats surrounding kidney and the intestines, and marbling fats between the muscle blocks; phospholipids within cell membranes and nervous tissues; glycolipids in brain and other neural tissues; and lipoproteins in many tissues. In lean tissues that have been carefully dissected the major lipids are phospholipids the triglycerides are the most abundant and the fat in meat is principally triglyceride.

The fatty acid composition of the fat in meats depends on whether or not the species is a ruminant. The fat in non-ruminants is mainly dependent on the fatty acid composition of the fats in the animal's diet, whereas that of the ruminant is affected by the activities of the microflora in the rumen, which hydrogenate much of the ingested fat, so that the fats of ruminant animals are usually highly saturated. This is illustrated in Table 7., which also shows that liver lipids are less saturated than the fat in the animal as a whole because they contain phospholipids in their cell membranes. The fats of wild ruminants also appear to be less saturated, because the fat contents are lower and the phospholipids consequently form a greater proportion of the total.

Table 7. Fatty acid composition of some meats (g/100 g total fatty acids)

	Saturated						Monounsaturated					Polyunsaturated						
	14:0	15:0	16:0	17:0	18:0	total	16:1	17:1	18:1	20:1	total	18:2	18:3	20:3	20:4	20:5	22:5	total
Beef	3.2	0.6	26.9	1.2	13.0	(44.9)	6.3	1.0	42.0	tr	(49.4)	2.0	1.3	tr	1.0	tr	tr	(4.3)
Lamb	5.4	0.6	24.2	1.0	20.9	(52.1)	1.3	1.0	38.2	tr	(40.5)	2.5	2.5	0	0	tr	tr	(5.0)
Pork*	1.6	tr	27.1	tr	13.8	(42.5)	3.4	tr	43.8	0.7	(47.9)	7.4	0.9	0	tr	tr	tr	(8.3)
Chicken*	1.3	tr	26.7	tr	7.1	(35.1)	7.2	tr	39.8	0.6	(47.6)	13.5	0.7	tr	0.7		tr	(14.9)
Turkey	1.0	tr	25.0	0.5	10.0	(36.5)	5.0	tr	21.5	0.4	(26.9)	20.0	1.0	tr	5.0	1.5	2.0	(29.5)
Calf liver	0.8	tr	16.5	0.6	23.3	(41.2)	1.9	0.7	20.8	tr	(23.4)	15.0	1.4	2.1	9.0	0.3	4.0	(16.8)
Lamb liver	1.3	0.5	20.4	1.0	18.3	(41.5)	3.5	1.6	29.7	0	(34.8)	5.0	3.8	0.6	5.1	0	3.0	(17.5)

tr = trace

* = depends on diet fed

Meats also contain a range of inorganic constituents; they are relatively low in sodium and calcium, and high in potassium, phosphorus and magnesium. However it is the amount of essential micronutrients they provide that is of nutritional importance; iron levels are high in meats that have not been bled out at slaughter, and in blood products; zinc, copper and several other trace elements are present in meat. The inorganic constituents are mostly found in the lean portion, so concentrations are lower in high-fat meats. One very important nutritional characteristic of meats is the high bioavailability of the inorganic nutrients they contain.

Meats contain most of the B-vitamins and they are especially important as a source of vitamin B_{12}. The fat-soluble vitamins are present in the fat, the concentrations being highly dependent on the diet eaten by the animal. Vitamin A is stored in the liver, and very high concentrations can be seen in animals given vitamin A supplemented rations.

3. Nutritional role of meats and meat products

In the developed countries meat consumption is substantially higher than in the less developed ones, where plant products and the carbohydrates they supply provide up to 80% of the total energy intake, and the major protein sources are plants. Meat is not an essential component of the diet and societies that have adopted vegetarian diets for religious or other reasons do not show evidence of malnutrition when the supply of total food is adequate.

Meat provides 16% of the energy, 30% of the protein and 26% of the fat. In food purchased for the home, poultry is the most important single type of meat, but the total usage of carcass meats greatly exceeds poultry. Meat products account for nearly half of total meat consumption, with bacon and ham making up about a quarter of this. Meat fat provides about 23% of saturated fatty acid intake, and is less important than separated fats and dairy products in this respect; it also provides 16% of the polyunsaturated fatty acid intake. Meat is an important source of highly bioavailable inorganic nutrients, and provides 26% of the zinc, 29% of the copper, 15-25% of the selenium and 24% of the iron intakes. In the case of the vitamins, meat provides 55% of B_{12}, 36% of vitamin A, 26% of niacin, 23% of B_6, 18% of riboflavin and 14% of thiamin intakes.

Chapter 4. Fish and other seafoods

Fish and a wide variety of other seafoods have always been important in the diets of communities living close to the sea, rivers and lakes. The development of refrigerated transport first, and then that of on-board refrigeration on fishing vessels, has both improved the quality and shelf-life of fish and made it more available to populations distant from water. The development of attractive processed products has also been instrumental in widening fish consumption. Although fishcatches worldwide are increasing fish stocks in some waters are declining due to overfishing, and much of the fish caught is manufactured into animal feeds. Fish are unusual for a major a commodity because, with the exception of farmed trout and salmon, they are wild creatures that have to be located and taken from their natural environment - they are in fact one of the few animal foods that are hunted.

A very large number of species of fish are taken for food by the world's population as a whole.

Although there are still some fish caught in coastal waters, most fishing is done from deep-sea trawlers which either have on-board processing and refrigeration or are accompanied by factory ships that process the catch at sea. In all vessels the fish are cooled as quickly as possible after catching, in order to minimize postmortem deterioration. Fish are an unstable commodity, and among the early products of spoilage are trimethylamine and ammonia, which reduce consumer acceptability.

1. Composition of fish

There are three main categories of fish used as foods; the bony fishes, fall into two compositional groups, white fish such as cod, haddock, halibut, lemon sole, plaice (and most other flat fish), saithe, zander, catfish, bream, pike and whiting; and fatty fish such as eels, herring, pilchards, salmon, sardines, sprats, trout, tuna, carp, asp and whitebait. In South-East Asia Asian cichlid plays an important role as an animal protein source. The importance of tilapia is also increasing worldwide. The third category contains the cartilaginous Elasmobranch fish, such as dogfish, shark and skate.

1.1. White fish

The flesh of these fish is very low in fat and consists primarily of muscle blocks surrounded by thin sheets of connective tissue. The concentrations of most of the B-vitamins are lower than in mammalian muscle, with the possible exception of vitamin B_6. The mineral levels are similar, although the very fine bones in fish are often eaten with the flesh, raising the calcium content slightly but significantly. Fish, in common with most marine organisms, accumulate trace elements from seawater and are a rich source of iodine and, less fortunately, of toxic metal contamination if taken from heavily polluted waters. These fish accumulate fats, or more correctly oils, in their livers, which are a rich source of vitamins A and D, and long-chain polyunsaturated fatty acids in their triglycerides.

1.2. Fatty fish

These fish have fat in their flesh, which is usually much darker with similar blocks of muscle interspersed with connective tissue. The amount of fat is related to the breeding cycle of the fish, and after breeding the fat content falls considerably. Thus herring may have only 5% of fat from February to April, rising to 20% from July to October. Herring are normally fished in the seasons when they are fat, so that the typical value for fat in herrings as purchased is around 19%. The flesh of the fatty fish is usually richer in the B-vitamins than white fish, and there are significant amounts of vitamins A and D present. The mineral concentrations are not markedly different. The fat of these fish is particularly rich in very long-chain polyunsaturated fatty acids and thus very prone to develop rancidity, which may be one reason why many of these fish are traditionally smoked or pickled to preserve them.

1.3. Cartilaginous fish

These fish are almost exclusively marine and include the sharks and rays, which are among the most successful of all fish in their mastery of the seas. The flesh of these fish is relatively low in fat, although they do accumulate oils in their livers; compositionally the concentrations of the vitamins and minerals are very similar to those in white fish. These fish are remarkable in that they maintain the osmolality of their extracellular fluids by increasing the urea content, so that protein values based on total nitrogen values are substantially overestimated.

Table 8. gives some representative values for the composition of a range of fish, showing that within the major groups there is considerable similarity.

2. Invertebrate seafoods

The species popularly known as shellfish include species from two major and distinctive phyla, the Mollusca, the true shellfish and the Arthropoda, order Crustacea, which includes crabs, shrimps, prawns and lobsters.

2.1. Molluscs

A wide range of molluscs is eaten by man, including bivalves such as mussels, oysters and scallops, gastropods such as winkles and whelks, and molluscs that have lost their external shells but retain an inner pen - the squids and octopuses. The true shelled molluscs are often eaten whole after boiling, and sometimes raw. The flesh is very muscular, with low levels of fat, the mineral levels are usually higher than in true fish, and the vitamin levels are low.

Molluscs are generally filter feeders and accumulate trace elements, both essential and contaminant, from the seawater. They are also very prone to contamination from pathogenic organisms in the water, and most countries have regulations about the sites where molluscs can be taken, and some require the animals to be “rested” in unpolluted water for a period before sale. Usually only the muscular mantles of squids and octopuses are eaten, after cooking.

2.2. Crustacea

These include a range of species, both freshwater crayfish - and marine - crabs, shrimps, prawns and lobsters. These animals are characterized by tough exoskeletons composed of chitin and protein; the parts eaten are the muscular pans of the thorax and the muscles of the specialized appendages: the claws of crabs and lobsters. The animals may be trapped from the wild but techniques for farming them are under development, because in some communities they are gastronomically very highly valued.

The flesh is characteristically low in fat and high in minerals, especially sodium from marine species. The animals also accumulate trace elements from the water, and the vitamin levels are similar to those in white fish.

3. Nutrients in fish

The major part of fish eaten as food, both the true fish and the molluscs and crustacea, is a muscle, and fish are quite properly seen as important sources of good-quality protein, weight-for-weight providing similar amounts to lean meats. The amino acid composition of the proteins in most fishes is very similar, and although the molluscan and crustacean proteins are distinctive they are all rich sources of essential amino acids (Table 9.).

The protein is accompanied by very low amounts of fat in white fish, crustacea and molluscs, and the fat from fish as a whole is characterized by the high proportion of long-chain polyunsaturated fatty acids. Table 10. provides a selection of values that illustrate the fatty acid composition of a number of fats from fish compared with typical values for carcass meat.

Table 8. Composition of some fish, molluscs and crustaceans (g/100 g raw tissue)

Meat	Energy (kJ)	Water (g)	Protein (g)	Fat (g)
White fish				
cod	322	82.0	17.4	0.7
haddock	308	81.3	16.8	0.6
halibut	390	78.1	17.7	2.4
lemon sole	343	81.2	17.1	1.4
plaice	386	79.5	17.9	2.2
catfish	376	78.1	16.1	2.7
carp	481	77.8	18.0	4.2
bream	430	78.0	16.7	4.0
perch	355	81.0	18.1	1.3
pike	343	80.0	18.4	0.7
Fatty fish				
eel	700	71.3	16.6	11.3
herring	970	63.9	16.8	18.5
mackerel	926	64.0	19.0	16.3
salmon	761	65.4	18.8	12.0
trout, rainbow	670	71.0	18.6	9.6
tuna	770	65.0	24.2	9.9
Cartilaginous fish				
dogfish	653	72.3	17.6	9.9
shark	418	77.0	20.6	1.3
skate	410	77.8	21.5	0.7
Molluscs				
abalone	410	75.8	18.7	0.5
clam	343	80.8	14.0	1.9
cockle	339	79.9	16.8	1.0
mussel	397	78.6	14.4	2.2
oyster	176	84.6	8.4	1.8
scallop	339	79.8	15.3	0.2
whelk	289	83.6	11.6	0.6
cuttlefish	339	81.0	16.1	0.9
octopus	305	82.2	15.3	0.8
squid	314	82.0	15.3	0.8
Crustaceans				
crab	418	76.8	17.9	2.0
crayfish	285	82.0	14.6	0.5
lobster	365	79.0	16.9	1.9
shrimp	365	79.0	18.1	0.8

The concentrations of the inorganic nutrients in fish are not particularly unusual when compared with meats, with the exception of calcium in fish with fine bones, such as herring, where the bones are eaten with the flesh. The levels of sodium are higher in marine species, and the levels of the intercellular elements potassium and phosphorus are higher than in meats.

The iron and zinc levels tend to be lower, except for the shellfish, which tend to accumulate trace elements, so that oysters have the distinction of being one of the richest sources of zinc eaten, with levels of up to 100 mg/100 g being recorded. Fish are a major source of iodine, again being accumulated from their environment.

Table 9. Amino acid composition of some animal products (mg/g total N)

Amino acids	Fish	Crustacea	Molluscs	Beef	Milk	Egg	Wheat
Essential							
histidine	180	120	150	230	190	150	130
isoleucine	330	290	300	320	350	350	210
leucine	530	540	480	500	640	520	420
lysine	610	490	500	570	510	390	150
methionine	180	180	170	170	180	200	100
phenylalanine	260	250	260	280	340	320	280
threonine	300	290	290	290	310	320	170
tryptophan	70	70	80	80	90	110	70
valine	360	300	390	330	460	470	280
Nonessential							
arginine	400	520	470	420	250	380	290
alanine	430	420	350	440	240	340	230
aspartic acid	650	680	700	600	530	670	310
cystine	70	80	100	80	60	110	160
glutamic acid	950	980	880	1080	1440	750	1710
glycine	290	410	320	350	140	190	250
proline	260	270	260	320	590	240	660
serine	310	320	320	280	370	490	330
tyrosine	220	230	260	240	280	250	190

4. Nutritional role of fish

The consumption of fish in Hungary is relatively low compared with countries such as Spain, Portugal and Italy. It is true that these countries have access to a wider range of species, and the dietary culture in these countries is probably more dependent on fresh foods. Consumption appears to have increased very slightly over recent years, but over the longer term has remained relatively low.

Table 10. Fatty acid composition of the lipids of some fish compared with other foods (% of total fatty acid content)

	Fatty acid	Cod	Herring	Beef	Milk	Corn
Saturated	C16:0	21.5	13.7	26.9	26.0	14.0
	C18:0	3.5	1.2	13.0	11.2	2.3
	Others	1.1	7.4	5.0	26.0	0.9
Monounsaturated	C16:1	2.3	10.0	6.3	2.7	0.3
	C18:1	11.0	15.2	42.0	27.8	30.0
	C20:1	1.8	13.2	-	-	0.2
	C22:1	0.8	17.4	-	-	0.2
	Others	-	-	2.5	3.2	-
Polyunsaturated	C18:2	0.5	1.4	2.0	1.4	50.0
	C18:3	0.1	1.2	1.3	1.5	1.6
	C18:4	0.2	1.8	-	-	-
	C20:4	3.9	0.6	1.0	-	-
	C20:5	17.2	7.0	-	-	-
	C22:5	1.5	1.1	-	-	-
	C22:6	33.4	6.5	-	-	-

Chapter 5. Eggs

The eggs of a range of avian species are eaten in many human cultures, and although in some cultures eggs are proscribed for women, in most they form a common, if not important, part of the diet.

Most hens' eggs are produced intensively under battery conditions, although there is a growing demand for eggs produced under less intensive systems, such as deep-litter where the hens are enclosed in a controlled environment, sometimes known as “barn” eggs; or range eggs, where the hens are allowed access to open space to forage, although they are fed specially formulated rations. True free-range production, where the hens are not confined and range freely in search of food, is seen as the ideal by many animal welfare organizations, but such systems are not common. Detailed comparisons of the composition of eggs produced by the different systems show no nutritionally significant differences. Differences in yolk colour can be seen when free-range hens have access to green fodder, where the carotenoids pass into the yolk; natural and synthetic pigments are commonly incorporated into the rations fed to battery hens to produce acceptable yolk colours. The white of freshly laid eggs has better functional properties, for example when whipped to produce foam. This property deteriorates when the egg is stored, as is common in the production and distribution of battery eggs; it is not, however, a direct effect of the system.

1. Composition of eggs

Some typical values for the composition of different eggs are given in Table 11., which shows a remarkable similarity between the eggs of different avian species.

The proteins of eggs contain the amino acids essential for the complete development of the embryo, and for this reason egg protein was seen as having the perfect amino acid composition; the reference protein for biological evaluation and assessing amino acid patterns was, for a considerable period, egg protein. It is now recognized that it is perfect for the chicken, but not necessarily for other species, and other amino acid compositions are now seen as ideal for humans.

The lipids in eggs are rich in phospholipids and the fatty acid composition shows quite a high polyunsaturated to saturated (P/S) ratio. Cholesterol is present in the egg lipid, where it forms a key precursor for membrane synthesis in the chick. It is possible to manipulate the cholesterol content of the egg by dietary means, but it is not yet clears whether this is a useful or stable change. The eggs contain the range of minerals and vitamins necessary for the development of the chick, and thus eggs are a valuable food. The iron in eggs has been shown to have a low bioavailability, possibly because it is bound to the egg proteins. Egg white contains the protein avidin, which bound biotin and makes it unavailable to man; cooking the egg denatures the avidin and abolishes the effect.

2. Nutritional role of eggs

Eggs provide a versatile food of high biological value. They can be produced efficiently and relatively cheaply and many developing countries have established egg production as a means of improving the supply of animal protein. In the developed world the focus on cholesterol in the diet as a potential risk factor for coronary heart disease has led to a fall in egg consumption and, although the climate of opinion regarding the effects of dietary cholesterol on blood levels has changed, a negative view is still taken by many consumers of the cholesterol levels in eggs.

Table 11. Composition of eggs of different species (per 100 g)

	Hen	Duck	Pigeon	Quail	Goose	Turkey
Water (g)	74.8	70.6	79.8	73.7	70.4	72.2
Energy (kJ)	615	787	485	674	774	715
Protein (g)	11.8	13.2	10.7	13.1	13.9	13.1
Fat (g)	9.6	14.2	7.0	12.1	13.9	12.1
Calcium (mg)	52	64	62	49	56	49
Iron (mg)	2.0	3.6	3.5	4.1	2.8	4.1
Retinol (μg)	140	370	95	-	-	-
Vitamin D (μg)	1.75	-	-	-	-	-
Thiamin (mg)	0.09	0.16	0.13	-	0.18	0.11
Riboflavin (mg)	0.47	0.40	0.65	-	0.36	0.47

Chapter 6. Animal fats

Butter

The most important fat from animal sources is butter obtained by churning cream or milk vigorously enough to break the emulsion and to separate the fat as a mass; the buttermilk is drained off and the mass washed and then salted. The butter is then worked to distribute the salt and moulded prior to division into packs for retail sale. The amount of salt added varies greatly, depending primarily on the market for which it is intended. Current nutritional concerns about the levels of salt in the diet have made unsalted butter more popular.

Butter contains water, small amounts of protein, added salt and vitamins A and D. The main aspect of composition of nutritional importance is the fatty acid composition of the different fats.

Lard

Lard is fat that has been rendered (heated, liquefied and strained) from adipose tissues trimmed from pork carcases.

Ghee

Ghee is used in many Asian cultures; it is prepared by heating and clarifying butter.

Suet

This is obtained from the shredded adipose tissue of cattle or other ruminants, and usually contains a little protein.

1. Nutritional role of fats

Fats provide a source of energy and are the most energy-rich of the proximate nutrients, with a gross energy value of 39.3 KJ/g. The concentration of fat in a food or the diet is the major determinant of its energy density, and in circumstances where the weight of food to be carried is critical, for example in rations for an expedition, or in combat rations, a high fat content is often desirable, since the immediate risks are greater than the longer-term risks associated with high fat intakes. Fats also provide the essential fatty acids and contribute to the absorption of the fat-soluble vitamins. Fats are also important in connection with the palatability of foods. Many of the characteristic aromas associated with cooked foods are due to interactions between the lipids and the amino acids in foods. The fat in foods is also associated with satiety, by mechanisms that are not clearly understood, but which may be related to the effects of fats on gastric emptying and interactions with gastrointestinal hormones.

The links between fat and the palatability of foods have profound nutritional implications because they act as a constraint on the adoption of nutritional advice to reduce total fat intakes. The introduction of low-fat and polyunsaturated margarines is one avenue of attack on this problem, but does not address the use of fats and oils as cooking media in frying, and as ingredients in cakes, pastries and similar foods. Here the approach may lie in the development of oils with physical characteristics that minimize their penetration into foods, or that drain rapidly from the cooked food. Other more sophisticated approaches lie in the development of fat substitutes, and one of these based on fatty acid esters of sucrose has the required organoleptic properties; it now has to meet the food safety and nutritional requirements for a fat substitute.

Chapter 7. Milk and milk products

Milk and milk products became part of the diet of adult humans when the hunter-gatherer developed into the pastoralist, and the exploitation of animals for products other than meat and skins began. Since that time the milk of many species has been used as a food and as a source of a range of products. Liquid milk is an unstable commodity and many products that evolved were fermented foods that could be stored and transported, thus extending their value. A land “flowing with milk and honey” was clearly very attractive to the tribes of Israel, and is clear evidence of the value that has been placed on milk in the diet for many thousands of years.

Milk is the secretion of the mammary gland and is the staple food for all young mammals, including human infants. The milk of all species has undergone evolutionary pressure during the development of the species, and it is reasonable to argue that the compo-sition of the milk secreted by each species is adapted in some way to the specific needs of the species in question. The milks used as human foods are therefore adapted to the needs of the young animal for which they evolved, and not man, and there are distinct differences between, for example, cows' milk and human milk that can be related to the differences in rates of growth and the ways in which maternal immunity is transferred to the young animal.

Milk in the EU context implies milk from the cow (*Bos domesticus*), with a minor but expanding contribution from goats and sheep. In the Middle East, goats and camels are the milk animals and in the Far East water buffalo are important; the Lapps consume reindeer milk. In some communities other species of cattle are used, for example in Africa Bos indicus is important, because it is resistant to many diseases that affect European breeds. The milk from the mare and the ass was important to the herdsman of the Eurasian plains.

The compositions of some milk are given in Table 12. illustrating the range of compositions that are seen.

Cows are milked by machine - usually twice a day, although improved yields can be obtained by more frequent milking, paralleling the feeding pattern of calves - and the milk is pooled and pasteurized. There is a small amount of raw milk produced without pasteurization.

Table 12. Composition of milks of different species (per 100g)

Constituent	Cow	Goat	Sheep	Camel	Buffalo	Human
Water (g)	87.8	88.9	83.0	88.8	83.3	88.2
Energy (kJ)	276	253	396	264	385	289
Protein (g)	3.2	3.1	5.4	2.0	4.1	1.3
Fat (g)	3.9	3.5	6.0	4.1	5.9	4.1
Lactose (g)	4.6	4.4	5.1	4.7	5.9	7.2
Calcium (mg)	115	100	170	94	175	34

Pasteurization is usually carried out using continuous-flow equipment giving a heat treatment of at least 72°C for 15s, which is sufficient to kill all non-sporing pathogens and non-thermoduric organisms; the resistance of spores is one reason why milk needs to be stored at refrigeration temperatures, to prevent the growth of sporing organisms. The hygienic quality of milk is still very dependent on the maintenance of hygienic production standards.

1. Milk products

Whole milk has long had a special status. The removal of the separated cream produced skimmed milk, which until recently was of little interest as a human food, and in some countries was used as an animal food. The evolution of dietary guidelines recommending the reduced consumption of saturated fatty acids radically changed this and there has been a substantial demand for both completely and semi-skimmed milks. The difference in composition of these products is illustrated in Table 13.

Table 13. Composition of some milk products (per 100 g)

	Milks					Creams	
	Semi-skimmed	Skimmed	Dried skimmed	Evaporated whole	Condensed sweetened whole	Single	Double
Water (g)	89.8	91.1	3.0	69.1	25.9	74.0	48.0
Energy (kJ)	194	140	1491	664	1390	776	1849
Protein (g)	3.3	3.3	36.0	8.2	8.5	2.6	1.7
Fat (g)	1.6	0.1	1.0	9.0	9.0	18.0	48.0
Lactose (g)	4.7	4.8	50.1	12.0	12.3	3.9	2.6
Sucrose (g)					43.2		

2. Dried, condensed and ultra-heat treated milks

Milk has high water content and is unstable, and a number of processes have been developed to reduce the water content and make the product more stable. Dried milks were originally produced by roller-drying, where the milk passed in a thin film over heated rollers; this was a rather vigorous treatment and produced flavour changes and substantial losses of vitamins. It also caused changes in colour due to the formation of Maillard reaction products between the some amino acids and lactose, which were associated with a reduction in the biological value of the proteins. Roller-drying has been largely replaced by spray-drying, where a thin spray of milk is passed into a heated chamber. This is a milder treatment that can be more closely controlled, and therefore leads to less nutritional and sensory damage. Evaporated milks have had about a third of their water removed, and are usually canned to ensure stability. Condensed milks have sucrose added. These milks can be prepared from whole or skimmed starting materials. Sterilized milk was widely used before domestic refrigeration became common, and the specific flavour produced by sterilization is still preferred by some consumers. Sterilized milk is now often prepared from ultra-heat treated milk (UHT), where the milk has been treated at 130°C for 1s. This milk has a very long storage life when packed aseptically in packs that exclude oxygen.

3. Cream

The separated fat layer of milk is used to produce a range of different types of cream, varying principally in the fat content but also in the methods used in their production, which modify their physical properties. Single cream contains about 18% fat and is usually pasteurized. Double cream contains about 48% fat, whereas whipping cream contains about 39%; both of these products may be pasteurized without it affecting their capacity to form foams. Clotted creams are produced by scalding the milk in heated pans, producing a very efficient separation of fat, and the clotted creams contain 60% fat. Some creams are ultra-heat treated to produce a long-life product. The creams also contain some of the residual aqueous phase of the milk and this contains the water-soluble nutrients in milk in the same proportions.

4. Cheese

Cheese-making from milk was one of the earliest ways of converting an unstable liquid product into a concentrated food that could be stored. It is possible that milk's capacity to undergo fermentation, and the subsequent coagulation of the protein, led to the development of cheese-making. There are a very large number of different types of cheese, which vary because of differences in the treatment of the starting material and the way in which the curd is subsequently treated and matured. In the traditional Cheddar process the milk is treated with a starter, originally rennet prepared from calf stomach, which coagulates one of the protein fractions of the milk, casein, to produce a curd; this is heated to around 30°C and the resultant mass is cut, stirred and reheated at a higher temperature (38.5°C). The cheese curd is then stacked to develop cohesion, milled, salted and pressed into moulds. The finished cheese is traditionally stored to mature and develop its characteristic flavour. The consistency of cheese can be modified by varying the starting milk, the temperature at which the curd is heated, and the efficiency with which the residual whey is expelled. Blue-veined cheeses are produced by inoculating the cheese with bacterial cultures. Because of the many variations in cheese production it is difficult to generalize about its composition. The compositions of some major types of cheeses are shown in Table 14.. The composition of two samples of the same-named cheese may differ, as much as two differently named cheeses.

Table 14. Composition of some cheeses (per 100 g)

	Camembert	Cheddar	Danish blue	Edam	Parmesan	Cottage	Processed
Water (g)	50.7	36.0	45.3	43.8	18.4	79.1	45.7
Energy (kJ)	1232	1708	1437	138 2	1880	413	1367
Protein (g)	20.9	25.5	20.1	26.0	39.4	13.8	20.8
Fat (g)	23.7	34.4	29.6	25.4	32.7	4.0	27.0

5. Fermented milks

The fermentation of milks with lactobacilli leads to the production of lactic acid from the lactose, and the fall in pH inhibits the growth of many pathogenic organisms, so that fermentation provides an early type of milk stabilization. Acidified milks have been prized foods in many cultures, and at one time it was argued that they had a value in infant feeding for encouraging the establishment of a desirable intestinal flora in young infants.

One of the most important fermented foods is yogurt, a food originating in south-east Europe and Turkey, where the milk is fermented with *Lactobacillus bulgaricus*. The acid conditions cause the milk to form a soft curd. Yogurts contain all the constituents present in the original milk, with the exception of the lactose which is substantially reduced; the organism uses the glucose moiety of the lactose preferentially, so that some residual galactose is present, making the carbohydrates of yogurt quite distinctive. Yogurt can be produced from skimmed or whole milk, and there is a large range of flavours used commercially.

6. Products based on the constituents of milk

Whole milk can be processed to produce products based on its major components, and these are also important in the diet both as foods and as food ingredients. Butter is prepared by churning milk or cream to break down the fat emulsion in milk, so that the fat separates and forms a mass that can be process into the finished butter. The nutritional aspects of butter were discussed earlier, with the other fats and oils. The major protein fraction in milk, casein, can be precipitated easily and the isolated protein finds considerable use as a food ingredient, either as the protein or as caseinates. The other major component of the aqueous whey, lactose, is difficult to isolate by chemical means but physical separation by membrane filtration or reversed osmosis is recently used on a commercial scale. Lactose has less sweetening capacity as compared with sucrose, and has limited value as a food ingredient; it has been used as a fermentation stock for the production of ethanol, but this is not really economical. Hydrogenation of lactose produces the disaccharide sugar alcohol lactitol, and this is used as a bulk sweetener because it has a lower energy value than lactose itself. Its use for this purpose has been approved in several countries.

7. Nutrients in milk and milk products

Milk is the sole food of virtually all young mammals and contains all the nutrients essential for mammalian growth.

7.1. Proteins

The major protein fraction in milk is casein, which in cows' milk is around 80% of the total. The other major proteins are lactalbumin and a range of immunoglobulins. Casein is a phosphoprotein, and the organization of the casein into micelles is responsible for the physical properties of milk. It appears to be a major factor in retaining the calcium and phosphate present in solution above concentrations that would lead to their precipitation in aqueous solution. The casein micelles are stabilized by calcium phosphates. The casein is present in milk as caseinogen, which is converted into casein by gastric enzymes.

In human milk the proportion of lactalbumin is higher and the proteins are believed to be better digested because of reduced clotting in the stomach. The immunoglobulins are responsible for the transfer of maternal immunity to the young animal in the early stages after birth, when the gastrointestinal mucosa is permeable to large molecules. In the cow some transference of immunity across the placenta also occurs, but in man the immunoglobulins of milk are believed to be very important to neonatal immunity.

7.2. Fats

The amount of fat in milk varies between different species. In ruminant milks the fat contains a significant proportion of short-chain volatile fatty acids, derived from the fermentation of carbohydrate in the rumen; this anaerobic fermentation also leads to the saturation of fatty acids in the diet, so that the fat in the milk contains only low levels of unsaturated fatty acids (Table 15.). In non-ruminants the saturation of the fat can be altered by dietary means. It is possible to feed protected fats to ruminants to increase the levels of unsaturation, but this has not proved to be economically viable because it leads to loss of condition in the cow and reduced yields.

Table 15. Fatty acid composition of cow's and human milk (fatty acids % of total fatty acids)

	4:0	6:0	8:0	10:0	12:0	14:0	16:0	18:0	14:1	16:1	18:1	18:2	18:3
Cow's milk	3.2	2.0	1.2	2.8	3.5	11.2	26.0	11.2	1.4	2.7	27.8	1.4	1.5
Human milk	0	0	tr	1.4	5.4	7.3	26.5	9.5	tr	4.0	35.4	7.2	0.88

tr = trace

7.3. Carbohydrate

Milk contains the disaccharide lactose and is the only known source of this sugar in the diet. The amounts vary in the milks of different species, the level in human milk being among the highest. Human milks also contain small amounts of other oligosaccharides, derived from lactose. The role of these oligosaccharides is not known, but they are found in the milks of some other species and may have immunological properties.

7.4. Inorganic nutrients

Some typical values for the inorganic nutrients in the milks of different species are given in Table 16., and for milk products in Table 17.. The sodium levels in milks vary over a narrow range, with that of mature (after 10 days' lactation) human milk being substantially lower than that of cow's milk. Human milk also contains lower levels of potassium, calcium, magnesium, and especially phosphorus, where the value is only 16% of that in cow's milk. The concentrations in the products are proportional to the protein concentrations, because the inorganic nutrients are principally in the aqueous phase. Hence skimmed products contain higher levels of inorganic nutrients. In cheese, the addition of sodium chloride as common salt produces very substantial increases in the sodium level, and the level of addition can vary in the same-named cheese from batch to batch.

Table 16. Inorganic constituents in milks of different species (mg/100g)

	Cow	Goat	Sheep	Human
Sodium	55	42	44	15
Potassium	140	170	120	58
Calcium	115	100	170	34
Magnesium	11	13	18	3
Phosphorus	92	90	150	15
Iron	0.06	0.12	0.03	0.07
Zinc	0.4	0.5	0.7	0.3

Table 17. Inorganic constituents of some milk products (mg/100g)

	Milk			Yoghurt	Cottage	Cheddar	Parmesan
	whole	skimmed	dried skimmed	whole	cheese	cheese	cheese
Protein (g)	3.2	3.3	36.1	5.7	13.8	25.5	39.4
Sodium	55	54	550	80	380	670	1090
Potassium	140	150	1590	280	89	77	110
Calcium	115	120	1280	200	73	720	1200
Magnesium	11	12	130	19	9	25	45
Phosphorus	92	94	970	170	160	490	810
Iron	0.06	0.06	0.27	0.1	0.1	0.3	1.1
Zinc	0.4	0.4	4.0	0.7	0.6	2.3	5.3

7.5. Vitamins

Milks contain both fat-soluble and water-soluble vitamins (Table 18.). The concentrations of fat-soluble vitamins are dependent on the type of feeding the animals are receiving, and are usually higher in the summer months when the animals are grazing and lower in the winter when they are fed concentrates. The levels are broadly proportional to the fat content in both milks and milk products, because these vitamins are essentially stable during the processing of milk. Skimmed milks are consequently low in the fat-soluble vitamins, and many proprietary products using skimmed milks are fortified with a vitamin mix. Milks are a good source of the B-vitamins, but riboflavin levels decline on storage if the milk is exposed to sunlight or fluorescent lighting. Some losses of thiamin occur on pasteurization, and these losses are higher in sterilized and UHT milks, which also show losses of B_5, B_{12} and folates. Raw milk contains significant amounts of vitamin C but substantial losses occur on storage and following heat processing.

Table 18. Vitamins in some milks and milk products (per 100 g)

	Milks		Creams		Cheeses	
	Whole	Skimmed	Single	Double	Edam	Cheddar
Fat (g)	3.9	0.1	18.0	48.0	26.0	34.4
Retinol (μg)	52	1	315	600	175	325
Carotene (μg)	21	tr	125	325	150	225
Vitamin D (μg)	0.03	tr	0.14	0.27	-	0.26
Vitamin E (mg)	0.09	tr	0.40	1.10	0.48	0.53
Thiamin (mg)	0.03	0.04	0.04	0.02	0.03	0.03
Riboflavin (mg)	0.17	0.17	0.17	0.18	0.35	0.40
Vitamin B_6 (mg)	0.06	0.06	0.05	0.03	0.09	0.10
Vitamin B_{12} (μg)	0.4	0.4	0.3	0.2	2.1	1.1
Folates (μg)	6	5	7	7	40	33

8. Nutritional role of milk and milk products

The nutritional composition of milk and its products clearly demonstrates the fact that these are excellent sources of many nutrients. The milk proteins are of high biological value, and their high lysine content means that when consumed with cereals there is a substantial supplementation between the two sources of protein. The heat processing of milk leads to some loss of biological value, and this often correlates well with the proportion of lysine that has become unavailable because of interaction with carbohydrate. Milk and its products are important as sources of inorganic nutrients, especially calcium, and of vitamins.

The current nutritional advice to reduce the consumption of total fat, and especially saturated fatty acids, has focused considerable attention on the fat in dairy products which, as mentioned earlier, is low in unsaturated fatty acids. This has led to a decline in the consumption of dairy products in some sectors of the population, and to an increase in the consumption of skimmed or semi-skimmed products. It is important that the major role of milk in the provision of nutrients such as calcium and riboflavin is not prejudiced by the improper interpretation of nutritional guidance, which recommends a modest reduction in fat intake, not total abstinence. This caveat is particularly important where the diet of children is concerned, where milk and its products are valuable components.

Milk and its products are not without adverse effects in some individuals. Allergic reactions to milk proteins are one of the most common forms of food intolerance in infants, with antibodies to milk proteins frequently being demonstrable. In these infants the use of a soya milk preparation is necessary, although goats' milk appears to be less allergenic. In these infants with the inherited disorder galactosaemia cannot metabolize galactose effectively, and since the consumption of galactose will lead to cataract formation all lactose-containing foods must be excluded.

The production of cheese leads to the release of free amino acids into the product and the conversion of some of these to amines; the presence of tyramine can stimulate the sympathetic nervous system and is believed to be associated with migraine in susceptible people; patients receiving monoamine oxidase inhibitory drugs must also avoid the consumption of this amine, and therefore cheeses.

Chapter 8. Animal products and human health

The food-borne diseases of man that arise from farm animals form a relatively small - but nevertheless important - group and are summarised in Table 19. The infection of man with these diseases can be minimised by various means, the first of which involves their restriction in, or elimination from, animals. One example is the regular use of anthelmintics to restrict intestinal parasites, and another is the slaughter of infected stock to restrict or eradicate bovine tuberculosis. The pasteurisation (heat treatment) of milk is designed to kill tuberculosis bacilli and other bacteria. Attention to hygiene in slaughterhouses and food stores, and appropriate cooking of meat, are also important in the control of zoonoses.

Table 19. Some important diseases transmissible in food from farm animals to man

Disease	Causative organism	Farm animals involved
Bacteria		
Brucellosis	*Brucella abortus*	Cattle
	B. melitensis	Goats, sheep
Campilobacter enteritis	*Campylobacter* spp.	All farm animals
Clostridial disease	*Clostridium botulinum*	Domestic animals
	C. perfringens	
Coliform infections	*Escherichia coli*	Poultry, pigs and cattle
Listeriosis	*Listeria monocytogenes*	All farm animals
Salmonellosis	*Salmonella* spp.	Poultry, pigs, cattle, horses
Tuberculosis	*Mycobacterium bovis*	Cattle
Protozoa		
Sarcocystosis	*Sarcocystis suihominis*	Pigs and cattle
Cryptosporidiosis	*Cryptosporidium parvum*	Cattle
Cestodes, trematodes and nematodes		
Fascioliasis	*Fasciola hepatica*	Cattle and sheep
Tapeworms	*Echinococcus and Taenia spp.*	Cattle, sheep and pigs
Trichinosis	*Trichinella spiralis*	Pigs

Antibiotics in feeds have been used in intensive livestock systems to restrict infections, but their routine administration is recently prohibited or discouraged because of the danger of producing antibiotic-resistant organisms.

Of the diseases listed, those regarded today as being the most important in developed countries are the enteric infections from *Campylobacter, E. coli and Salmonella* spp. . Although cases of `food poisoning' have always occurred, people today are now less tolerant of them, both mentally and perhaps physically.

It is the possible zoonosis arising from bovine spongiform encephalopathy (BSE). There is no evidence that the transmissible spongiform encephalopathies of man are acquired from animals, but the occurrence of so-called new variant Creutzfeld-Jacob disease in man that has coincided with an epidemic of “mad cow disease” in cattle and related species has inevitably cast doubt on this statement and has led to the introduction of special control.

The main chemical constituents of animal products that are implicated in diseases of man are fats in general and saturated fatty acids in particular. The diseases with which they are associated are those of the circulatory system that are characterised by damage to the arterial walls (atherogenesis) and the formation of blood clots (thrombogenesis). When arteries are damaged, fibrous plaques containing lipids are formed, and these may form clots. If clots form in the blood vessels and impede the blood supply to the heart muscle they cause what is commonly called coronary heart disease (CHD); if they block the continuous blood flow in vessels supplying the brain it causes “stroke”; if they block the blood blow in vessels of the lungs it causes pulmonary embolism. These conditions are frequently fatal, and if the victim survives, afterwards may be severely handicapped. Similar conditions can be caused by the rupture of damaged blood vessels.

The link between fatty deposits in the circulatory system and dietary fats is the lipid transport system that employs lipoproteins. The lipoproteins occur in various forms, which are defined by their density and the concentrations of these forms in blood are used to assess the risk of heart attacks and strokes. High risk factors are high concentrations of low-density lipoproteins (LDL) and very low-density lipoproteins (VLDL).

Conversely, high concentrations of high-density lipoproteins (HDL) indicate a low risk. A high concentration of blood cholesterol, which is a constituent of lipoproteins, is also regarded as a high-risk indicator. The significance of these indicators is a matter of continuing research and debate, but recently generally acceptable that the sum of LDL and VLDL and their cholesterol content is the main atherogenic marker.

As mentioned earlier, it is the saturated fatty acids (SFA) of foods that are regarded as the cause of a high-risk pattern of blood lipoproteins; octadecanoic (stearic, C_{18}), tetradecanoic (myristic, C_{14}) and any *trans* acids are considered to be the most damaging. With increasing consumption of SFA, blood levels of cholesterol and LDL are raised. Conversely, the polyunsaturated fatty acids (PUFA) are judged to be beneficial, although the various families of PUFA differ in their effects; the omega-6 (n-6) PUFA (which occur mainly in plant lipids) reduce the blood concentration of LDL, and the omega-3 (n-3) PUFA (from fish lipids) reduce VLDL. In between the SFA and PUFA are the monounsaturated fatty acids (MUFA), such as octadecenoic (oleic, 18:1), which are regarded as neutral or possibly beneficial to blood lipoproteins.

As the association between lipid consumption and cardiovascular disease has been exposed and explored, many countries have produced nutritional guidelines that are intended to induce people to reduce their intake of fat and especially of SFA. A common recommendation is that fat should provide no more than 30 per cent of total energy intake, and that this fat should be divided equally among SFA, MUFA and PUFA (i.e. each supplying 10 per cent of energy intake). A less extreme proposal is that the ratio of PUFA to SFA (called the P : S ratio) should be 0.5-0.8.

In Hungary, fat intake is still high, 45-50 per cent of energy intake and further changes are needed to meet the guidelines. Only plant lipids have the 10 : 10 : 10 ratio suggested above. The fats of terrestrial animals have a predominance of saturated fatty acids. Thus in milk fat the ratio SFA : MUFA : PUFA is 8.5 :3.3 :0.3, and in meat, 8.3 :8.3 :2.0.

The figures given above demonstrate the difficulty - perhaps even the impossibility - of meeting the guidelines for fat consumption with a diet containing a high proportion of animal products. The preferred strategy of those who wish to meet the guidelines seems to be a reduction in intake of animal fat but no reduction in consumption of the other constituents of animal products. In other words, people tend to maintain their consumption of meat and milk (and their products), but to select against the fat in these foods. Selection can be exercised by switching from high-fat meat to that containing less fat in total and less SFA in particular; this is one reason for the continuing replacement of beef by chicken. Fat may be trimmed from joints of meat and replaced as a cooking aid by vegetable oils. Much of the milk consumed in liquid form has its fat content reduced to around 20 g/kg (i.e. half the 'natural' content). Of milk products, butter has to a large extent been replaced by spreads based on vegetable oils.

Animal nutritionists, in association with animal breeders, have responded to the challenge of maintaining the acceptability of animal-derived foods by modifying their lipid constituents. Animals are selected for leanness, are fed to give maximal growth of muscle and are slaughtered when immature (hence having less fat). With pigs and poultry it is possible to modify the constitution of body fats via their diet; for example, the proportions of n-3 and n-6 PUFA can be changed. Ruminants tend to deposit saturated fat because the unsaturated lipids of their plant diet are hydrogenated in the rumen.

The fat content of cow's milk can be reduced by feeding the cow on an extreme type of diet, typically, a diet low in fibre, but the reduction is achieved only by upsetting the normal metabolism of the animal. This raises the question of whether it is morally acceptable to disadvantage the animal in order to meet the perceived needs of its consumer. Pigs selected to be ultra-lean have metabolic problems, and all pigs rely on subcutaneous fat to provide insulation against a cold environment.

Comparisons of national populations have shown some association between the consumption of meat (especially red meat, such as beef and lamb) and the incidence of cancer of the bowel, breast and prostate gland. However, comparisons made within populations (e.g. between vegetarians and meat eaters) have shown no such association, and the whole sale condemnation of meat, or other animal products, as being responsible for cancer is therefore not justified.

The place of animal fats - and particularly the fats of ruminants - in the diets of man has been given a new dimension by the discovery that one particular fatty acid, known popularly as conjugated linoleic acid (CLA) or more precisely as *cis-9, trans-11* octadecadienoic acid, has a beneficial role in the body. This acid has been shown to be anti-atherogenic and anti-carcinogenic, and also to limit obesity and stimulate immune function. The CLA is produced in the rumen as an intermediate in the bacterial hydrogenation of unsaturated fatty acids present in the diet, but it may also be synthesised in the large intestine. It is therefore present in both milk and meat from ruminants. Ruminants given foods that contain relatively high concentrations of unsaturated fatty acids, such as young pasture herbage, produce fats with particularly high contents of CLA.

Chapter 9. Future trends in the consumption of animal products

Despite the arguments advanced against meat consumption - on ethical, environmental and health grounds - world demand for all types of meat is predicted to increase steadily over the next 20 years or so. For meat in total, consumption per person per year in the developed countries is predicted to continue to rise slowly, by 0.2 per cent per year, but for the developing countries the corresponding figure is much greater, at 1.6 per cent per year. World demand on an absolute basis (i.e. allowing for population growth) is predicted to increase more rapidly, by 0.6 per cent per year in developed countries and by 4.1 per cent per year in developing countries. There are some interesting differences in the projections for individual animal species; for example, the demand for production of pig meat in the developed countries is predicted to grow more slowly than that for poultry meat.

It is possible that the arguments against the consumption of meat have yet to make their full impact on consumers. However, it has been calculated that if consumers in the developed countries (i.e. those most likely to be influenced by anti-meat arguments) were to reduce their meat consumption, world demand for meat would still increase, by about 1.5 per cent per year. Moreover, additional projections show that, because of the adverse economic effects on world agriculture of a reduced demand for meat in the developed countries, the partial switch from animal to vegetable foods would not increase the world supply of food per person per day by any significant amount.